PROCEEDINGS

DMS 2006

The 12th International Conference on Distributed Multimedia Systems

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August 30 – September 1, 2006

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DMS'2006 Foreword

The Program Committee of the Twelfth International Conference on Distributed Multimedia Systems (DMS'2006) welcomes you to the Grand Canyon, USA. This conference and its two associated workshops (International Workshop on Visual Languages and Computing, International Workshop on Distance Education Technology) bring together experts in multimedia systems, visual languages, and distance education technology to discuss their research results, with special emphasis on the cross-pollination of ideas across these multiple disciplines.

By the deadline of March 31, 2006, the main conference and its two associated workshops received 84 submissions from 22 countries. All papers were thoroughly reviewed by at least 3 members of the Program Committee. Based on the review results, 44 papers were accepted as regular papers, an acceptance rate of 52%, while 21 papers were accepted as short papers, an acceptance rate of 25%. We thank all the authors for their contributions.

We have a very interesting collection of activities in the technical program, including two keynote presentations, one panel discussion, two workshops, 14 technical sessions, and a multimedia arts competition with 16 participants from 5 countries. These activities comprise a wide range of topics, including:

Content-Based Multimedia Retrieval
Data Visualization
Distance Education management
Distance Learning Tools and Experiences
Educational Technologies
Human-GIS Interaction
Intelligent Resources for E-Learning
Large Real-Time Multimedia Systems
Media Streaming
Multimedia Authorization and Security
Multimedia Coding
Multimedia Representation and Indexing
Theoretical Aspects of Visual Languages
Visual Languages and Techniques for Human-Computer Interaction
Visual Modeling Languages
Wireless Networking

We are very grateful to the two keynote speakers, Catherine Plaisant and Erland Jungert, to our publicity chair, Jing Dong, and to the workshop organizers, Heng-Shuen Chen, Gennaro Costagliola, Paolo Maresca, Monical Sebillo, Genny Tortora, Goran Trajkovski, and Giuliana Vitiello. We especially thank the members of the Program Committee for their hard work during the review process.

Finally, we offer our thanks to Shi-Kuo Chang for his guidance and leadership throughout the organization of this conference. Rex Lee and the staff at KSI was especially helpful to us during the paper submission and review process, and we would like to thank them for their dedication.

William I. Grosky, University of Michigan-Dearborn
Chabane Djeraba, University of Sciences and Technologies of Lille, France
Mohan Kankanhalli, National University of Singapore, Singapore

The 12th International Conference on Distributed Multimedia Systems (DMS'2006)

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Note: (**S**) means short paper.

DMS'2006 Conference

Competition in Multimedia Arts

First Prize Winner

Drawer of Memory, Po-Chou Chi, Taiwan

Second Prize Winner

Surprise, Min-Yuan Cheng, Taiwan

Third Prize Winner

Clock, Li-Jung Tseng, Taiwan

Fourth Prize Winners

Being and Space, Ruben Coen Cagli, Italy

Health Care, Yuhun Li, Taiwan

Jungle, Valentin Partenie, Romania

Fly Catcher, Wan-Ju Chen, Taiwan

Honorable Mentions

Swim and Slim, Mei-Miao Lu, USA

Groucho and Chaplin, Parag Agarwal, USA

Cherry Tree, Chen-Cheang Huang, USA

Keynote I: Reaching Our Users

Dr. Catherine Plaisant

As our field matures, the tools and ideas described in our research publications are reaching users. How can we make sure we develop powerful visual tools that can deal with user diversity (age, language, disabilities, etc.) but also with the variety of technology used and the gaps in user's knowledge? Another challenge is to adequately study the impact of our technologies. We will review many examples, and discuss evaluation methods and the emergence of Multi-dimensional In-depth Long-term Case studies (MILCs) to study the creative activities that users engage in.

About Dr. Catherine Plaisant

Dr. Catherine Plaisant is Associate Research Scientist at the Human-Computer Interaction Laboratory of the University of Maryland Institute for Advanced Computer Studies. She earned a Doctorat d'Ingenieur degree in France in 1982. In 1987 she joined the Human-Computer Interaction Laboratory. Her research contributions range from focused user interaction techniques (e.g. Excentric Labeling) to innovative visualizations (such as LifeLines for personal records or SpaceTree for hierarchical data exploration) and interactive search interface techniques such as Query Previews. She has written over 90 refereed technical publications and recently co-authored with Ben Shneiderman the 4th Edition of "Designing the User Interface".

Catherine Plaisant
http://www.cs.umd.edu/hcil/members/cplaisant/

Keynote II: Using Multi-Media to support Command and Control in Crisis Management Systems

Dr. Erland Jungert

Societies have always been challenged by different kinds of crises, disasters and difficult times. During such challenging events society must be able to deal with the situations that often require major efforts. It is thus important to be aware of which resources that are needed to handle these crises. As a consequence, tools that can support command and control functionality in various types of crisis management systems are needed. These tools should support both proactive and operative crisis management, that is, they are needed to support the prevention of those situations that may occur as well as operative handling of ongoing crises. They must also be able to handle the uncertain situations related to crises where the conditions hastily can change. Consequently, crucial qualities needed in the crisis management systems will include situational and crisis awareness. Furthermore, to achieve reliable command and control functionality, supporting net centric crisis management means for collection, analysis, handling, visualization as well as exchange of large amounts data between different users are necessary. These data are generally of spatial/temporal type and originate in most cases from multiple sensor data sources. For these reasons techniques for handling multi-media data in various ways are required when developing command and control functionalities in crisis management systems. Other corner-stones, besides the above mentioned, that touches upon multi-media aspects in connection to crisis management architectures, are command and control models, service related structures, distributed ontologies and models of information flow.

Proactive aspects of crisis management are quite often dealing with physical protection of facilities that eventually can be subject to different types of threats. Historically, such systems can be seen as simple alarm systems i.e. the threat becomes a reality and the alarm is activated. Most of the time, when the alarm goes off the effects of the possible actions that can be carried out are limited since nothing or very little can be done to prevent the consequences of the activated threats. For these reasons, the surroundings of the facilities must be subject to intelligent over long periods of time to achieve knowledge about possible activities that may be set into effect by antagonistic individuals or groups of individuals. Multi-media systems can here play an important role to achieve a higher degree of security. For instance, by supporting the detection of anomalous behavior.

In this presentation aspects of multi-media will be discussed in connection to techniques that can be used to give the society higher levels of security both before and during crises. Other techniques and methods that may influence the design of multi-media systems for support of crisis management systems will be discussed as well. Among these are information fusion, interoperability and means for situation awareness.

About Dr. Erland Jungert

Erland Jungert has a Ph. D. in Computer Science from the University of Linköping, Sweden, 1980. Currently he is Director of Compute Science Research at FOI, Linköping, Sweden since 1987 and since 1998 he is also part time professor in Geoinformatics at the Department of Computer and Information Science, at Linköping University. He has also been visiting Associate Professor at the department of Electrical Engineering, at the Illinois Institute of Technology, Chicago, Ill. in1985-1986. Dr Jungert is co-author of one book on spatial reasoning and the co-editor of two other books on Visual Languages and on Intelligent Database Systems. Furthermore, he is also associate editor of the journal of Visual Languages and Computing. His interests are concerned with methods for spatial reasoning, query languages especially for sensor data sources. Lately, he has developed an interest for command and control systems for crisis management also including techniques and methods for prevention of crises and antagonistic threat activities.

H.264 Fast Encoder with Adaptive Interpolation Based on Motion Detection Algorithm

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Abstract

H.264/MPEG-4 AVC is the latest video-coding standard jointly developed by VCEG (Video Coding Experts Group of ITU-T and MPEG (Moving Picture Experts Group) of ISO/IEC. It uses state of the art video signals algorithms providing enhanced efficiency, compared with previous standards, for a wide range of applications.

In order to reduce the bitrate of the video signal in H.264, the ISO and ITU coding standards use a ¼ pel displacement resolution.

H.264 saves 50% bit-rate maintaining the same quality if compared with existing video coder standards, but such a result demands additional computational complexity.

In this paper, we propose an algorithm for the reduction of the interpolation computational time. The goal is to adapt the H.264 ¼ pel interpolation to the complexity of the video stream to encode, on the basis of our motion detection algorithm.

The proposed solution allows to decrease the overall encoder complexity both in low and high complex sequences. This paper illustrates the integration of the H.264 encoder with our motion detection algorithm for the development of an adaptive interpolation. The obtained results are compared with the jm86 standard interpolation using different quantization values.

1. Introduction

The video coding standard H.264 [1] introduces many new features in all the aspects of the video encoding process. The compression efficiency has been highly improved maintaining the same video quality. Anyway, the complexity of the encoder has been increased of more than one order of magnitude (while the decoder is increased by a factor of 2) [3], if compared with previous standards such as H.263 [2]. The high compression rate together with the good quality obtained by the H.264 standard make it suitable for a large variety of applications. The H.264 encoding application area requires high power efficiency in order to work on embedded systems and mobile terminals. This requirement implies the need to reduce the complexity of the H.264 video encoder.

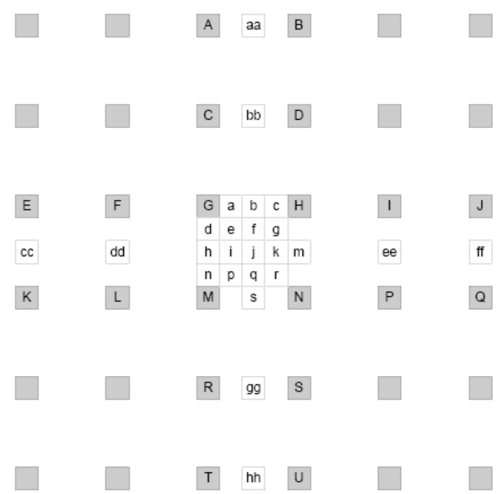


Figure 1: Integer samples (shaded box with upper-case letters) and fractional samples (un-shaded box with lower-case letters) for ¼ pixel Interpolation.

The most time-consuming modules of the encoder are the motion estimation (ME) and the ¼ pel interpolation. The complexity of the ME is due to the great number of SAD operations; while the major part of interpolation calculations are due to the use of a 6-tap Wiener interpolation filter (with coefficients similar to the proposal of Werner [9]) and the averaging samples at full and half sample position. The interpolation process is depicted in figure 1 and it can be divided into two steps. First, the horizontal or vertical Wiener filter is applied to calculate the half-pel positions, then, a bilinear filtering is applied to both the already calculated half-pel positions and the existing full-pel samples in order to compute residual quarter-pel positions.

This sequence of calculation is very heavy, and it represents the 18% of entire compression process. In the following, we will introduce the Local Dynamic Interpolation (LDI) approach tending to minimize calculation, based on our Motion Detection (MD) algorithm. The main idea is to utilize the complete ¼ pixel bilinear interpolation just in those areas where the MD module indicates the presence of motion. Otherwise, only the first part of the full interpolation (the Wiener filtering), together with a very simple ¼ interpolation, will be used.

The reference JVT software version is jm86 and comparative tests are performed with standard fast motion estimation built in. The quality/compression ratio results very close to the standard full interpolation. Section 2 shows how our MD works. Section 3 shows how MD interacts with the H.264 interpolation module. LDI algorithm results are also compared with standard one, as shows in Section 4.

2. Motion detection algorithm

The new approach to MD algorithm can be subdivided into the following steps:

- Binary image difference evaluation
- Blob coloring with minimum object size threshold of entire difference image, with single pixel precision.
- Merging overlapped blobs

Image difference is performed calculating the difference between two subsequent frames (unlike the work presented in [7] this approach avoid background estimation). The input of MD is the luminance image and the output is a set of information about motion area, like position and size.

2.1. Binary image difference evaluation

The inputs of this block are the current image and the background; the output is a binary image with motion pixels.

The image difference D(n) is calculated by the difference between the current image I(n) and previously stored image I(n-1). Then a threshold value (*detection value*) is applied to D(n) in order to obtain Dth(n), the binary image that represents motion pixels into the image.

The formula for frame *n* is:

$D(n) = I(n) - I(n-1)$

$Dth(n)=0$ if $D(n) <$ detection value.

$Dth(n)=1$ if $D(n) >=$ detection value.

2.2. Blob coloring with minimum blob size threshold

Blob coloring is a computer vision technique to obtain region growing and region separation for images.

The input of this block is the difference image and the output is a set of moving object. We use this technique on the entire difference image, instead of using a subsampled 8x8 difference image as in [7], to separate motion regions and growing it. Blob coloring can be performed with the algorithm described in [5]. The regions coordinates are the output of this step. After the blob coloring, the resulting object set is filtered through a threshold that permits to delete the smallest moving regions, in order to avoid the errors due to image noise.

2.3. Merging overlapped blobs

At this point, there are a lot of blobs that may be overlapped. If we would obtain region growing, there is the need to check for overlapped regions and then fuse them together into a single region. The algorithm analyzes region coordinates for finding overlapping in the following way: if there are two or more overlapped regions, a new region having size growing to max dimension of overlapped blobs is created; otherwise the regions are maintained as original sets. This operation reduces object count and permit moving region separation. The input is a set of moving objects and the output is a reduced set of the same objects having enlarged size.

3. Local Dynamic Interpolation

The proposed algorithm is based on the idea that exhaustive interpolation is useful only when a video sequence contains large motions and not in low motion conditions, that is the usual situation for real video-surveillance sequences. The H.264 interpolation can be applied just when the motion detection algorithm identifies motion and, specifically, in the region where the motion is detected. In particular, the 6-tap Wiener filtering is always calculated, whereas the residual quarter-pel position, obtained by applying the bilinear filtering to half-pel and full-pel positions, is only computed in the motion regions (blobs) identified by the MD module. The motion detection evaluates where and when to apply the bilinear-filtering; otherwise a very simple interpolation is carried out (figure 2 shows LDI in the encoder scheme).

The information obtained by the MD algorithm, is utilized to define a Motion Image (MI). This is an approximation of the MD output result because we need as little as possible

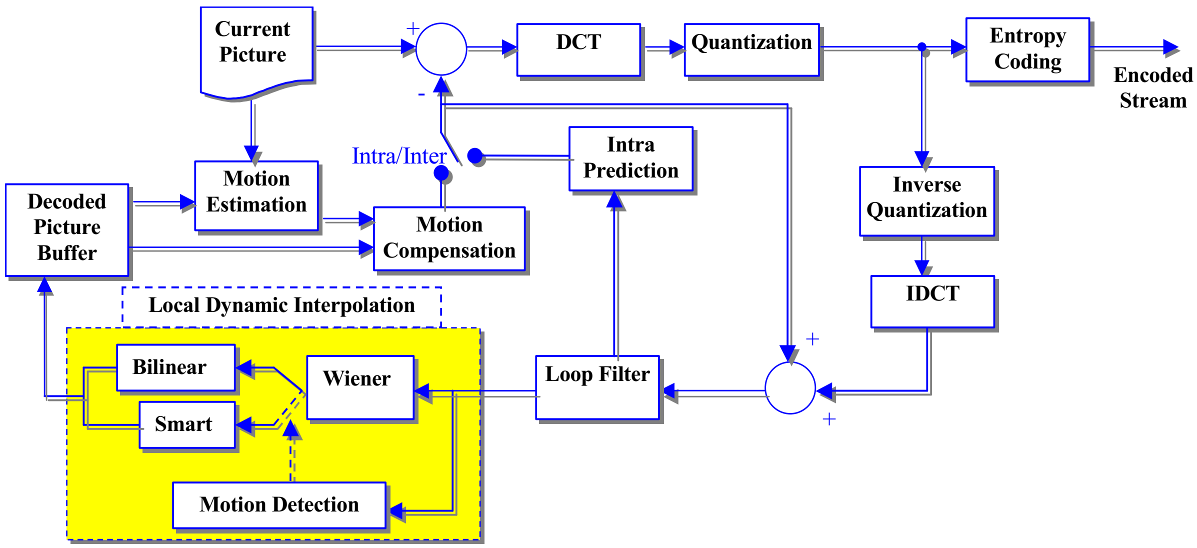


Figure 2: the MD module controls the output of Wiener filter for choosing between smart or bilinear filtering, (input is the original size image, output is the ¼ pel interpolated image)

complexity in the motion detection algorithm. This virtual image is the interface between motion detection and H.264 interpolation.

0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	1	0	0	1	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	1	1	1	1	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0

Figure 3: MD interface; the motion image scanned for searching motion areas.

During the video coding, the MI (Figure 3) is scanned in order to decide the area where bilinear interpolation is applied. Alternatively, a *smart* interpolation will be applied. The *smart* interpolation uses the pixels evaluated by Wiener filtering, replicating them to the near blank positions without other calculation.

4. Results

The proposed algorithm has been validated on the reference JVT software version jm86 [6] implementing the H.264 video encoder, which include a fast ME (we used this option). The reported tests have been performed using standard sequences in QCIF format. *Hall, Salesman, Silent, Highway, and News* have been utilized in order to test the proposed algorithm with both simple and complex sequences (*Highway)*. In the following tests, we encoded 200 frames of every test sequence at 30fps. The selected block configurations are 16x16, 16x8, and 8x16; the CAVLC entropy coder is used for all the tests; Hadamard transform is not used. The RD optimization option in the reference encoder is turned off for all the experiments. The reported tests show the algorithm performance for different quantization values (Q inter) selected from 8 to 28. The results show that our approach can simplify the encoder complexity, maintaining high compression rate and good video quality. The proposed algorithm is strongly influenced by the *detection value* threshold: using a very high value not all of the motions can be detected; otherwise, a very low value can cause the detection of background noise as relevant motion. In the following tests we have set the *detection value* to 15; this value is based on previous studies reported in [7] on the Search Window Estimation (SWE). For every sequence, two tests are performed in order to compare the following implementations: the jm86 Standard Fast with original interpolation algorithm (STDI), and the jm86 Standard Fast with LDI algorithm (LDI). Tests are performed on standard pc class workstation Pentium 4 3.0 Ghz equipped with 1024 MB main memory.

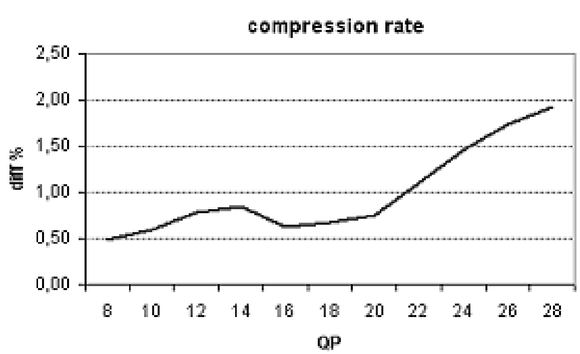
Table 1 shows the differences between the standard algorithm and the proposed approach for a given quantization value. The video quality is compared using the *PSNR*. The *compression* and the *interpolation time* entries represent the percentage increase (positive) or decrease (negative) of the LDI approach.

The reported interpolation time is the computational time of the interpolation module (summed with the MD module time in case of LDI test).

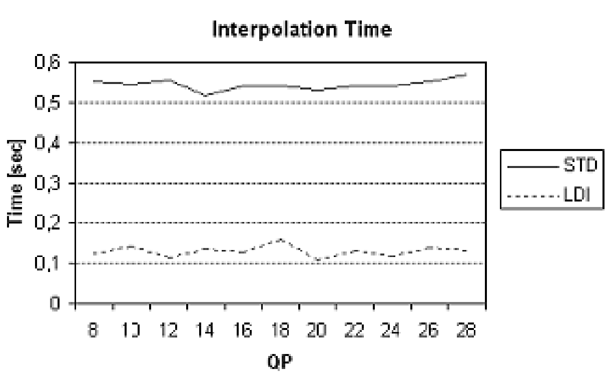
The proposed algorithm (LDI) obtains a consistent reduction in interpolation time for all the sequences: LDI is about 3 times faster than the reference software STDI. Noticeable fact is that there is little loss of bitrate/compression values. In particular graph 1 and graph 2 focus on the behavior of the *Hall* sequence (video surveillance – low complexity case). The difference in bitrate and interpolation time between STDI and LDI is shown for several quantization values (8-28). Graph 1 shows the decrement in compression efficiency of the LDI, anyway the differences ranges from 0.5% to 2%, increasing with inter quantization (QP). The speed-up is the same in all the selected quantization range (see graph 2).

Q Inter 20	Psnry (dB)	Compression (%)	Interpolation Time (%)
Hall	-0.01	-0.740	-76.4
Salesman	-0.03	-4.900	-72.8
Silent	-0.05	-5.217	-70.6
Highway	-0.09	-4.272	-74.0
News	-0.05	-5.174	-77.3

Table 1 – Comparative test for quantization value of 20



Graph 1 – Differential percentage bit rate for hall sequence



Graph 2 – Differential percentage rate for hall sequence

5. Conclusion

This paper presents an adaptive interpolation module for the video coding standard H.264. The proposed solution allows decreasing the overall encoder complexity both in low and high complex sequences, having small side effects either in image quality or in compression efficiency.

The integration of our Motion Detection module in the H.264 encoder is described and tested using the JVT reference software jm86 [6]. The reduction of the interpolation computational time has been measured using standard QCIF sequences.

The main idea of the Local Dynamic Interpolation (LDI) algorithm is to reduce the interpolation complexity using a partial bilinear interpolation in motion areas, and a simple interpolation in background areas.

Future developments will focus on a further reduction of the H.264 overall complexity by using the MD to drive the LDI together with the SWE. Since both the algorithms use the same MD module's output, the system efficiency will be even improved.

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Speed and Area Optimized Implementation of H.264 8 × 8 DCT Transform and Quantizer

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Abstract

H.264 is a video codec standard which delivers high resolution video even at low bit rates. To provide high throughput at low bit rates hardware implementations are essential.

In this paper, we propose hardware implementations for speed and area optimized DCT and quantizer modules. To target above criteria we propose two architectures. First architecture is speed optimized which gives a high throughput and can meet requirements of 4096 × 2304 frame at 30 frames/sec. Second architecture is area optimized and occupies 2009 LUTs in Altera's stratix-II and can meet the requirements of 1080HD at 30 frames/sec.

1. Introduction

H.264 is an advanced digital video codec standard that can deliver high resolution video even at low bit rates. Video is used in a wide range of applications in various fields. Applications like satellite imaging and medical imaging require high resolution video. With the advent of digital video, Digital Multimedia Broadcasting, and HDTV high resolution media presentation is a requirement that can not be compromised. In applications like video conferencing it is required to encode video and transfer it over the network in real time. It requires high throughput and high compression ratios to provide consumer with better quality. H.264 is an advanced video codec standard that satisfy these requirements. Hardware realization of H.264 can easily meet the high performance requirements set by the standard.

H.264 FRExt (Fidelity Range Extension) has made amendments to increase quality and compression of the video. One of the proposed changes is to use a 8 × 8 transform instead of the 4 × 4 transform used in the earlier standards to achieve low bit rates. 8 × 8 transform coefficient matrix is more complex than 4 × 4 coefficient matrix.

In this paper, we propose a hardware implementation for DCT and quantizer block. Various approaches for 4 × 4 transform can be found in [1], [2], [3], and [6]. The authors in [1] and [6] give an implementation of Direct 2D transform in two cycles with 100MHz and 35MHz clock respectively. The work reported in [2] implements a fully parallel transform which produces one 4 × 4 transform in one cycle. Chen et. al. [3] proposes a 1-D DCT transform, that is performed twice and an interconnect switch to connect outputs from first stage to the inputs of the second stage. The authors in [4] use the three stage approach suggested in the standard to implement 8 × 8 transform. It uses a three stage pipeline for performing 1-D DCT. In this paper we propose a 2D-Direct approach for DCT which is an extension of the 4 × 4 transform proposed in [1].

The remaining sections are organized as follows. Section II, describes the high throughput architecture in detail. Section III gives a description of the area optimized architecture. In section IV, we report results and evaluate the performance. Paper is concluded in section V.

2. High throughput architecture

The proposed architecture is an extension of the approach in [1] in which 4 × 4 transform is performed in two cycles. We extend it to perform an 8 × 8 transform in one clock cycle. Proposed architecture runs with a clock of 97MHz. The throughput obtained is 1264 16VGA frames/second. High level block diagram of the architecture is shown in Fig. 1 and the corresponding DCT and quantizer are detailed in later sections.

2.1. DCT Block

The 2D DCT expression of 8 × 8 transform is given in equation (1). Matrix C_f is defined by H.264 FRExt standard [5].

$$Y = C_f X C_f^T \quad (1)$$

where

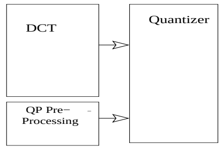

Figure 1. High level Block Diagram of DCT and Quantizer Blocks

X is the input matrix and
Y is the transformed matrix

For Direct-2D implementation we can re-write the expression as

$$\begin{bmatrix} Y0u \\ Y1u \\ Y2u \\ Y3u \\ Y4u \\ Y5u \\ Y6u \\ Y7u \end{bmatrix} = C_{2D} 1/64 \begin{bmatrix} X0u \\ X1u \\ X2u \\ X3u \\ X4u \\ X5u \\ X6u \\ X7u \end{bmatrix} \qquad (2)$$

$where$

$$Xiu = \begin{bmatrix} xi0 & xi1 & xi2 & xi3 & xi4 & xi5 & xi6 & xi7 \end{bmatrix}^T \qquad (3)$$

and

$$C_{2D} = \begin{bmatrix} 8C_f & 8C_f & 8C_f & 8C_f & 8C_f & 8C_f & 8C_f & 8C_f \\ 12C_f & 10C_f & 6C_f & 3C_f & -3C_f & -6C_f & -10C_f & -12C_f \\ 8C_f & 4C_f & -4C_f & -8C_f & -8C_f & -4C_f & 4C_f & 8C_f \\ 10C_f & -3C_f & -12C_f & -6C_f & 6C_f & 12C_f & 3C_f & -10C_f \\ 8C_f & -8C_f & -8C_f & 8C_f & 8C_f & -8C_f & -8C_f & 8C_f \\ 6C_f & -12C_f & 3C_f & 10C_f & -10C_f & -3C_f & 12C_f & -6C_f \\ 4C_f & -8C_f & 8C_f & -4C_f & -4C_f & 8C_f & -8C_f & 4C_f \\ 3C_f & -6C_f & 10C_f & -12C_f & 12C_f & -10C_f & 6C_f & -3C_f \end{bmatrix}$$

Symmetry of the C_{2D} matrix allows us to decompose equation (2) into following two expressions:

$$\begin{bmatrix} Y0u \\ Y2u \\ Y4u \\ Y6u \end{bmatrix} = \begin{bmatrix} 8C_f & 8C_f & 8C_f & 8C_f \\ 8C_f & 4C_f & -4C_f & -8C_f \\ 8C_f & -8C_f & -8C_f & 8C_f \\ 4C_f & -8C_f & 8C_f & -4C_f \end{bmatrix} 1/64 \begin{bmatrix} X0u + X7u \\ X1u + X6u \\ X2u + X5u \\ X3u + X4u \end{bmatrix} \qquad (4)$$

$$\begin{bmatrix} Y1u \\ Y3u \\ Y5u \\ Y7u \end{bmatrix} = \begin{bmatrix} 12C_f & 10C_f & 6C_f & 3C_f \\ 10C_f & -3C_f & -12C_f & -6C_f \\ 6C_f & -12C_f & 3C_f & 10C_f \\ 3C_f & -6C_f & 10C_f & -12C_f \end{bmatrix} 1/64 \begin{bmatrix} X0u - X7u \\ X1u - X6u \\ X2u - X5u \\ X3u - X4u \end{bmatrix} \qquad (5)$$

Exploiting the symmetry of the matrix in equation (2) we can further decompose it as:

$$\begin{bmatrix} Y0u \\ Y4u \end{bmatrix} = \begin{bmatrix} 8C_f & 8C_f \\ 8C_f & -8C_f \end{bmatrix} 1/64 \begin{bmatrix} X0u + X7u + X3u + X4u \\ X1u + X6u + X2u + X5u \end{bmatrix} \qquad (6)$$

$$\begin{bmatrix} Y2u \\ Y6u \end{bmatrix} = \begin{bmatrix} 8C_f & 4C_f \\ 4C_f & -8C_f \end{bmatrix} 1/64 \begin{bmatrix} X0u + X7u - X3u - X4u \\ X1u + X6u - X2u - X5u \end{bmatrix} \qquad (7)$$

Based on the above equations implementation of DCT is divided into two parts. First block performs the computation of Y_{0u}, Y_{2u}, Y_{4u}, Y_{6u}. Second block computes Y_{1u}, Y_{3u}, Y_{5u}, Y_{7u}. Fig. 2 gives the schematic of an e-cell which is a basic computing structure to compute matrix multiplication of even rows (0, 2, 4, 6) of C_f with one column of input matrix. Similarly, Fig. 3 gives schematic of an o-cell which computes matrix multiplication of odd rows of C_f with one column of input matrix. First block requires 8 e-cells followed by 4 e-cells and 4 o-cells. The output of 8 e-cells is fed into following stage comprising of 4 e-cells and 4 o-cells. Similarly Second block requires 8 o-cells followed by 4 o-cells and 4 e-cells.

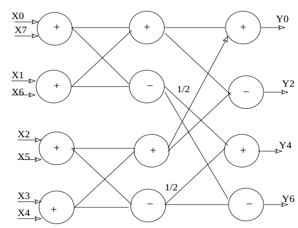

Figure 2. Schematic Diagram of e-cell

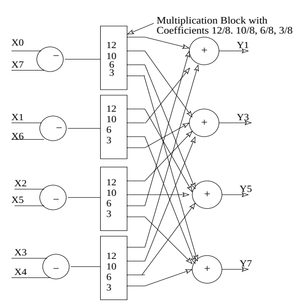

Figure 3. Schematic Diagram of o-cell

Multiplication by $12/8$, $10/8$, $6/8$ and $3/8$ in o-cell is computed using a shift and add as shown in following equations:

$$Y * 12/8 = Y + Shr(Y, 1) \qquad (8)$$

$$Y * 10/8 = Y + Shr(Y, 2) \qquad (9)$$

$$Y * 6/8 = Y - Shr(Y, 2) \qquad (10)$$

$$Y * 3/8 = Shr(Y, 1) - Shr(Y, 2) \tag{11}$$

where Shr(Y, n) is right shift Y by n

2.2. Quantizer Block

Quantization in H.264 is given by the following equation:

$$Z = Shr((Y * MF + f), qbits) \tag{12}$$

where MF, f, and qbits are calculated from Quantization parameter as described in standard

Quantizer block uses two stage pipeline. Pre-processing is done to calculate the six possible values of MF, f, and qbits which depend on quantization parameter. We use a simple combinational logic instead of memory look up. Memory lookup increases critical path delay in quantizer block, reducing clock frequencies. It does not add much overhead on resources used. On Altera Stratix-II we realize this using 38 Logic Elements(LEs). This is overlapped with the DCT process, so that critical path in quantizer block can be reduced by making the MF available by the time quantization starts. The actual quantization is done in two stages to achieve higher clock frequencies. First stage multiplies the transformed coefficient with the multiplication factor and second stage performs an add and a shift. There are two minor variations in the implementation of the first stage. One variation uses a single stage multiplier and other uses a two stage multiplier. Two stage multiplier increases the resources required but improves clock frequency. In our implementation on Altera's stratix-II architecture DSP elements are used to perform multiplication.

3. Area optimized Architecture

Area optimized architectures generally perform a row transform followed by column transform and use memory to store the intermediate values. The throughput is limited by memory latency, which will not meet the throughput requirements of high end applications. To meet the performance we propose a direct 2D transform without need for intermediate memory.

3.1. DCT Block

Equation (1) can be divided into row and column transforms given by the following expressions:

$$M = C_f.X \tag{13}$$

$$Y = (C_f.M^T)^T \tag{14}$$

Using normal matrix multiplication M_{ij} and Y_{ij} are:

$$M_{ij} = \sum_{t=0}^{N-1} C_{it} * X_{tj} \tag{15}$$

$$Y_{ij} = \sum_{u=0}^{N-1} (C_{iu} * M_{uj}^T)^T \tag{16}$$

Substituting M_{ij} in the equation (16) and expanding the summation yields:

$$Y_{ij}^T = Y_{ji} = \sum_{u=0}^{N-1} C_{iu} * M_{uj}^T = \sum_{u=0}^{N-1} C_{iu} * M_{ju}$$
$$= C_{i0}.M_{j0} + C_{i1}.M_{j1} + ... + C_{i7}.M_{j7} \tag{17}$$

Looking at the above equation it is clear that it is enough to compute M_{k0} to M_{k7} to compute Y_{k0} to Y_{k7}. The proposed approach takes advantage of this dependency. The high level DCT architecture is shown in Fig. 4. First stage

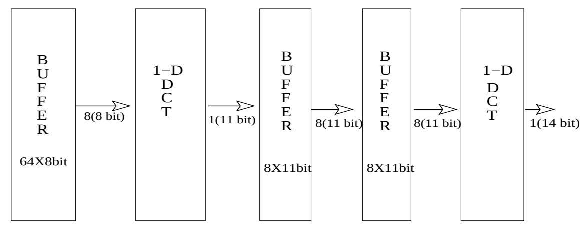

Figure 4. High Level Block Diagram of Area Optimized Architecture

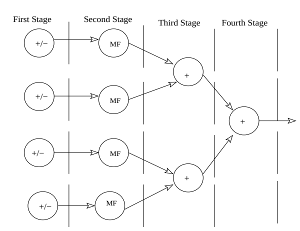

Figure 5. 1D Transform of Area Optimized Architecture

generates elements column wise and second stage performs row wise transform. In the proposed architecture it requires one clock cycle at a frequency of 167MHz to compute one element. It takes eight cycles to generate M_{0k} to M_{7k}. Second stage can start the computation after an initial latency of eight cycles. Once the pipeline is full computation of M_{0k+1} to M_{7k+1} is overlapped with computation of Y_{k0} to Y_{k7}. There are two buffers between the two stages. First stage writes into the first buffer and second stage reads from the second buffer. Data from one buffer is moved into the other buffer every eight cycles. This architecture requires 64 cycles to perform one 8×8 transform.

Fig. 5 gives a schematic of 1D DCT component . It is a four stage pipeline. Each stage performs a simple add operation which allows us to generate at a frequency of 167MHz. The first stage of the pipeline adds or subtracts the data depending on the row being processed. The second stage carries out the multiplication with the appropriate coefficient. As described in the previous section, multiplication is performed by one shift and one add operation. In subsequent stages they are added together to produce the result. Necessary controls are generated by control logic. The same architecture can be used even if the matrix changes.

3.2. Quantizer Block

High level architecture of Quantizer block is same as described in previous section. The most compute intensive part in the quantization is multiplying with the multiplication factor. Fully Pipelined multiplier is used to achieve high clock frequencies. It generates 16 partial products in the first stage and then adds them in the subsequent stages. When implementing on the FPGA we can also use the DSP or 18 $\times$ 18 multipliers present on most of the FPGA's. Using them will decrease the clock frequency as the multipliers are slow.

4. Results

The proposed architectures are synthesized using Quartus-II 5.0 from Altera and Xilinx 7.1 from Xilinx. The target technology is Stratix II (EP1S30F780C5) FPGA for Quartus and Virtex-4 (Xc4Vlx25) for Xilinx synthesis. In the following sections we present the methodology and comparison of our results.

4.1. Methodology

Throughput is calculated assuming a 4:2:0 format. In this format one macroblock contains four 8 $\times$ 8 luma blocks and two 8 $\times$ 8 chroma blocks. In the high throughput architecture each 8 $\times$ 8 transform takes one clock cycle, so it takes 6 clock cycles per macroblock. Area optimized architecture takes 64 clock cycles for a 8 $\times$ 8 transform, hence it takes 384 cycles per macroblock.

The area reported includes the necessary buffering at the input and output for both architectures. Area of high throughput architecture includes 64 pixel buffer both at input and output. For Area optimized architecture area reported includes 64 pixel buffer at the input.

4.2. High Throughput architecture

On Quartus-II 5.0 we obtain a critical path of 13.2 ns for the parallel 2D-Direct architecture and a single stage pipeline in quantizer block. Multiplier is implemented by a DSP block present on Stratix II. This forms the critical path, that determines clock frequencies. This architecture is shown as *PA_I* in the results. To achieve higher clock frequencies option of using a two-stage multiplier is explored. This architecture is referred as *PA_II*. First stage of multiplication multiplies with first eight bits of the multiplier and second stage with the next eight bits. The critical path in this two stage pipeline is 10.3 ns. The number of resources used is 33% more than the previous approach. Since the throughput of *PA_I* is sufficient to meet very high throughput requirements *PA_II* is not of practical importance. *PA_I* should run above 6MHz to meet the requirements of a 4096 $\times$ 2304 frame at 30 frames/sec.

4.3. Area Optimized architecture

In area optimized approach it is feasible to add more pipeline stages as the overhead of one stage of pipeline is limited to one register in contrast to 64 registers in case of speed optimized architecture. To achieve high clock frequencies both DCT and quantizer blocks are aggressively pipelined. Instead of pipelined multiplier in the quantizer block, a DSP block on the FPGA can be used if lower frequencies are sufficient. With a DSP block for multiplication we get a critical path of 7.8 ns with 1397 LEs in stratix II (EP1S30F780C5). The throughput obtained for this architecture is sufficient to meet throughput requirement of 1080HD frame at 30 frames/second. This architecture can be scaled by replicating all the blocks to meet throughput for higher frame sizes. The two 1-D DCT stages and the two buffers between them in Fig. 4 can be replicated one more time to get twice the current throughput. The area required will be less than double as control logic and input buffer do not change.

4.4. Comparison

[4] obtains a critical path of 14.598 ns on Virtex II (XC2v4000) and uses 29018 LUTs. We can not directly compare with those results as the target platforms are different. They did not mention about multiplier blocks present on Virtex II, but are possibly using them to realize their design.

The results of synthesis on Quartus are summarized in table 1. The results of synthesis on Xilinx are summarized in table 2. Parallel architecture *PA_I* uses a single stage multiplier and Parallel architecture *PA_II* uses two stage pipeline. Throughput is shown in terms of 16VGA frames/second. We could not fit parallel *PA_II* on Virtex-II using Xilinx. The values shown are approximate values given by Xilinx. We achieve a improvement of 44% in terms of LUTs and 32% in the frequency in comparison with [4].

METHOD	LEs	DSPs	Clock Period	Throughput Frames/sec
PA_I	19015	96	13.2	986
PA_II	28708	96	10.3	1264
Area Optimized	2009	0	6.0	33.9

Table 1. Summary of results on Stratix II

METHOD	LUTs	DSPs	Clock Period	Throughput Frames/sec
PA_I	16200	48	9.9	1315
PA_II	14998	112	7.3	-
Area Optimized	2040	0	6.0	33.9
[4] on Virtex-II	29018	Not Specified	14.598	891

Table 2. Summary of results on Virtex-4

5. Conclusion

In this paper we presented two architectures for an efficient implementation of DCT and Quantizer in H.264. *PA_I* architecture is targeted for very high throughput and runs at a clock frequency of 97MHz and transforms one 8×8 matrix in one clock cycle. Throughput given by this architecture meets the throughput required by the current day high end applications using a 4096×2304 frame. The Area optimized architecture for optimum area transforms one 8-bit pixel in one clock cycle with a frequency of 167MHz. The throughput of the second architecture meets throughput requirement of applications with 33 16VGA frames/second with area requirement of 2009 LEs on Altera's Stratix II. A gain of 44% in area and 32% in throughput is achieved when compared to [4].

The area optimized architecture is suitable for consumer electronic devices, since the throughput of this architecture is sufficient to provide a real time video at 30 frames/sec for a frame as large as 16VGA using less area. Since the throughput provided is high it can provide wide screen, high color movies which give superior user experience. Higher throughput is an overkill for consumer electronics as the resolution required is not very high. First architecture caters for the requirements of very high resolutions where area is not a concern.

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A New Approach to Watermark MPEG-2 Videos

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Abstract

Even though many recent watermarking procedures achieve a high level of security and robustness by adopting "readable" insertion schemes based on "blind" and not publicly available decoders as well as letting the embedded watermarks depend on the host contents, the "nonblind" watermarking schemes are usually considered more robust then the blind ones. However, differently from the blind ones, the nonblind schemes need the original contents to run the watermark detection or extraction algorithms, and this is considered a relevant drawback particularly for the procedures that aim at being adopted in a web context. This paper presents a nonblind watermarking procedure for MPEG-2 videos. The procedure exploits XML documents in order to avoid the problem reported above. To this end, it can achieve the usual security and robustness levels characterizing the nonblind watermarking schemes without requiring the original unprotected, large size videos to be exchanged on the Internet whenever watermark extractions have to be carried out.

1. Introduction

The rise of the Internet and the advances in multimedia techniques have prompted increasing interest in the problem of protecting copyrighted multimedia contents, such as images, audio files, and videos. Although early research concentrated on many different multimedia technologies [1], the copyright protection of digital contents distributed on the Internet is currently more and more based on *digital watermarking* [2, 3]. To this end, most of the recent watermarking procedures proposed in literature tend to adopt "blind" insertion schemes, which can achieve high levels of security and robustness [3]. However, the "nonblind" watermarking schemes are typically considered more robust then the blind ones [4, 5], even though they, differently from the blind ones, need the original, unprotected contents to run watermark detection or extraction algorithms. This is considered a relevant drawback particularly for the procedures that aim at being adopted in a web context, because such procedures cannot be exploited within "watermarking protocols" that resort to trusted third parties (TTPs) to run sophisticated "identification and arbitration" protocols [5, 6, 7]. In fact, such watermarking protocols state that watermark extractions have not to be carried out by the copyright owners, but have to be performed by distinct TTPs in order to correctly take into account both the buyers' and the owners' rights. As a consequence, such protocols force copyright owners to send their unprotected, large size original contents to TTPs whenever watermarks have to be extracted from pirated copies found in the market according to nonblind watermarking procedures. However, the exchange of unprotected original contents with web entities distinct from the copyright owners can give rise to some documented and relevant protection problems [5, 7], which can make the whole protection process legally invalid.

This paper presents a watermarking procedure for MPEG-2 compressed videos based on the use of XML documents. The procedure follows the web oriented approach presented in [8] to embed a distinct code identifying the buyer into each copy of the videos distributed by web content providers. Moreover, in order to increase its level of security and robustness against the most common attacks known in literature, the proposed procedure allows for repeatedly embedding watermark into some selected I-frames of a video in the DCT domain at different frequencies and by exploiting both block classification techniques and perceptual analysis. The embedded watermark can be then extracted from a video according to the information contained in a protected XML document associated to the video. Thus, the usual security and robustness levels characterizing the nonblind watermarking schemes can be achieved without requiring the original unprotected, large size videos to be exchanged on the Internet whenever watermark extractions have to be carried out. In addition, the XML technology makes it also easier to automate the document access in a web context, since it is well supported by the Java world, and document parsers, such as SAX and DOM parsers, are freely available.

The paper is organized as follows. Section 2 presents the proposed watermarking procedure, whereas Section 3 describes the use of XML documents associated to the videos to be protected. Section 4 describes the watermark extraction procedure. Section 5 reports on some experimental results. Section 6 reports conclusion remarks.

2. The Watermarking Procedure

The watermarking procedure makes it possible to insert into an MPEG-2 video a binary code able to unambiguously identify a user. The code, which is represented by a sequence of bits $\mu \in \{0,1\}$ and whose length is denoted as n_μ, can be repeatedly embedded into each of some selected I-frames of the video, denoted as ε_1, $\varepsilon_2 \ldots \varepsilon_r$, in the DCT domain at different frequencies, denoted as γ_1, $\gamma_2 \ldots \gamma_f$. In particular, each frequency γ identifies a coefficient in each 8×8 DCT block, and so it can range from 1 to $8^2 = 64$ [9]. Furthermore, in order to increase the security and robustness of the procedure, the watermark insertion is assumed to be carried out at low, middle and high frequencies chosen on the basis of the video to be watermarked.

More precisely, the proposed procedure assumes that only some coefficients belonging to the luminance DCT blocks of the selected I-frames can be chosen to be modified by a value representing a watermark information. In fact, such a choice depends on the "perceptual capacity" of the coefficients, which is preliminarily estimated by exploiting both block classification techniques and perceptual analysis. In particular, the block classification techniques [9, 10] are applied to indicate the best DCT coefficients of the selected I-frames that can be altered without reducing the visual quality. They classify each luminance DCT block with respect to its energy distribution. The result of this procedure is a first selection of DCT coefficients whose modification has a minimal or no impact to the perceptual quality of the selected I-frames.

The perceptual analysis is then applied to calculate the "just noticeable difference" (*jnd*) values for the DCT coefficients [11, 12, 13]. Such values are the thresholds beyond which any changes to the respective coefficient will most likely be visible. Therefore, let $X^{\varepsilon}_{b_m}(\gamma)$ denote the DCT coefficient at the frequency γ in the block b_m of the I-frame ε, and let $JND^{\varepsilon}_{b_m}(\gamma)$ denote the *jnd* value calculated for the $X^{\varepsilon}_{b_m}(\gamma)$ coefficient. $JND^{\varepsilon}_{b_m}(\gamma)$ can be expressed as:

$$JND^{\varepsilon}_{b_m}(\gamma) = \max\left\{C^{\varepsilon}_{b_m}(\gamma), \left|C^{\varepsilon}_{b_m}(\gamma)\right| E^{\varepsilon}_{b_m}(\gamma)^{g}\right\} \qquad (1)$$

where $C^{\varepsilon}_{b_m}(\gamma)$ represents the perceptual threshold of the contrast masking and can be expressed as:

$$C^{\varepsilon}_{b_m}(\gamma) = \max\left\{t^{\varepsilon}_{b_m}(\gamma), \left|X^{\varepsilon}_{b_m}(\gamma)\right|^{h} t^{\varepsilon}_{b_m}(\gamma)^{1-h}\right\} \qquad (2)$$

$E^{\varepsilon}_{b_m}(\gamma)$ is the entropy value calculated over the eight neighbors of the coefficient $X^{\varepsilon}_{b_m}(\gamma)$ [11, 12], and can be approximated by the following expression:

$$E^{\varepsilon}_{b_m}(\gamma) = X^{\varepsilon}_{b_m}(\gamma) - u^{\varepsilon}_{b_m}(\gamma)q(\gamma) \qquad (3)$$

In (1) g is assumed equal to 0.5, whereas in (2) h is assumed equal to 0.7 and $t^{\varepsilon}_{b_m}(\gamma)$ is equal to $t(\gamma)(X^{\varepsilon}_{b_m}(1)/X(1))$. $X^{\varepsilon}_{b_m}(1)$ is the DC coefficient of the block b_m of the I-frame ε, whereas $X(1)$ is a DC coefficient corresponding to the mean luminance of the display. In fact, $t(\gamma)$ can be approximated by the value $q(\gamma)/2$, where $q(\gamma)$ represents the coefficient of the quantization matrix corresponding to the frequency γ [12]. Finally, in (3) $u^{\varepsilon}_{b_m}(\gamma)$ can be assumed equal to $round(X^{\varepsilon}_{b_m}(\gamma)/q(\gamma))$.

The insertion procedure at the frequency γ of a selected I-frame assumes that each bit of the sequence μ is inserted into the I-frame by altering a pair of DCT coefficients associated to the frequency γ and chosen among the ones previously selected by applying the block classification techniques and perceptual analysis. In particular, the "choice rule" states that two DCT coefficients of a selected I-frame are allowed to belong to a same pair only if they have a "similar" value.

Furthermore, to insert the bits of μ into an I-frame ε, the "encoding function" $\mathscr{K}$ has to be defined. $\mathscr{K}$ defines an encoding rule by which the bits 0 and 1 are translated to the symbols of the alphabet composed by $\{\nearrow, \searrow\}$, respectively called the *up* symbol and the *down* symbol. Thus, a sequence $\mu \in \{0,1\}$ is translated to a corresponding sequence $\sigma \in \{\nearrow, \searrow\}$ depending on the function $\mathscr{K}$. For example, the sequence $\{01101\ldots\}$ is translated to the sequence $\{\nearrow\searrow\searrow\nearrow\searrow\ldots\}$, if $\mathscr{K}$ associates the *up* symbol to 0 and the *down* symbol to 1.

Let μ be a user sequence, and let σ be the sequence obtained by applying a $\mathscr{K}$ function. Let γ_i, $\forall i = 1\ldots f$, be the insertion frequencies, and let ε_p, $\forall p = 1\ldots r$, be the selected I-frames of the video. Let $W^{\varepsilon_p}_{b_m}(\gamma_i)$ denote the watermarked DCT coefficient at the frequency γ_i in the block b_m of the I-frame ε_p. A symbol of σ is inserted into a pair of DCT coefficients belonging to the blocks b_m and b_n, at the frequency γ_i of the I-frame ε_p, by the following expressions:

$$\begin{cases} W^{\varepsilon_p}_{b_m}(\gamma_i) = X^{\varepsilon_p}_{b_m}(\gamma_i) - JND^{\varepsilon_p}_{b_m}(\gamma_i) \\ W^{\varepsilon_p}_{b_n}(\gamma_i) = X^{\varepsilon_p}_{b_n}(\gamma_i) + JND^{\varepsilon_p}_{b_n}(\gamma_i) \end{cases} \text{to insert } \nearrow$$

$$\begin{cases} W^{\varepsilon_p}_{b_m}(\gamma_i) = X^{\varepsilon_p}_{b_m}(\gamma_i) + JND^{\varepsilon_p}_{b_m}(\gamma_i) \\ W^{\varepsilon_p}_{b_n}(\gamma_i) = X^{\varepsilon_p}_{b_n}(\gamma_i) - JND^{\varepsilon_p}_{b_n}(\gamma_i) \end{cases} \text{to insert } \searrow$$

$$\forall i = 1\ldots f \text{ and } \forall p = 1\ldots r$$

In fact, as specified above, since the choice rule requires that $X^{\varepsilon_p}_{b_m}(\gamma_i) \approx X^{\varepsilon_p}_{b_n}(\gamma_i)$, $\forall i = 1\ldots f$ and $\forall p = 1\ldots r$, the insertion process ends up maximizing the difference existing between the coefficients of the pair according to the direction specified by the insertion symbol and by an amount that cannot compromise the final visual quality of the video. Consequently, the insertion process should be carried out according to the following rules:

- The I-frames to watermark should qualify significant scenes of the video, and more than three consecutive I-frames should belong to each selected scene.
- The insertion frequencies should be evenly distributed among the low, middle and high frequencies, and should be chosen so that attacks characterized by a filtering behavior on the video frames would end up reducing the final video quality. This can be achieved by selecting the frequencies characterized by high spectrum values, which, if filtered, can impair the video.
- At each insertion frequency and for each selected I-frame, the pairs of the selected DCT coefficients should belong to spatial regions that cannot be cropped without impairing the video.

Once the symbols of the sequence σ have been inserted into the selected I-frames at the chosen frequencies, in order to increase the security and robustness of the proposed procedure against "collusion" attacks [4], the modifications made to the DCT coefficients of the I-frames have to be hidden. Therefore, let $\gamma_1, \gamma_2 \ldots \gamma_f$ be the insertion frequencies chosen for the video, and let $\Sigma^{\varepsilon_p}(\gamma_i)$ denote the sequences of the pairs of DCT entries $(b_m^{\varepsilon_p}(\gamma_i), b_n^{\varepsilon_p}(\gamma_i))$ that have been involved in the watermarking process for a given frequency γ_i, $\forall i = 1 \ldots f$ and for a given I-frame ε_p, $\forall p = 1 \ldots r$. It is worth noting that both the set of the frequencies γ_i and the sets $\Sigma^{\varepsilon_p}(\gamma_i)$ are always the same for all the copies of a given video to be protected. Consequently, the DCT coefficients modified at the different insertion frequencies in the selected I-frames remain the same for all the copies of the video. Therefore, in order to prevent malicious users from individuating the DCT coefficients modified by the insertion process, the procedure adds the *jnd* values modulated by a binary pseudo-noise sequence $\rho \in \{-1, 1\}$ to all the unmodified DCT coefficients of the selected I-frames of the watermarked video:

$$X_{b_k}^{\varepsilon_p}(\gamma_i) = X_{b_k}^{\varepsilon_p}(\gamma_i) + \alpha_k \rho_k JND_{b_k}^{\varepsilon_p}(\gamma_i),$$
$$(\forall p = 1 \ldots r) \text{ and}$$
$$((i \neq 1 \ldots f) \text{ or } (i = 1 \ldots f \text{ and } b_k \notin \Sigma^{\varepsilon_p}(\gamma_i)))$$

where $0 < \alpha_k < 0.5$ is a randomly varied amplitude factor.

3. The XML Documents

The adopted watermarking scheme makes it necessary to save the insertion information used to protect the copies of a video in order to enable the watermark extraction. To this end, the proposed procedure assumes that such information is stored in XML documents. Therefore, the XML document associated to all the watermarked copies of a video has to include:

1. the insertion frequencies $\gamma_1, \gamma_2 \ldots \gamma_f$;
2. the selected I-frames $\varepsilon_1, \varepsilon_2 \ldots \varepsilon_r$, also specified in terms of significant scenes which they refer to;
3. the sets $\Sigma^{\varepsilon_p}(\gamma_i)$, $\forall i = 1 \ldots f$ and $\forall p = 1 \ldots r$;
4. the definition of the encoding function $\mathscr{K}$.

However, further information can be saved in the XML document associated to a video. In fact, such information can be exploited to synthetically describe or characterize the video as well as individuate possible geometric modifications performed on it. In particular, information can be stored in both textual and quantitative form. The textual information can individuate and describe the scenes which the I-frames belong to, and some evident and significant "feature points" and boundary segments of the selected I-frames. The quantitative information can provide the original dimensions of the video, the coordinates of the feature points and selected boundaries, some Fourier descriptors and statistical moments of K-point digital boundaries, as well as the eigenvectors and eigenvalues of some well-defined regions of the selected I-frames. Thus, inverse geometric transformations can be performed on an attacked video to restore it before the watermark extraction [2, 9].

4. The Watermark Extraction

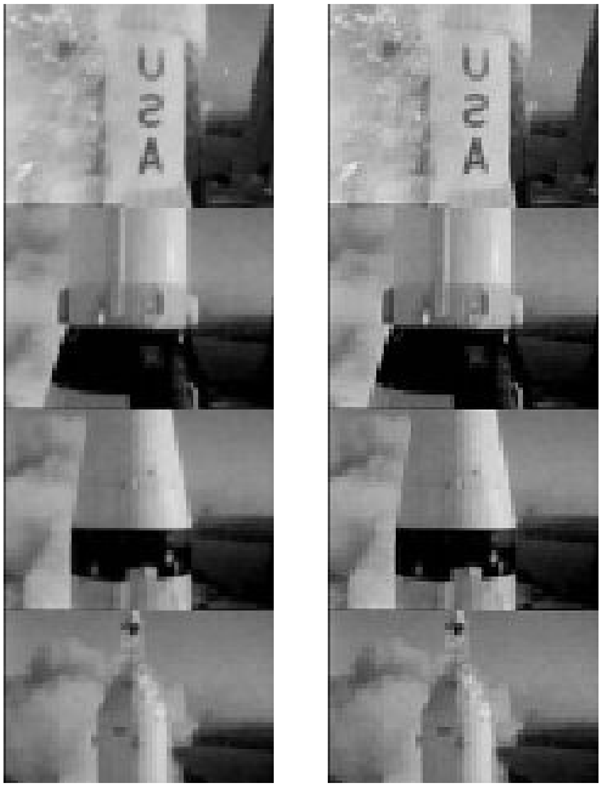
To extract the watermark from a video, it is necessary to examine the pairs of coefficients specified by the DCT entries $(b_m^{\varepsilon_p}(\gamma_i), b_n^{\varepsilon_p}(\gamma_i))$ belonging to the set $\Sigma^{\varepsilon_p}(\gamma_i)$, with $i = 1 \ldots f$ and $p = 1 \ldots r$, that is, for each insertion frequency γ_i and for each selected I-frame ε_p.

Therefore, let $\hat{W}_{b_m}^{\varepsilon_p}(\gamma_i)$ and $\hat{W}_{b_n}^{\varepsilon_p}(\gamma_i)$ be the two coefficients of a pair belonging to $\Sigma^{\varepsilon_p}(\gamma_i)$. To extract the watermark symbol they host, the following expressions have to be evaluated:

$$\begin{cases} \hat{W}_{b_m}^{\varepsilon_p}(\gamma_i) - \hat{W}_{b_n}^{\varepsilon_p}(\gamma_i) > 0 \implies \searrow \text{ is extracted} \\ \hat{W}_{b_m}^{\varepsilon_p}(\gamma_i) - \hat{W}_{b_n}^{\varepsilon_p}(\gamma_i) < 0 \implies \nearrow \text{ is extracted} \end{cases} \tag{4}$$

Then, the extracted symbol is translated to a bit depending on the $\mathscr{K}$ function.

After having completed the watermark extraction process, $f \cdot r$ user sequences $\hat{\mu_{i,p}}$ result in being re-built, one for each different insertion frequency γ_i and I-frame ε_p. Therefore, let $\mu(j)$ denote the j-th bit in the user sequence μ. $\mu(j)$ can be derived from the sequences $\hat{\mu_{i,p}}$ by



Original Watermarked

Figure 1. A classic NAS video.

the following expression:

$$\mu(j) \equiv 1 \iff \frac{\sum_{i=1}^{f} \sum_{p=1}^{r} \hat{\mu_{i,p}}(j)}{f \cdot r} > 0.5,\ \forall j = 1 \dots n_\mu \quad (5)$$

Furthermore, it is worth noting that the conducted tests have evidenced that the expressions reported in (4) can be also improved in order to make the watermark extraction more robust against "collusion" attacks [4]. Therefore, the expressions in (4) can be thus modified [8]:

$$\begin{cases} \hat{W}_{b_m}(\gamma_i) - \hat{W}_{b_n}(\gamma_i) > th & \Longrightarrow \searrow \text{ is extracted} \\ \hat{W}_{b_m}(\gamma_i) - \hat{W}_{b_n}(\gamma_i) < -th & \Longrightarrow \nearrow \text{ is extracted} \end{cases} \quad (6)$$

where th is a threshold calculated as

$$th = \omega(JND_{b_m}(\gamma_i) + JND_{b_n}(\gamma_i)), \quad 0.45 < \omega < 0.55$$

and ω is a factor depending on the characteristics of the video.

5. Experimental Results

The robustness and security achieved by the proposed procedure have been assessed by conducting tests on many videos available on the web. However, for the sake of brevity, only the results obtained on a classic NASA video (see Figure 1) have been reported. In particular, the resolution of the video is 160×120 pixels and its duration is about 6 seconds. The user sequence μ is assumed 48 bit long.

Attack	***f***	***r***	***ber*** (%)
Add Noise	3	9	3.46
Add Noise	6	12	3.23
Add Noise	9	15	3.01
Sharpening	3	9	2.95
Sharpening	6	12	2.65
Sharpening	9	15	2.27
Median	3	9	3.75
Median	6	12	3.19
Median	9	15	2.81
Rotating 45.2°	3	9	6.67
Rotating 45.2°	6	12	6.21
Rotating 45.2°	9	15	5.96

Table 1. The results of some simple attacks.

The bit error rate (*ber*) under a different number of the insertion frequencies f and of the watermarked I-frames r has been measured for each conducted test. In particular, the *ber* is expressed in percentage and is calculated as

$$ber = \frac{\sum_{i=1}^{f} \sum_{p=1}^{r} ber_{i,p}}{f \cdot r}$$

where $ber_{i,p}$ is the number of bit errors reported in the watermark extraction carried out at the frequency γ_i from the I-frame ε_p.

Table 1 shows the results obtained under some "simple" or "detection-disabling" attacks [14]. In fact, the "simple" attacks attempt to impair the embedded watermark by manipulations of the whole watermarked video, such as filtering or compression manipulations or addition of noise. On the contrary, the "detection-disabling" attacks attempt to break the correlation and to make the recovery of the watermark impossible or infeasible, mostly by geometric distortion like rotation. Moreover, Table 2 reports the results obtained under some "linear" and "non linear" collusion attacks, whose definitions are reported in [4]. In particular, k denotes the number of the colluding videos, whereas the anticollusion codes used in the tests have been generated according to what reported in [15].

The results summarized in the tables show that the proposed procedure can achieve a good performance against attacks that are considered able to prove a high level of robustness and security [16]. In particular, the *ber* values are rather low, and the user sequence μ can be re-built from

Attack	*f*	*r*	*k*	***ber*** (%)
Linear attacks				
Averaging	3	9	5	7.76
Averaging	6	12	10	7.44
Averaging	9	15	15	7.28
Nonlinear attacks				
Minimum	3	9	5	5.49
Minimum	6	12	10	5.23
Minimum	9	15	15	5.07
Median	3	9	5	3.71
Median	6	12	10	3.46
Median	9	15	15	3.12
Maximum	3	9	5	4.93
Maximum	6	12	10	4.54
Maximum	9	15	15	4.19

Table 2. The results of some collusion attacks.

the sequences extracted for each test by applying the expressions in (5). In fact, the redundancy assured by the insertion process enables the procedure to behave as other well known, robust and secure watermarking procedures [17, 18]. This also because the procedure allows for choosing the insertion frequencies as well as the regions of the selected I-frames where to embed watermark information. Moreover, in the conducted tests, the values of f and r are small, but they can be also increased in order to improve the security and robustness of the procedure without compromising the final visual quality of the video.

6. Conclusions

This paper has presented a nonblind procedure to watermark MPEG-2 videos. The procedure has been purposely designed to be adopted in a web context. Therefore, it directly acts on compressed videos and adopts a redundant watermark insertion process that enables the procedure to achieve a good performance against the most common and dangerous attacks. Furthermore, the procedure exploits protected XML documents to store information needed to the watermark extraction. Thus, it can behave as nonblind watermarking schemes without requiring the original unprotected, large size videos to be exchanged on the Internet whenever watermark extractions have to be carried out.

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Design and Implementation Issues for MobFish

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Abstract

New advances in mobile-computer technology, together with the advent of wireless networking, introduce new requirements, capabilities and concerns to the computer science and industry. In this paper, we discuss the special requirements of file sharing in mobile environments. Then our proposed architecture for mobile file sharing (MobFish) is presented. Finally, we present an implementation of the proposed architecture based on its special design tactics.

Keywords: *Mobile File Sharing, Mobile Computing, File Sharing Architecture, Ubiquitous Computing,*

1. Introduction

New advances in mobile-computer technology together with the advent of wireless networking has lead to ever increasing number of smart mobile elements over the planet. This new trend has introduced new requirements, capabilities and concerns to the computer science and industry. The whole issue is recognized as a new paradigm, namely the mobile computing [2, 4, 5, 7, and 18].

The main aspect of mobile computing is the need of users to compute ubiquitously, anywhere and anytime [6, 22]. Transferring and sharing electronic files in a mobile environment is an important requirement of ubiquitous computing. In this paper, we aim at proposing an architecture for file sharing systems that operates on mobile environments. Since the mobility may be logical or physical [15], in the design of a mobile file sharing system, one is to consider the mobility of software agents [12] and their shared data (recognized as logical mobility) as well as the physical mobility of hosts.

Due to the constraints imposed by the nature of mobility, mobile computers such as laptops, third generation mobile phones, personal digital assistants and the like lack some of the capabilities to static hosts [9]. Moreover, the wireless networks are more error prone due to the use of electromagnetic waves as their transmission medium. Therefore there is a widely accepted understanding that mobile computing has its own special characteristics. For example [18 and 19] have enumerated four constraints for mobile computing:

- *"Mobile elements are resource-poor relative to static elements."*
- *"Mobility is inherently hazardous"*
- *"Mobile connectivity is highly variable in performance and reliability."*
- *"Mobile elements rely on a finite energy source."*

Considering the above constraints, our proposed architecture is based on a set of simple but effective principles, some design tactics and abstractions. Our case study here is a mobile hospital information system (mobile HIS) exemplifying a mobile environment with characteristics of both physical and logical mobility. Physicians and nurses as the principal and very active agents of a hospital environment, with frequent displacements, can make best use of mobile hosts to connect to the hospital information system ubiquitously. Besides, mobile software agents exist in the system and migrate between the hosts to gather information and help in decision making.

The rest of this paper is organized as follows: Section 2 explains four basic principles of MobFish architecture that have been extracted from mobile environment characteristics. These principles shape the proposed architecture for mobile file sharing system. Section 3 describes design issues of the mobile file sharing system; this section includes applied tactics and the general structure of the system. Section 4 illustrates one of the implementations of MobFish and shows some results of the implemented system.

2. Principles

Our architecture is based on a set of principles to satisfy the additional requirements of the mobile file sharing system. These principles are core of our design phase and have designated as a supplement to notion of typical file sharing systems.

1. **Support for heterogeneous networks and adaptive behavior**

Since nomadic users need pervasive information access, mobile platforms are supposed to connect to the network ubiquitously. As a result, the mobile file sharing systems should support several access technologies including wireless LAN, short range radio and packet radio and ought to work in heterogeneous environments. It means, in contrast to classic file sharing systems, mobile file sharing systems should operate on different types of networks. For example in mobile HIS, two hosts may be able to establish several connections through the global wireless network (i.e. UMTS) or the hospital wireless LAN or a transient ad-hoc network. In this case, the file sharing system should select the appropriate network automatically or with the help of users.

On the other hand, as a result of hand-over of mobile users between diverse networks as well as alteration in connectivity of the networks - and in general due to dynamic change of the computational context - designers have the tendency to use adaptive[1,8,17,19] systems for mobile environments. Adaptation is based on the rule that when the situation changes, then the behavior of the system adjusts in line with predefined or instant policies of the user. Network-adaptation, application specific adaptation and adaptation in content transmission are some examples of adaptation strategies have been researched [14]. Assume that a nomadic user move to a low bandwidth and costly network when he is downloading a large file, in this case the system should not continue file transfer unwisely. It should make a decision through predefined policies or ask the user to decide.

Consequently, the first principle is focused on supporting heterogeneity in file transmission plus methods for adaptation of the system with the environment changes.

2. **Decrease the number of unnecessary and inefficient file transfers**

In fixed networks it is usual to download a file from a host incorrectly just because of name similarity or other mistakes. These unnecessary file transmissions are not desirable in mobile environments while the cost of data transfer in mobile networks is much more than fixed ones.

In addition to unnecessary file transmissions, inefficient file transfers may appear. Inefficient file transfers may happen due to lack of information about the shared files and the sharers. As an example, the file may be downloaded from a host with poor connectivity while the file has been shared by its original source with a better connection. Furthermore, it is likely to start file transmission from a host which is going to leave the network in minutes.

Both incorrect and inefficient file transmissions occur owing to lack of information. Indeed, in fixed networks as the speed is high and the cost of communication is low, descriptive information about shared files are limited. However, in mobile environments due to dynamic behavior of the mobile nodes as well as high cost and low speed of the network, this information is important.

Therefore, the second design principle is providing services in the system to hold sufficient metadata attached to the shared files. This information is required to decrease the number of incorrect and inefficient file transmissions.

3. **Avoid unsolicited waits**

In wireless networks, absence of the wanted host is common. So, when a file placed on an absent host is requested, the requester goes to waiting state. Usually in typical file sharing systems, the requester will not be informed on the return of sharer. So, in general the requester uses the polling method to become aware of the return of the sharer. Sometimes, this leads to a long delay before file transmission. Since, the requester itself may not be within reach when the sharer returns to the network. Another obstacle is that the sharer will not be informed about file requests sent to it in its absence time. This cause unnecessary waits too.

As the third principle, to avoid mentioned unwanted waits, the file sharing system should support a scheme to inform waited hosts when the wanted host returned to the network. It should maintain asynchronous file requests too.

4. **Use simple and consistent naming system**

In a mobile environment, with both logical and physical mobility, everything is dynamic. Mobile hosts are moving between networks and mobile agents are moving between hosts. Users are also mobile and may even change their host to have ubiquitous information access. Naming elements in such an environment is an interesting research topic.

The fourth principle is focused on the fact that using an appropriate naming strategy for mobile file sharing system can increase its performance and effectiveness. For this purpose, we designed and employed a consistent naming system in which shared files have persistent access names with low degree of complexity.

3. Design Issues

MobFish architecture is based on a number of tactics [3] to satisfy the requirements and quality attributes of the system. These tactics are a collection of related works that are managed with a predefined policy based on the principles mentioned in section 2.

3.1 Tactics

1. **Layered Design**

Like most of distributed systems, MobFish exploits a layered system. It has three major layers and each layer is almost separate from the others. The lowest layer is *relay layer* which is responsible for data communication; the median layer is *coordination layer* which provides the abstraction of a shared space and helps the hosts to convey file sharing control records; the highest layer is *file sharing managerial layer* which determines the arrangement and meaning of file sharing control records. In figure 2 the structure is represented. In this scheme, the heterogeneity is supported, as communication method in relay layer is absolutely independent from upper layers.

2. **XML structures as descriptive metadata**

As described in section 2, maintaining descriptive metadata will reduce the number of inefficient and incorrect file transfers. Consequently, we used two internal xml structures; one for publishing a shared file metadata (FXMD) and the other for describing status of a sharer host (HXMD). The former will be extended by the latter to compose the shared file effective metadata (EXMD).

When a file sharer receives a request, it generates effective metadata and passes it to the requester. Figure 1 represents an instance of a shared file effective metadata. The brief description of the file, the original source of the file (or the file fixed hosts), the exact size, the possibility of segmentation are some of the information that may be placed in FXMD.

Estimated time the host stays in the network, estimated time the mobile agent remains on the host, the supported file transfer methods, the quality of shared connections are some information passes with the HXMD.

```
<EXMD>
   <FXMD>
        <filename> P028CH </filename>
        <source> HIS File Server 2 </source>
        <description> History of cardiograph
        outputs for patient 028. From 2005/06/15
        to 2005/11/09  </description>
        <size> 15 KB </size>
        <dividable> no </dividable>
   </FXMD>
   <HXMD>
        <connections>
          <C><N> TCI </N><Q> average </Q>
          <C><N> LHIS </N><Q>excellent </Q>
          <C><N> A12 </N><Q> not good </Q>
        </connections>
        <EDD> 14:20 </EDD>
        <EAD> N </EAD>
   </HXMD>
</EXMD>
```

Figure 1. Sample Effective Metadata

3. Application aware adaptation

Adaptation stands for dynamic balance between two paradigms, autonomy of mobile hosts and interdependence of them. In MobFish, both mobile file sharers and requesters can adapt their behavior with the environment changes. This adaptation is based on the concept of application-awareness. The range of adaptation strategies is delimited by two extremes and application-aware adaptation [11, 16] is a spectrum of possibilities between these two extremes. At one extreme, adaptation is entirely the responsibility of individual applications. At the other extreme, application-transparent adaptation places entire responsibility for adaptation on the system [17]. In mobile file sharing system, a customizable adaptation handler is defined in managerial layer to work based on application-aware adaptation strategy.

4. Using listeners, status info and ASYN requests

An effective approach to avoid unsolicited waits is taking advantage of asynchronous communication. In our design, this approach is applied in three ways.

Putting status info of the hosts in the shared space

Before attempt to file transfer, the requester checks for the presence of the sharer host. Putting status info of the hosts in the shared space could reduce the cost of communication as well as waiting times. Status info of a host is updated when it decides to leave the network. Moreover, on revisiting the network, it updates its status info in the shared space and changes the status to present.

Setting listeners for the hosts when they are absent

When a sharer host is absent, requesters can set listeners for it in the shared space and ask the system to notify them when the sharer host revisits the network. Using this technique, the requesters will be informed about sharer return immediately and they will be able to apply for the shared file at once.

Using ASYN file requests if a file sharer is absent

When a sharer host is absent the requester can put an ASYN request for a file in the shared space and ask the sharer to send him the file. The ASYN request may suggest asynchronous or synchronous file transfer methods for sending the file. That is, if the requester predicts an unstable state, it asks for asynchronous transmission and in contrast, stable state prediction may cause a synchronous file transmission.

In mentioned techniques, the concept of shared space is an essential part of the communications. This concept is realized by the coordination layer as stated before. The coordination layer divides the shared space into two parts, a *public area* which is common between all hosts and a *private area* which holds a message inbox for each host. Listeners and ASYN file requests are put in the private area and status info records are located at public area.

5. Two-level naming system

In a mobile file sharing system hosts migrate between networks and agents. Also, their associated files migrate between hosts. Moreover, users change their hosts and their related data according to required computing context.

In such environments with high degree of mobility, the traditional naming systems are not well suited [21]. So addressing the files and locating them with a non-complex structure that runs on mobile hosts efficiently is an important challenge. Our solution uses a two level naming system, in which *access names* as permanent and human-friendly names are mapped to *address names* as temporal and location dependent names. The idea is simple. The sole names that are not changing in this environment are sharer identifiers. File sharers are either mobile users or mobile software agents. Both classes have permanent and human-friendly identifiers. So access names consist of sharer identifiers as the first segment and file names as the second segment. For example in a mobile hospital information system if the user "Nurse103" is going to share the file "BloodPressureA29" the shared file access name will be "/Nurse103/BloodPressureA29". It emulates a big shared space, wherein each user has a separate directory and there are some automatic mount points to user directories. This scheme leads permanent names that do not change by migration of software agents and users. It means, even if Nurse103 migrate from a host to another, the access name of the file wont change.

On the contrary, address names consist of three segments, network name, host network address and file address. Network name indicates the last network visited by the mobile host. Host network address is the address of the host in the last visited network addressing system. The file address is the file address in the host addressing system. This method supports migration of users between hosts, mobile hosts between networks and also data between hosts without any change to access names. Like the shared space, the naming system can be implemented by distributed or centralized approaches.

The advantage of mentioned naming system is acquiring name transparency with a direct single-level mapping instead of using complex multi-level mappings which do not fit into the constraints of mobility.

3.2 Structure

The first level decomposition [3] of mobile file sharing system based on the mentioned principles and tactics is shown in figure 2.

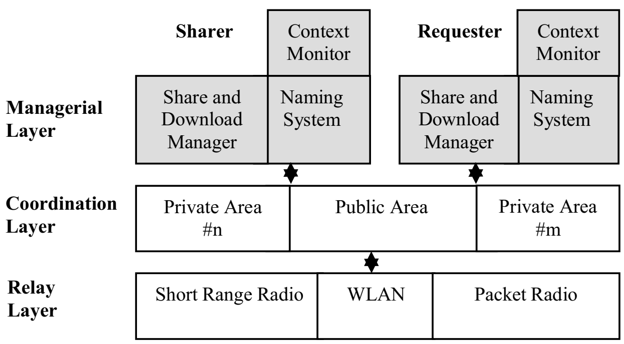

Figure 2. First Level Decomposition of the System

Figure 2 simply shows the involved elements of the system and their conceptual representation in a file transfer scenario. The deployment model of the components will be explained in next section.

Below is a brief description of the components of the managerial layer.

Context Monitor:

Context monitor is responsible for monitoring the changes of computing context including quality of network, remaining battery power, hosts physical location and etc. It provides adaptation data for the share and download manager component.

Share and Download Manager:

Share and download manager is in charge of the main procedures of the file sharing system including procedures of sharing and downloading files, handling XML metadata structures, listeners, status info records, and ASYN requests. This component has a significant role in adaptive behavior of the system.

Naming System:

Naming System manages the two-level naming scheme. It uses the public area of the coordination layer to store the names. When a user changes his host, or a software agent migrate from one host to another, the naming system of the new host updates the address of the shared files in the public area. When a mobile host enters to a new network or changes its network address the update is done by naming system of the mobile host itself.

4. Implementation

The presented architecture for mobile file sharing is high level and it can be realized by several methods. We have worked on particular implementations for different environments. In this paper, SmartFish as a client-server realization of MobFish for small file sharing networks is presented to show the correctness and effectiveness of the proposed architecture. In SmartFish, clients are held on mobile hosts and they are responsible for the mobile part procedures of file sharing. In this scheme, a central server is placed to store meta-data information and manage the public shared space. SmartFish is suitable for the environments with availability of a fixed server. On the other hand in agent oriented implementation of the architecture (LimeFiSh[20]) the existence of a fixed server is not assumed and everything is done on mobile hosts.

In SmartFish, the client side is implemented on Windows CE platform, while server is implemented using J2EE. Figure 3 shows the general structure of the system. The implemented system uses Multimedia Messaging Service as the communication interface between the mobile clients and the server for transferring meta-data, requests and etc. The server has a link to the MMS center and works as an MMS value added service provider. As the size of meta-data information transferred between a client and server hardly exceeds 10 Kbytes per transaction, our experience showed that MMS is the best choice for the client-server communication in SmartFish. The assumption that all mobile clients have MMS is not much restricting the users of the system (due to its popularity), its range is very wide (scope of a mobile network operator), and it is over WAP which is a bearer independent transport protocol (i.e. CSD, CDMA, USSD, SMS and many other bearers can carry WAP messages).

The following steps show a common scenario of the file transfer in the SmartFish client-server model:

- When a sharer start to share a file, the client on its host collects information of the shared file (i.e. name, size, user comments, etc.) from both system and user. This information, along with the host's recent specific information (i.e. location, context information, communication interface updates, etc.) is packed as an EXMD file. This file is sent to the server using MMS.
- The server receives this information and updates its meta-data information base.
- When a requester requests for a file, the client on its host generates a query including related keywords and file size interval. It sends the request to the server.

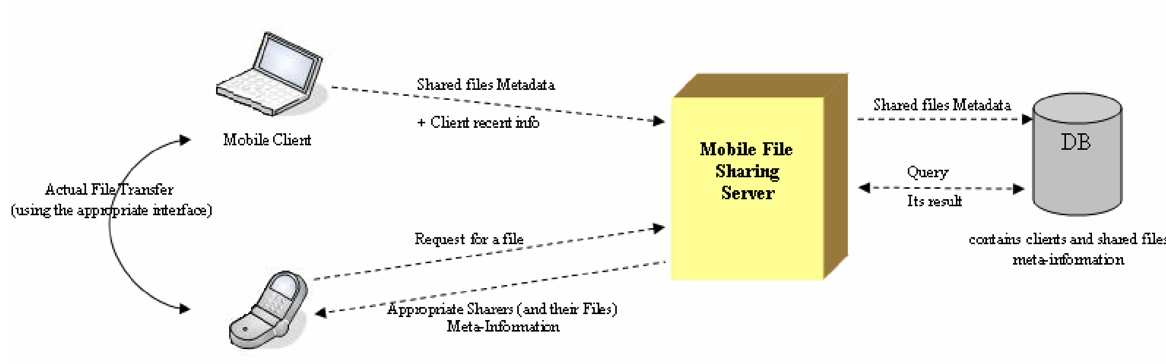

Figure 3. The general structure of SmartFish

- When the server receives the query, it searches the information base for the appropriate files and then makes a ranked list of the sharers. Besides file name, type, and size similarity, the aptness of the sharer's connection interfaces impacts the ranking. The result will be sent to the requester client in XML format.
- Based on its location and available connection interfaces, the requester selects the appropriate sharer and starts the actual transfer of its shared file. The automatic selection of the best sharer is synchronized with adaptation rules of the system.

Figure 4 shows two snapshots of the SmartFish client application running.

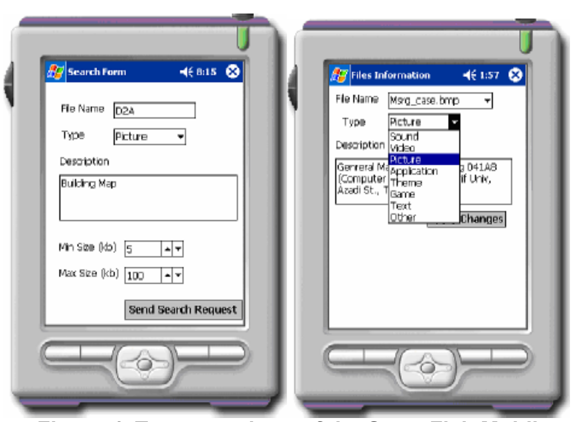

Figure 4. Two snapshots of the SmartFish Mobile Applications

In order to show how well this system satisfies the requirements of mobile environment, we have captured some characteristics of our implemented system. Although, these parameters can not be regarded as a very complete benchmark of the system, we believe the measured parameters reflect the essential requirements of an appropriate mobile file sharing system. Some of the results are discussed below.

Figure 5 shows the average response time of the server across different query sizes. It shows that the server fulfill mobile client's requests quite well. Usage of a scalable platform and simplicity of the whole system keeps the server efficient while used by a lot of clients.

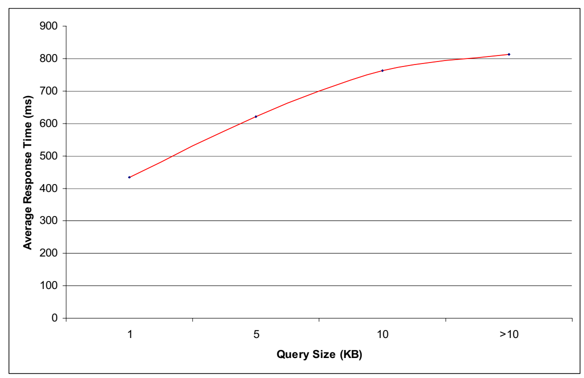

Figure 5. Average Response Time of the server across different file sizes

Figure 6 shows the percentage of the transfers which were successful in first try across different file sizes. As the size of the file grows, the use of communication interfaces is more restricted (i.e. MMS and Bluetooth are normally out of place for transferring more than 50K files).

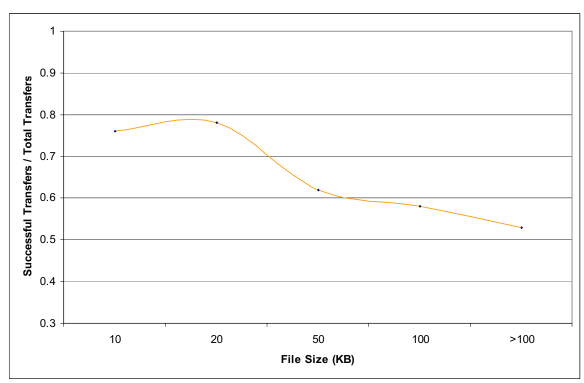

Figure 6. Successful file transfers (in first try) across different file sizes

5. Conclusion and Future Work

It can be seen from this paper that using new models for file sharing in mobile environments, can improve usability, performance and effectiveness of file sharing systems with mobility support. In our recent work on mobile file sharing systems, we employed an architectural style and several design techniques to fulfill the requirements and quality attributes of the mobile file sharing system. Adaptation as a key solution for mobility problems, asynchronous communication and supplementary information as two ways for reducing unnecessary waits, and innovative naming system to simplify addressing the mobile units are some design techniques exploited in our model.

In our ongoing research we plan to investigate further on adaptation and design more clever applications. To address this issue, we have divided our domain into two areas, the first denotes to pure mobile networks in which there are not auxiliary fixed hosts and everything is mobile, and the second denotes to common mobile networks that benefits from supporting fixed hosts.

The next studies can focus on specific models and implementations for each area as well as working on flexible systems to cover both areas with the ability of switching between them.

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An Evaluation of Two Policies for Placement of Continuous Media in Multi-hop Wireless Networks

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Abstract

This paper focuses on a greedy data placement strategy for a mesh network of peer-to-peer devices that collaborate to stream continuous media, audio and video clips. The greedy placement strategy, termed Simple, strives to maximize the number of references served by the local storage of a peer. We analyze two policies to realize this placement: Frequency-based and Byte-hit. The first sorts clips based on their access frequency, assigning the frequently accessed clips to each node. Byte-hit computes the frequency of access to each byte of a clip, sorts clips based on this value, and assigns those with the highest byte-hit value to each node. Both have the same complexity and almost identical implementations. A simulation study shows Byte-hit is superior to Frequency-based for two reasons. First, it maximizes the number of peers that can simultaneously display their referenced clips. Second, it is more robust to error in access frequencies. In all our experiments, Byte-hit performs almost identical to the optimal placement strategy.

1 Introduction

Advances in communication and processing have made ad-hoc networks of wireless devices a reality. A device, termed a peer, is typically configured with a fast processor, a mass storage device, either one or several types of wireless networking cards [20, 11]. Peers strive to provide their users with ubiquitous access to their data everywhere and are building components of complex systems such as Memex [4] and MyLifeBits [12].

In this study, we focus on devices configured with wireless networking cards that offer bandwidths in the order of a few Mega bits per second (Mbps) with a limited radio range, a few hundred feet. Examples include 802.11a, b, and g networking cards [3, 2]. Devices communicate with each other when they are in the radio range of one another. Some devices might be in the radio range of a WiMax (802.16a) base station or an access point, providing the ad-hoc network with access to the wired infrastructure.

In multi-hop wireless networks, two peers may communicate through a number of intermediate peers that collaborate to relay information. An interesting subclass of networks, termed mesh networks, is more constrained by bandwidth and storage limitations and less constrained by node mobility and power consumption. An example might be Canada's SuperNet [6] which delivers educational material to remote areas in Alberta. It consists of wireless peers that complement the wired infrastructure. Another application might be an office setting [20] or a home entertainment system [14] where multiple peers collaborate to provide on-demand access to content. With the latter, a household may store its personal video library on a peer for retrieval everywhere, e.g., when visiting a friend's home. A peer may encrypt its content to either protect it from un-authorized access, i.e., authentication, or implement a business model for generating revenues. These mesh networks raise a host of privacy and security issues [5] which constitute an active area of research by several communities and beyond the focus of this paper.

A challenge of these ad-hoc networks is how to display continuous media, audio and video clips. Continuous media consists of a sequence of quanta, either audio samples or video frames, that convey meaning when presented at a pre-specified rate [13, 19]. Once the display is initiated, if the data is delivered below this rate then the display may suffer from frequent disruptions and delays termed hiccups.

A peer may store clips in its local storage in anticipation of future references either by its user or a neighboring peer. Many studies from mid 1990s describe techniques for a hiccup-free display of a clip that resides in the local storage of a peer, [17, 13] to name a few. One may use one of these techniques when a user references a clip resident on local storage of a peer. Otherwise, this peer (denoted D_d) must locate a peer that contains the referenced clip (denoted D_p). Next, it must admit itself into the system by reserving one or more paths from D_p to D_d in order to stream the referenced clip at a pre-specified bandwidth. This process is termed admission control. It involves collaboration of other peers serving as intermediate application-based routers by requiring them to reserve their network bandwidth on behalf of this stream. By reserving bandwidth along a path, D_d overlaps its display with delivery of data from D_p, minimizing the latency observed by a user.

A peer may set aside a fraction of its available storage to store audio and video clips. Without loss of generality and in order to simplify discussion, the term storage refers to this fraction. The Simple data placement strategy strives to maximize number of references made by a peer to clips resident in its storage. It realizes this objective by assigning as many clips as possible to a peer. This assignment is trivial when the storage capacity of each peer is larger than the repository size because one may assign the entire repository to each peer. Otherwise, the greedy algorithm must determine the identity of clips that should be assigned to each peer. We present two policies to address this research topic, termed Frequency-based and Byte-hit. Both assume an estimate of frequency of access to clips is available. We compare these two policies by quantifying the number of peers that may display their referenced clips simultaneously. This is also termed system throughput.

Obtained results provide the following key insights. First, when the estimated frequency of access to clips is precise, Byte-hit enables a larger number of requests to find their referenced titles locally, maximizing the throughput of the system. Second, when the estimated frequency of access is not precise, Byte-hit is more robust and continues to provide a higher throughput. Third, Byte-hit has the same complexity as the Frequency-based techniques with an almost identical implementation. These provide a convincing case for a system designer to employ the Byte-hit policy.

The rest of this paper is organized as follows. Section 2 provides a survey of the relevant literature. In Section 3, we present the details of Simple and its alternative policies. Section 4 presents a comparison of the alternative policies using a simulation study. Brief conclusions and future research directions are presented in Section 5.

2 Related Work

Placement of data in ad-hoc networks is an emerging area of research. We categorize prior studies into those that share or do not share storage. When storage is shared, a design strives to enhance a global performance metric that impacts all peers. When storage is not shared, a design strives to enhance a metric local to each peer. Simple does not share storage and its outlined policies strive to enhance the number of user requests satisfied using the local storage of a peer. All prior studies assume storage is a shared resource.

Parameter	Definition
$B_{Display}$	Bandwidth required to display a clip
B_{Link}	Bandwidth of a link
C	Number of clips, $1 \leq i \leq C$
f_i	Frequency of access to clip i
$\mathcal{N}$	Number of peers
$S_{C,i}$	Size of clip i
S_{DB}	Size of the database, $S_{DB} = \sum_{i=1}^{C} S_{C,i}$
S_N	Storage capacity of a peer
S_T	Total storage capacity of peers, $S_T = \mathcal{N} \cdot S_N$

Table 1. Parameters and their definitions

Below, we summarize these studies.

Studies that assume storage of a peer is shared include [21, 7, 1]. The global performance metric of each study includes: average search size for a clip [7], euclidian distance between a client and a server [21], and number of simultaneous displays [1]. With [7, 1], the number of replicas for a clip is proportional to the square root of its frequency of access. With [21], this number is proportional to $\frac{p_i^{0.667}}{clip\ size}$ where p_i is the frequency of access to clip i. Simple does not compute the number of replicas for a clip. A comparison of Simple with [21, 7, 1] is a future research topic, see [16].

We focus on Simple in order to (1) identify which of its policies is superior, and (2) use the superior policy for comparison with those techniques that share storage. A key contribution of this paper is to show superiority of Byte-hit. See [16] for a preliminary comparison of Byte-hit with a storage sharing technique.

3 Simple Data Placement

We assume an ad-hoc network of $\mathcal{N}$ peers and a base-station. The base-station provides access to the wired infrastructure and remote servers. It might be in the radio range of a few peers.

When a user employs a peer to reference a clip, the peer checks to see if the clip is available in its local storage. In this case, it initiates the display of the clip from its local storage. Otherwise, it tries to admit itself to stream the clip from either a peer containing the referenced clip or the base station.

Simple assigns clips to peers with the objective to maximize the number of simultaneous displays while minimizing the incurred startup latency. Startup latency is defined as the delay incurred from when a peer references a clip to the onset of its display. An effective heuristic is to maximize the number of requests serviced using the local storage of a peer, minimizing the demand for the network bandwidth.

With a homogeneous repository consisting of equi-sized

Clip id	$S_{C,i}$	f_i	$f_i/S_{C,i}$
1	14	0.7	0.05
2	1	0.1	0.1
3	20	0.2	0.01

Table 2. Byte-hit may not always yield the Optimal solution.

clips, the placement of data is similar to the fractional knapsack problem [8]. When the objective is to maximize the frequency of access to the local data stored on each peer, defined as $\sum_{i \epsilon S} f_i$, the optimal solution is to assign the S most popular clips to each peer. See [15] for a proof.

A repository consisting of a mix of media types is more realistic. In this case, the size of clips will be different, changing the placement of data with Simple into a 0-1 knapsack problem. This problem has been well studied in the literature. A dynamic program to realize the maximum hit ratio is outlined in [8]. This solution is a pseudo-polynomial algorithm with $O(C \cdot S_N)$ complexity. Note that the granularity of S_N is in bytes. When the storage capacity of a node is in the order of hundreds of Gigabytes, this optimal algorithm may incur a long execution time.

There exists suitable heuristics to approximate the optimal solution. An effective heuristic is to (1) sort clips based on their $f_i/S_{C,i}$ value, (2) assign the first S clips to each node where $\sum_{i \epsilon S} S_{C,i} \leq S_N$. The process is repeated until storage of a peer, S_N, is exhausted i.e. $S_N - \sum_{i \epsilon S} S_{C,i} < S_{C,j}$ for all $j \epsilon S'$. This is the **Byte-hit** policy. Another heuristic, termed **Frequency-based**, is to repeat the above procedure using f_i instead of $f_i/S_{C,i}$.

Section 4 shows Byte-hit approximates an optimal assignment. However, Byte-hit may not always yield the optimal assignment as illustrated by the following example. Assume $S_N = 14$ and a repository of 3 clips. Table 2 shows the size of each clip and its frequency of access. The Byte-hit policy assigns clip 2 to each peer, observing a 10% hit ratio. The Optimal assignment would assign clip 1 to each peer, increasing this hit ratio to 70%. While the reader may observe the Frequency-based policy would produce the optimal solution, it is important to note that one may devise counter examples to show that Frequency-based also does not always produce an optimal assignment.

4 A Comparison

In this section, we compare the Frequency-based and Byte-hit policies. We start with a description of our simulation environment. Next, we show Byte-hit provides a higher throughput when the assumed frequency of access to clips is precise. Finally, we show Byte-hit is more robust when the frequency of access to clips is erroneous. Due to lack of space, we refer the interested reader to [15] for an analysis of scenarios with two different demographics, showing Frequency-based observes higher improvements. However, Byte-hit continues to outperform Frequency-based.

Simulation Set-up: We consider a heterogeneous repository consisting of two media types: audio and video clips with display bandwidth requirement ($B_{Display}$) of 300 Kbps and 4 Mbps. There were 3 different clip sizes for each media type. With video, we have clips with a display time of 2 hours, 60 minutes, and 30 minutes. The size of these clips are 2 Gigabytes (GB), 1 GB, and 0.5 GB, respectively. With audio, the clip display times are 4 minutes, 2 minutes, and 1 minute. Resulting clip sizes are 9 Megabytes (MB), 4.5 MB, and 2.25 MB.

With a database of C clips (say C=100), the clips are numbered sequentially from 1 to 100. Odd numbered clips are video and even numbered clips are audio. Thus, the pattern of clip sizes is 2 GB, 9 MB, 1 GB, 4.5 MB, 0.5 GB and 2.25 MB. This pattern repeats itself until all 100 clips that constitute the repository are constructed. This numbering is important because distribution of requests across clips is generated using a Zipfian distribution with a mean of 0.27. This distribution is shown to resemble the sale of movie tickets in the United States [10].

We analyzed two different network topologies: String and Grid. With String, each peer (except the two peers at the end of the topology) is in the radio range of two neighboring peers. This might represent a community of houses lined up in front of a lake. With Grid, a peer is in the radio range of those peers with a Manhattan distance of one. This means each peer, except for those on the border of the Grid, is in the radio range of 4 other peers. This is more representative of a metropolitan neighborhood in a city such as Los Angeles. The link bandwidth between two peers is 4 Mbps, B_{Link}=4 Mbps. With all topologies, we assume the presence of a base station. It is located at one end of the String topology and one corner of the Grid topology.

In each iteration of a simulation run, peers are picked in a round-robin manner to reference a clip for display. The referenced clip is selected as per the Zipfian distribution. If the referenced clip resides in local storage of the peer then the number of simultaneous displays is incremented by one. Otherwise, it invokes a centralized admission control component that employs the Ford-Fulkerson algorithm [9]. This component tries to reserve one or more paths from the target peer to the base station with bandwidth equivalent to that required for continuous display of the clip ($B_{Display}$). If such a path exists then the request is admitted into the system and the number of simultaneous displays is increased by one. Otherwise, the request is rejected. Since the request is either admitted or rejected instantaneously, the tolerable startup latency in this case is 0. This would be different in

N	25	81	100	144	196	324
C	100	324	400	576	784	1296
$Optimal$	0.893	0.763	0.743	0.715	0.693	0.662
$Byte-hit$	0.891	0.763	0.743	0.715	0.693	0.662
$Freq-based$	0.868	0.665	0.621	0.552	0.501	0.428

Table 3. $\sum f_i$ for the different policies for a constant C/N ratio of 4, $S_N = 26$ Gigabytes.

a real system. An iteration ends once all N peers have invoked this procedure. Note that the maximum number of simultaneous displays for an iteration is N.

A key metric is the average number of simultaneous displays. It is an average of 100,000 iterations. Another metric is the hit ratio observed by each peer. It is an average across 100,000 requests over N peers. We also study how robust this metric is to errors in the clip access frequencies.

We observed identical trends for both the String and Grid topologies. This is because the base station is located at one end of the topology. Hence, for the remainder of this paper, we focus on the Grid topology. A future research direction would be to identify alternative placements of the base station(s) and quantify the effects of B_{Link} and $B_{Display}$ on the number of simultaneous displays.

4.1 Number of Simultaneous displays

Figure 1 shows the results observed with a scale-up experiment. It is termed scale-up because the number of clips (C) is a function of the number of peers (N), $C = 4N$. Thus, when we increase the number of peers (N) from 25 to 50, the number of clips (C) increases from 100 to 200. The storage capacity of each peer is fixed at 26 GB ($S_N = 26$ GB). We assume the bandwidth between the peers is fixed at 4 Mbps.

In Figure 1, the dashed line shows the desired number of simultaneous displays. Its values are dictated by the number of peers shown on the x-axis. This is the theoretical upper bound on system throughput.

Figure 1 shows the following two observations as a function of C and N. First, all strategies diverge from the theoretical upper bound. Second, Byte-hit and Optimal provide the same throughput, outperforming Frequency-based by a wider margin. We explain each in turn.

As we increase C and N, a smaller fraction of repository fits on each peer because the storage capacity of each peer is fixed at 26 GB, S_N=26 GB. This causes a larger fraction of requests to stream clips from the base station. With the bandwidth of a connection between two peers fixed at 4 Mbps ($B_{link} = 4$ Mbps), the admission control admits

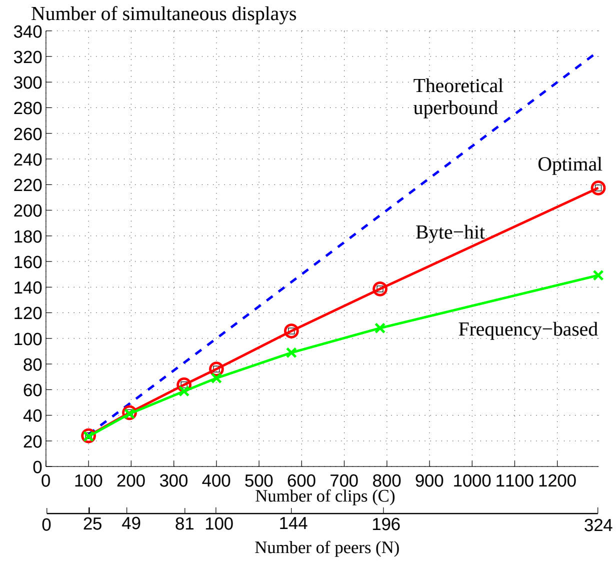

Figure 1. Throughput as a function of C, N.

fewer requests. This causes all policies to diverge by a wider margin from the theoretical upper bound.

To explain the second observation, we show the total frequency of access to the clips assigned to each peer with Optimal, Byte-hit and Frequency-based in Table 3. Each column of this table corresponds to a different N and C values, i.e., ticks on the x-axis of Figure 1. The total frequency with each strategy drops as a function of C. This is because the storage capacity of each peer is fixed and the frequency of access to each clip decreases with higher C values.

Table 3 shows identical access frequencies with Byte-hit and Optimal which is higher than that with Frequency-based. This is because Byte-hit and Optimal assign a different collection of clips to each peer for each value of C and N. With Frequency-based, the same collection of clips is assigned to each peer for value of N greater than 49. With $N = 25$, a subset of these clips is assigned to each peer.

To elaborate on these, observe that the frequency of access to each clip changes as a function of C. This changes the value of $\frac{f_i}{S_{C,i}}$, causing Byte-hit to assign a different collection of clips to each peer. With Frequency-based, the sorted order of clips using their access frequency remains unchanged as a function of C. Recall the pattern of clip sizes is: 2 GB, 9 MB, 1 GB, 4.5 MB, 0.5 GB, and 2.25 MB. Total size of each pattern is S_P=3515.75 MB. Frequency-based assigns 7 of these patterns to a peer. This leaves 1389.75 MB of free storage. Thus, the first video clip of the eighth pattern (clip 43) cannot be assigned because it is 2 GB in size. Frequency-based is able to assign only clips 44, 45, 46, and 47 of the eighth pattern. This leaves 374 MB of free space. Only audio clips can be assigned to this free

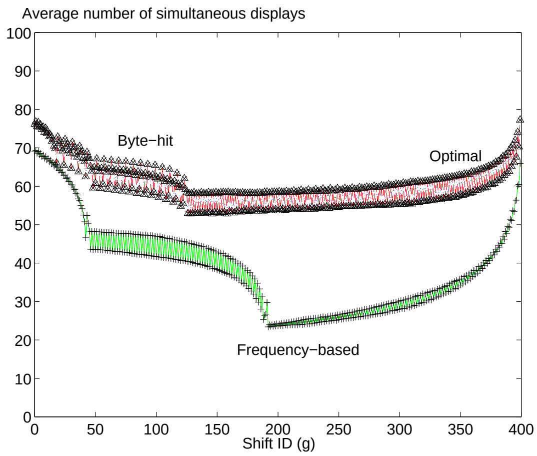

Figure 2. Error in access frequency.

space. When $N = 25$ and $C = 100$, a total of 79 clips are assigned to each peer, assigning all the audio clips and leaving 200.75 MB of free space. When $N = 49$ and $C = 196$, there are additional audio clips because the repository size is larger, allowing Frequency-based to exhaust all free storage of each peer. In this case, it assigns 117 clips to each peer. The identity of last assigned clip is 192. With values of N higher than 49, the value of C exceeds 192. This means the same collection of clips are assigned to each peer because their sorted order does not change as a function of C.

Robustness to Frequency of Access: We analyzed the sensitivity of the alternative policies by placing data using a Zipfian distribution of access. Next, the workload generator was modified to generate a clip request using a *shifted*-Zipfian distribution. The latter is generated by shifting the original Zipfian distribution with parameter g. The value of g ranges from 1 to C. This means the frequency of access for clip i is assigned to clip $(i + g)\ mod\ C$. When $g = 1$, the workload generator issues requests relative to the original distribution (g=0) in the following manner: Clip 2 is referenced as frequently as Clip 1, Clip 3 is referenced as frequently as Clip 2, so on until Clip 400 is referenced as frequently as Clip 399, and Clip 1 is referenced with the same access frequency as Clip 400. For a given shift value g, we conducted 100,000 iterations of each experiment using a Grid topology of 100 peers. Note that the original placement of clips remains unchanged in each iteration.

Figure 2 shows the average number of simultaneous displays supported by a grid topology consisting of 100 peers. As we increase the value of g, both techniques support fewer simultaneous displays because they must reference the remote base station more frequently. Obtained results show Byte-hit is more robust than Frequency-based. This is because Byte-hit assigns 232 clips to each peer. Frequency-based assigns only 117 clips to each peer. Many of the 232 clips are the smaller audio clips with a high byte-hit value. When the frequency of access to these clips increases, Byte-hit services these requests using the local storage of a peer.

System throughput drops in a step manner as a function of g. Below, we elaborate on this trend with the Frequency-based policy. The explanation for Byte-hit is similar. With Frequency-based, see Figure 2.b, the average number of simultaneous displays drops sharply as g approaches 42. This drop levels off when g is 43. There is another sharp drop as g approaches 192. The explanation for this is as follows. Recall from Section 4.1 that Frequency-based assigns the first 42 clips to each peer. As g approaches 42, the frequency of access to these clips decreases, reducing the number of requests that find their referenced clips locally. They are directed to the base station and the admission control rejects many due to the limited bandwidth between peers. This explains the first sharp drop as shift ID approaches 42.

When we increase g (shift ID) from 42 to 100, the drop becomes gradual. This is due to assignment of audio clips to local storage of the peers. Recall from Section 4.1 that the id of the last assigned clip is 192. As g approaches 192, throughput degrades faster as fewer references are serviced using local storage of a peer. The lowest point is when g is 193. Beyond this point, the throughput increases because the number of references to the first 42 clips starts to increase once again.

Similar trends are observed with Byte-hit where it assigns 232 clips to each peer. The trend is not as dramatic because it assigns many small audio clips to each peer and the id of the last assigned clip is 400.

5 Conclusions and Future Research

The primary contribution of this paper is to show the superiority of Byte-hit policy when peers of a mesh network do not share storage and store clips with the objective to maximize local hit ratio. When compared with the Frequency-based policy, Byte-hit provides a higher throughput and is more robust to the error in access frequencies. This means it is difficult, if not impossible, to design a policy that would outperform Byte-hit significantly.

A decentralized implementation of Simple using Byte-hit might be as follows. Periodically, either a remote server or one of the peers publishes v clips. Each clip has an anticipated frequency of access for different demographics. This meta-data is broadcasted to all peers. A peer uses the demographics of its household to lookup the frequency of access for each of the ρ clips occupying its available storage. It computes the Byte-hit value of these clips and the newly published v clips. Both lists are combined and sorted based on their Byte-hit ratio. Next, it assigns clips from this list to its available storage. We compare this assignment with the existing ρ clips to produce two lists. List one contains those clips to be evicted. List two contains κ clips out of υ to be stored in the local storage. Next, it stores the identity of these κ new clips in a message and transmits this message to the publishing peer. The publishing peer may employ either unicast or multicast to disseminate those new clips selected for storage by one or more peers.

A future research direction is to explore other placement strategies that utilize storage of a peer as a shared resource and compute the number of replicas for each clip [21, 7, 1]. Some preliminary results are reported in [16]. One may consider more sophisticated variations where a clip is partitioned into fragments and different peers store different fragments. The first few fragments of a clip might be replicated more aggressively because they are needed more urgently [18]. When displaying a clip, a peer will display its first few fragments from its local storage while streaming its remaining fragments from the neighboring peers.

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A Meta-Index to Integrate Specific Indexes: Application to Multimedia*

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Abstract

Although applications such as news, e-learning, e-commerce require multimedia data of different types to co-exist, data for each media type are often managed separately because technically they do not have much in common. The common approach for providing the user with an integrated multimedia database is to build an application layer that presents a unified interface and deals with the right mono-medium sub-system depending on the user request. The problem is that this approach does not fully integrate the underlying systems. Another solution is to push the integration into the query processor. This second approach necessitates to have access to the query processor which is not always possible especially if the multimedia system is using a commercial DBMS underneath. In this paper, we propose a meta-index that hosts different specific indexes and integrates the sub-query results to be returned to the user.

1. Introduction

Database Management Systems (DBMS) offer some functionalities (transaction management, declarative query languages, recovery, etc.) that are necessary for novel applications (e.g., multimedia and bio-informatics). Although current DBMSs offer solutions to store and manage the complex data that the novel applications manipulate, they cannot be used effectively for such applications. Even though more suitable indexes exist for the speci c application, current DBMSs do not allow speci c indexes to be "plugged-in". The reason is that indexes are to be used by the query processor as access methods and a new index cannot be used if the query processor is not aware of its existence. Most of the time, the query processor is not accessible to the users. This also means that a new index will not be recognized and used by the query processor.

For classical data, the B^+-tree has been widely accepted as the index structure and offered by Relational DBMSs. Such a standard does not exist for multidimensional data as multidimensional indexes are very specialized [9]. For example, range queries work better with an index of the R-tree family [10], whereas similarity search applications perform better with an index structure such as the SS-tree [15], the SR-tree [11] or the M-tree [6]. Further, different multidimensional indexes can be used for the same application. The endless increasing number of multidimensional index structures leave a lot of choices but pushes the choice of the index to the application designer.

In this paper we propose a meta-index that allows (1) a database system to integrate any user-de ned index and (2) an application developer to pick the appropriate indexes for his/her applications. We de ne the operators needed at the meta-index level to perform the integration of partial results based on partial orders. Then we show how the meta-index can be used together with a uni ed semantic index to create a full multimedia database system. The rest of the paper is organized as follows: Section 2 depicts the meta-index, Section 3 presents the semantic model for media object annotation, Section 4 presents the experimental results and Section 5 concludes.

2. The Meta-Index

We propose the meta-index as an interface between the query processor and the indexes (see Figure 1). The idea is to have the meta-index implemented in a database system

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in order to facilitate the integration of new indexes into the system. The meta-index is viewed by the query processor as a single index that is responsible of certain types of queries. As such, the meta-index has to be in charge of some of the

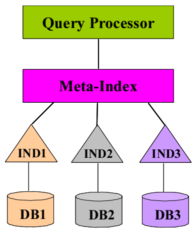


Figure 1. Query Processor, Meta-Index and Indexes

tasks typically devoted to the query processor: Decompose queries it receives into sub-queries to be sent to individual indexes; integrate the sub-query results received from individual indexes.

For the meta-index, an index refers to a piece of software that provides sorted access and/or random access to some data as result of a query. In that sense, for the meta-index an index can range from a regular index to a speci c database system.

2.1. Query Decomposition

The meta-index input is a well-formed query in disjunctive normal form, $Q = Q_1 \vee \ldots \vee Qn$, where Q_i is a mono-answer space query. We say that a query $Q_i = Q_i^1 \wedge \ldots \wedge Q_i^k$ is a mono-answer space query if each sub-query Q_i^j is a mono-index query (i.e., results are obtained from a single index) that expresses parts of the conditions of a query (Q_i) in conjunctive normal form. By well-formed we refer to the classical correctness rules for queries: A query has a single free variable (a query returns one type of objects as results) and all the variables are range-restricted. For example, the query " nd images similar in color and texture to a given image" is a mono-answer space query and each sub-query (on color and texture, respectively) is a mono-index query assuming that the features are indexed separately. The integration producing the nal result is performed within a single answer space. The term answer space comes from of a graphical interpretation of sub-result integration where each sub-query result is represented by an axis in a vector space.

When the meta-index receives a query Q from the query processor, the idea is to decompose this query into $\{Q_1, \ldots, Q_n\}$ so that each sub-query Q_i could be answered through one answer space. That means that each of the corresponding sub-queries Q_i^k uses one or more predicates de ned on the same objects. Hence the decomposition consists in: Grouping sub-queries with conditions that involve predicates on the same index; decomposing sub-queries with complex conditions that involve predicates on different indexes into smaller sub-queries with conditions on single indexes.

2.2. The Meta-Index as an Interface

Normally, any index can be added to the meta-index by the application developer. When an index is plugged into the meta-index, the application developer should also specify the types of queries the index should be in charge of. Basically, the query processor needs to be noti ed on the type of queries that should be passed to the meta-index and the meta-index should know the type of queries to be passed to each index.

Since the queries are in disjunctive normal form, the meta-index needs to know the type of atomic formulas to be sent to individual indexes. Indexes are used as access methods to select a subset of a set (table in the relational world) that satisfy a certain condition de ned on at least one of the features of the objects. The conditions are de ned using some predicates (i.e. $=, <, >$ in relational). These conditions are used to de ne atomic formulas: For example, $t.A = constant$, $t.A = s.B$, $t.A < s.B$ are atomic formulas on attributes A and B of tuples $t \in R$ and $s \in S$. If there is an index IND_i de ned on the attribute A of R that works for the predicates $<, >, =$, then atomic formulas of the form $t.A < constant$, $t.A > constant$ and $t.A = contant$ should be sent to IND_i for $t \in R$. So when parsing a query, the meta-index should look for $t \in R$ and at least one of the following atomic formulas: $t.A < constant$, $t.A > constant$ and $t.A = constant$ in order to determine if part of the query should be sent to the index IND_i.

When the meta-index gets the lists of atomic formulas that each index is in charge of, it compiles a complete list of atomic formulas that it can handle and noti es the query processor. The meta-index is between the query processor and the indexes. It is responsible for decomposing queries received into mono-index sub-queries, integrating the sub-query results received and sending the result back to the query processor.

2.3. Operators for Sub-Query Result Integration

For the meta index we de ne three operators: The join with order, the difference with order and the union with order as extensions respectively of the join, the difference and the union relational operators. These operators are de ned in terms of partial orders because we have to be able to reason about the queries and their results at the meta-index level without knowing the metric used to de ne them. As in relational databases, the conjunctive connectives are mapped to joins with order, a negation is a difference with order and a disjunctive connective is a union with order.

2.3.1 Join with Order

The result of a query posed against an index is a collection R of objects (e.g., "list images taken by Ilaria") or a ranked list (e.g., "list images similar to the query image"). Although ranked lists are usually based on a metric, for the sake of generality we represent a ranked list as a collection R of objects with a partial order $\prec$, i.e., $[R, \prec]$, since total orders are particular cases of partial orders. Note that $[R, \prec]$ actually is a graph, where nodes are elements of R and an arc (x, y), with $x, y \in R$, means that "x is better than y".

Complex queries can involve the integration of the results of two ranked lists from different indexes. For example, "images similar to a query image on texture and on color", assuming that colors and textures are indexed separately. The cases where the integration is about unordered collections is similar to the relational case. The novelty is introduced by the orders and here we will focus on these.

Definition 2.1 (Join with Order) *Given two collections R and S of objects of the same type, the condition of the partial order join is that the objects in both sets be identical and the join with order between two collections R and S, $R \bowtie_{\prec} S$, is defined as follows:*

Case 1*: R and S are sets: $R \bowtie_{\prec} S = R \bowtie S = R \cap S$ (recall that the join condition is that the objects are identical).*

Case 2*: One of the collections (let us say R with the partial order $\prec_r$) is a ranked list: $R \bowtie_{\prec} S = [R, \prec_r] \cap S = [R \cap S, \prec]$, where for $x \in R - S$ and $y \in R$, $\prec = \prec_r - \{(x, y), (y, x)\}$.*

Case 3*: Both R and S are ranked lists ($[R, \prec_r], [S, \prec_s]$): $R \bowtie_{\prec} S = [R, \prec_r] \bowtie_{\prec} [S, \prec_s] = [R \cup S, \prec]$, where $\prec$ defines a global partial order among the objects in R and S (see discussion).*

We will discuss only Cases 2 and 3 as Case 1 is identical to the join in the relational model. An example of query of Case 2 is Q: "list images taken by Ilaria that look like the image i". Given a collection S of images taken by Ilaria and a ranked list $[R, \prec_r]$ of images similar to image i, the aim is to select the objects of R that also belong to S and de ne a new partial order on the qualifying objects. This is derived from $\prec$ by simply removing from it all the pairs (x, y) where x is not part of the result, $x \in R - S$ (i.e., all images not taken by Ilaria).

Given at least 2 sub-query results with partial orders, the idea in Case 3 is to compute a set with only one partial order. Each sub-query deals with one index and the nal result is computed starting from sub-query partial results. The question is which order to use for the nal result. We discuss the solutions in Section 2.4.

The model of queries we consider includes the standard one, where the user is interested in obtaining the top-k results, the major difference being, of course, the criterion according to which objects are ranked. To this end, we rely on the well-de ned semantics of the $Best$ [14] and *Winnow* [5] operators, recently proposed in the context of relational DBs. The Best operator, $Best(R)$, returns all the objects o in R such that there is no object in R better than o according to $\prec$. Ranking can be easily obtained by recursively applying the Best operator to the remaining objects (i.e., those not in $R - Best(R)$, and so on). This leads to a *layered* view of the search space where all the objects in one layer are "indifferent".

2.3.2 Difference with Order

This is equivalent to integrating the results of sub-queries with negation.

Definition 2.2 (Difference with Order) *Given two collections R and S of objects of the same type, the difference with order between two collections R and S, $R -_{\prec} S$, is defined as follows:*

Case 1*: R and S are sets: $R -_{\prec} S = R - S$.*

Case 2 (a)*: R is a set and S is a ranked list $[S, \prec_s]$: $R -_{\prec} [S, \prec_s] = R - S$.*

Case 2 (b)*: R is a ranked list $[R, \prec_r]$ and S is a set: $[R, \prec_r] - S = [R - S, \prec]$ where for $x \in R \cap S$ and $y \in R$, $\prec = \prec_r - \{(x, y), (y, x)\}$.*

Case 3*: Both R and S are ranked lists ($[R, \prec_r], [S, \prec_s]$). Since the difference of two partial orders is not a partial order anymore (the transitivity property of partial orders cannot be guaranteed), this case is not considered.*

Let us consider the following two queries to illustrate the de nition: Q_1: "list images taken by Ilaria that do not look like the image i" and Q_2: "list images that look like the image i that are not taken by Ilaria". Again let us assume that S is the collection of images taken by Ilaria and $[R, \prec_r]$ the ranked list of images that are similar to the image i. Query Q_1 corresponds to Case 2 (a), where the result should be a set of image taken by Ilaria, that is, $S - R$, thus ignoring the partial order associated to R. This makes sense if R contains a top-k-like answer where not all the objects in the database are in the result, otherwise the result of the query will always be empty. Query Q_2 corresponds to Case 2 (b), where the result should consist of images of R that do not belong to S, with a new partial order that involves only the objects that are in R but not in S. This is obtained from $\prec$ by removing from it all the pairs (x, y) where $x \in R \cap S$ (i.e., images taken by Ilaria).

2.3.3 Union with Order

Definition 2.3 (Union with Order) *Given two collections R and S of objects of the same type, the union with order between two collections R and S $R \cup_{\prec} S$ is defined as follows:*

Case 1*: R and S are sets: $R \cup_{\prec} S = R \cup S$.*

Case 2*: R is a set and S is a ranked list $[S, \prec_s]$: $R \cup_{\prec} [S, \prec_s] = [R \cup S, \prec_s]$.*

Case 3*: Both R and S are ranked lists ($[R, \prec_r]$ and $[S, \prec_s]$). Again, taking the union of two partial orders do not yield a partial order. For this reason the union is not performed, but the two ranked lists are returned separately as alternate solutions. Note that this makes sense even when sub-results have different types (e.g., text and image).*

Let us brie y comment on Case 2. Since, by de nition, a partial order does not require that all the elements are ordered, when we take the union of a set R and a ranked list $[S, \prec_s]$, we can simply add the objects in $R - S$ without having to change the order of the objects in S.

2.4. Operator Implementation

The implementation of the *difference with order* is not too much different from a set difference with sorted and random access. We will then focus on the *join with order*.

Given a query divided in independent sub-queries, the goal is to provide the user with the set of top results minimizing the number of objects to be accessed for it. More in details, the top-k retrieval paradigm is applied, by splitting the initial complex query into a set of m simpler sub-queries. Each sub-query deals with only some of the query predicates and the nal result is computed starting from sub-query partial results. A relevant example of top-k queries are "middleware" queries [7, 8, 3, 2], where the best k objects are retrieved given the (partial) descriptions provided for such objects by m distinct data sources. In this scenario, a rst assumption is that each data source is able to return a ranked list of results. More precisely, each returned object comes with an ID that identi es the object in the data source plus a score that numerically quanti es in which measure the object matches the query on that data source (named *partial* score). By means of the $getNext()$ method it is possible to execute a *sorted access* obtaining the best next object together with its partial score.

With regard to the aggregation rule of partial scores, one possibility is to use a *scoring function*, such as the (weighted) *average*, the *maximum* and the *minimum*, that aggregates the m partial scores into a global similarity score. In this case, objects are linearly ordered and only the highest scored ones returned to the user. A more general solution, that contains the scoring function-based approach as special case, consists in adopting *qualitative preferences* (e.g., *Skyline* [1] and *Region-prioritized Skyline* [14]) able to de ne arbitrary partial orders on the objects. Moreover, with qualitative preferences a more e xible comparison criteria able to take into account all the partial scores is possible. The only requirement of this aggregation modality is thus to de ne a binary preference relation able to assert when an object is "better" than another one.

Although each of the above integration solutions could be applied to implement our operators, in this work we adopted the iMPO [2] algorithm. The aim of this paper, in fact, is to nd a minimum common denominator to the involved indexes, with or without ranking, and to propose an algebra to integrate their results, independently from the speci c integration choice; the only requirement being that it just t our framework.

iMPO is based on a partial order approach which means that the meta-index can integrate the results of the indexes without having to know the metrics they are using. In particular, for the computation of the top-k results we rely on the *BestTop* [2] operator that combines the semantics of the *Best* and top-k operators. BestTop recursively applies Best to the objects by computing the rst l layers containing the top-k results.

3. The Meta-Index for Multimedia

Although users want to be able to manipulate in the same application any type of medium and multimedia data (e.g., images, audio, documents and video), data of different media types are totally different: They have different representation schemes, different features, different possible queries and they need different tools to render the data. The MPEG-7 standard [4] gives an exhaustive description of the features for each media type. But different media objects can share the same semantics and a semantic index common to all the media type can help integrate the different media types and build a full multimedia application. Figure 2 depicts the functional architecture of the meta-index for a multimedia application in which the semantic index plays a central role. Although the semantic index is put at the same level as the other indexes, it references object in the other indexes.

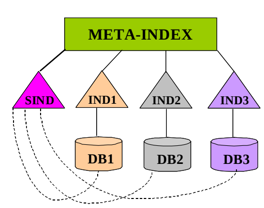


Figure 2. Semantic Integration of Multimedia Data with the Meta-Index

To that end, we propose a simple multimedia type system that follows the common multimedia system organization where each media type is handled by a specialized subsystem. As also shown in Figure 3, the type system should be rooted with *multimedia* as the root type. The rooted type system is important as it allows the semantic index to refer to only one type of objects (e.g., *multimedia*). The multimedia type defines two types of features, synthetic metadata (low-level features extracted from raw multimedia data) and semantic information (salient objects). In Figure 2, $SIND$ is the semantic index shared by all the media types, $IND1$ can be an index on image visual features, $IND2$ can be an index on video, and $IND3$ an index on text. The generic media type with synthetic and semantic information is the minimum required as the integration is based on the common semantics. The goal is not to discuss how to obtain the semantic information but how to use this information in a meta-index to glue data from different media types.

3.1. Media Content Description Model

The description of media objects mainly obeys two structures. The first one is the media class hierarchy and the second one is the media object aggregation hierarchy:

Media Class Hierarchy: The media class structure hierarchy is based on the "IS-A" relationship and defines the properties for each class. We distinguish the media class hierarchy used to group related media objects and the media content hierarchy that defines the descriptors for each media class. Note that the two hierarchies can be combined so that every media object comes with its content descriptors.

Media Object Aggregation Hierarchy: Every media object has an inherent structure. For example, the common hierarchy admitted for a video is: A video is composed of scenes, scenes are composed of shots, shots are composed of key frames (images). On the other hand, the structure of an XML document is given by a DTD or a XML schema.

The media class hierarchy defines the necessary descriptors for each media object depending of its class. It is application dependent so has to be provided when the application is being developed. We capture the user-defined media class hierarchy by attaching it to the right super-class in our pre-defined rooted type system as shown in Figure 3. The

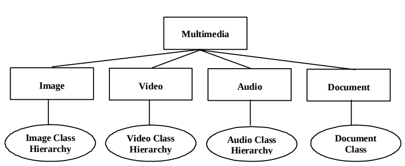


Figure 3. The Multimedia Type System

media object aggregation hierarchy defines different granularity levels for each media object. These granularity levels are important in the content description of the media object. The media class hierarchy and the media object aggregation hierarchy form the *media object metadata scheme* and can be defined using an object-relational model or MPEG-7.

3.2. Media Object Tree

Given a media object metadata scheme and a media object, we can construct the *media object tree* that reflects the composition of the media object and records the descriptors. Figure 4, for example, gives a media tree of a video composed of 2 scenes, 5 shots, and 7 key frames.

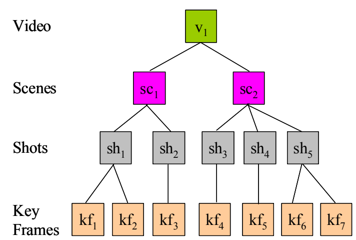


Figure 4. The Media Tree of a Video

The media object trees are media objects together with descriptors. They can be stored as MPEG-7 documents and queried using an XML query language like XQL [16]. The query processing will be more effective with an index. We used the MBM indexing method [12] that extends the BUS [13] method to index the media object trees. Each element of the media object is assigned a Unique element IDentifier (UID) using a left-to-right, top-to-bottom traversal that can be used to calculate the parent UID. The BUS also introduced the concept of the General element Identifier (GID) by extending the UID concept to include (1) Document Number, (2) the UID of the element, (3) the level of the element in the tree and (4) the element type number. The central concept of the BUS method that the MBM method inherited is that indexing information (the GID, term frequency, etc.) are maintained only for the leaf nodes of the media tree (e.g. keyframe for a video). We extended the GID to include the media type number (1:image, 2:video, 3:audio, and 4:document) stored using 2 bits. The media type information helps select the GID of a given media type as all the media types share the same semantic index.

4. Experiments

In the experimental section we design several scenarios to show how the meta-index interacts with the query processor and quantify, by means of a set of preliminary results, the improvement obtained by using the meta-index in term of both effectiveness and ef cienc y. All programs are written in *Java* programming language (J2SE, v. 1.5) and experiments are run on a Sun-Blade-1000 workstation under Solaris 2.8 with 1GB of memory. Results are obtained on a simple database which extracts video clips and key frames from two movies[1]. In details, the dataset contains 20 video clips, 230 key frames (images) extracted from the video clips, and 23 salient objects (for semantic queries). From each image, we extracted a 32-bins color histogram represented in the HSV color space and a 60-bin texture vector using Gabor lters. To compare both color and texture feature vectors we used the Euclidean distance.

The most typical queries that we want to test are mono-type (Q_1) and mixed-type media (Q_2) queries de ned as following:

Q_1: $\{i$: Image $\mid$ $i \in$ Images, $\exists A \in$ Objects, $\exists B \in$ Objects, i contains $A \wedge$ i contains $B \wedge$ i.color similar query.color $\wedge$ i.texture similar query.texture $\wedge$ A besides $B\}$;

Q_2: $\{i$: MM $\mid$ $i \in$ Images $\vee$ $i \in$ KFs $\exists$ $A \in$ Objects, $\exists$ $B \in$ Objects, i contains $A \wedge$ i contains $B \wedge$ i.color similar query.color $\wedge$ i.texture similar query.texture $\wedge$ A besides $B\}$.

In these formulas, *contains*, *similar* and *besides* are predicates, *MM* is a root type for multimedia, *Images* is a set of images, *KF*s is a set of key frames in videos and *Objects* is a set of salient objects. Finally, *query* is the example query image.

To deal with this type of queries, we implemented the join with order operator (see Section 2.3.1). In particular, we applied join with order (Case 3), for the integration of low-level features results, whereas for the integration with salient objects-based results we adopted join with order (Case 2). We indexed both feature vectors for color and texture using an index structure for high-dimensional nearest neighbor queries (i.e., the M-tree [6]), whereas for salient objects we adopted MBM [12].

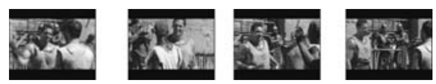
All results we present are averaged over a sample of 50 randomly-chosen query images containig two salient objects.

We test the ef cac y of meta-index using mono-type (Q_1) and mixed-type media (Q_2) queries. To measure the effectiveness of our solution we consider the classical *precision* metric, i.e., the percentage of relevant images found by a query (in our experiments we set $k = 20$), averaged over the query workload.

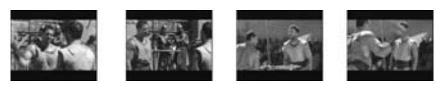
For each query Q_1 the meta-index rst decomposes the query into mono-type sub-queries and makes a search among registered indexes. Then, each mono-type sub-query is sent to the corresponding registered indexes, i.e., the color index, the texture index, and the salient object index. Results returned from low level image feature indexes (e.g., color and texture) are integrated by the meta-index using iMPO algorithm [2] (this correspond to Case 3). The set of images returned by salient-object index are combined with color-texture integrated results by taking their intersection (Case 2). As for queries Q_2, the meta-index preforms similar steps. This depends on the fact that a query Q_2 is composed by several queries Q_1. Further, in this case, in addition to images, video clips where images are extracted from are also returned.

We compared precision results obtained when the meta-index was switched on with those obtained without meta-index. We start by showing a visual example (depicted in Figure 5), where the top 3 results for the same query (the image on the left most column) are depicted when using a single index on color (a), a single index on texture (b), and the meta-index (c).

(a) color index results



(b) texture index results



(c) meta-index results

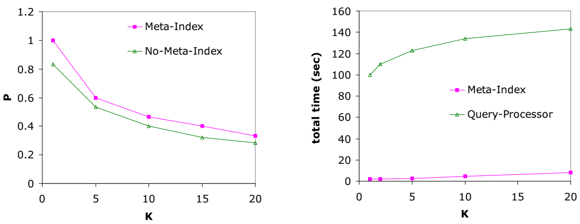
Figure 5. Visual Results using Color Index (a), Texture Index (b) and Meta-Index (c)

By Figure 5, we can nd out that with the meta-index, we can achieve more effective results: Images in (c) are much closer to the query in terms of both low level features and semantics than those obtained only using single indexes. The reason being that the meta-index gets the best from low-level features results (i.e., color and texture) and semantic results (i.e., salient objects).

The trend in visual example is generalized by Figure 6 (a), where averaged precision values for the query workload are reported. In particular, we use the term No-Meta-Index to refer to the average precision obtained using single indexes, whereas with Meta-Index results obtained by the meta-index. As we can observe from the graph, Meta-Index outperforms No-Meta-Index for all value of k with a nal average improvement of 19.44% (for $k = 15$) and 15% (for $k = 20$), respectively.

We report the ef cienc y test of using meta-index in answering queries. As for the measure, we consider the running time needed to answer a query based on low-level features (i.e., color and texture) and salient objects with re-

[1] "Gladiator", 2000 and "Life is Beautiful", 2000.



(a) (b)

Figure 6. Precision for Meta-Index and No-Meta-Index vs Number of Retrieved Images k (a) and Running Time Comparison Using Meta-Index and Query Processor (b)

spect to the number of retrieved object k (in our experiments we vary k between 1 and 20), averaged over the randomly picked up queries. For this experiment, we only use mono-type queries (Q_1). As shown in the previous section, queries Q_1 are the bases for mixed-type media queries Q_2. In particular, we assume that not all query features have supporting indexes (i.e., indexes for textures do not exist). Under this assumption, given a query Q_1, the query processor decomposes it into a set of mono-type sub-queries and keeps the sub-queries whose speci ed features do not have supporting indexes (the query processor can not nd the registered index in the interface to match the sub-query) and sends sub-queries with supporting indexes to the meta-index. Results returned from the indexes and the query processor are then integrated by the query processor. Performance is compared between queries using the meta-index and the query processor only. For the queries answered by the meta-index, the execution time can be saved by integrating the results returned by the indexes rst, once the results from the query processor are returned, the nal results can be intergraded. For the queries that are answered by the query processor directly, the results can only be integrated when all results are returned.

Figure 6 (b) shows average running time results. In particular, we observe how Meta-Index, by using indexes on salient objects (MBM) and low level features (M-tree), is able to achieve better performance than Query-Processor with a nal overage improvement of 94.47%. This depends on the correct selection of indexes and the early integration of ranked lists alloweb by the meta-index.

5. Conclusions

In this paper we have proposed a meta-index to integrate speci c indexes in a multimedia DBMS. We have de ned three operators for performing integration of ranked lists, namely, join with order, difference with order and union with order. These operators are de ned in terms of partial orders, which allows an integration of sub-results without knowing the speci c metrics used by the underlying indexes to order them. The experimental results con rm the ef cac y and ef cienc y of the meta-index in answering top-k queries.

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MULTIPLE SPATIAL OBJECTS INSERTION IN R-TREES

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ABSTRACT

Spatial databases have been more and more important in many applications such as Geographical Information System (GIS), Computer Aided Design (CAD), etc. The R-tree supports a dynamic index structure for efficiently retrieving objects. In the past, several papers discussed the access of individual object in R-tree, but rare mention how to access several objects simultaneously. In this paper, we propose a new operation, call *spatial-insert,* for R-tree. The function of this spatial-insert is to combine one group of objects into another group of objects while the two groups of objects have a special relationship and they belong to two different databases. That is, more than one spatial objects in one database are inserted into another database at once, and the corresponding R-tree of the inserted database is reconstructed due to the insertion of spatial objects. When many single-object insertions are replaced by a single multiple-objects insertion, many unnecessary node-splits or MBR-adjustments can be omitted to save a lot of time. When a node overflows due to the insertion of many objects, our method is once to generate enough nodes to contain all the objects inserted into the node. Each node does at most one node-split and/or MBR-adjustment if overflow and/or MBR-adjustment occur. The proposed spatial-insert operation can significantly reduce the number of node-splits and MBR-adjustments to improve the performance of database.

Keywords: Spatial-join, R-tree, Access method.

1. INTRODUCTION

Spatial databases have been more and more important in many applications such as Geographical Information System (GIS), Computer Aided Design (CAD), etc. Many dynamic indexes of spatial objects have been proposed for speeding up the object search. In general, multi-dimensional data can be classified into two types: zero-size objects and non-zero-size objects. The K-D-B tree [[11], proposed by Robinson, and the G-tree [8], proposed by Kumar, are indexing structures for zero-size objects. The Grid files [[9], proposed by Nievergelt *et al*., and the Filter tree [[14], proposed by Sevcik and koudas, are indexing structures for non-zero-size objects. A detailed survey on spatial objects access methods can be found in "Multidimensional access methods" [3] where is the R-tree family the most popular one [1,2,4,5,6,7,12,13]。In the past, the R-tree was used to improve the access speed [2,4], to reduce dead space [13,14], and to improve storage utilization [1,7]. No paper mentioned how to access several objects simultaneously. In general, the R-tree inserts an object at a time. However, we may need to insert several objects from a database B into another database A. If each insertion includes only one object, we should need much time to finish the job. The database performance will be influenced obviously because the corresponding R-tree of database A also needs to be reconstructed again and again.

Suppose that there is a relationship, such as overlap, between the objects of databases A and B. Sometimes, some objects in database B must be inserted into database A because of the overlap relationship. For example, database A stores the data of community while database B stores the data of park. If a part has to be combined to a community which overlaps the park, then some objects in database B must be taken out to insert into database A. The traditional operation is to take out park objects from database B and then to inserts into database A one bye one. It should take much time to execute the operation of taking out and inserting object repeatedly. Especially, node-split or MBR-adjustment may happen again and again in the R-tree for database A. To speed up the job, we propose a new operation, called *spatial-insert,* for R-tree. The proposed operation can efficiently find and insert the related objects from database B into database A at a time. The corresponding R-tree of the database A is reconstructed due to the insertion of spatial objects. Each node in the R-tree will have only one node-split or MBR-adjustment if overflow or MBR-adjustment occurs.

2. Previous Work

2.1. R-tree

An R-tree is a height-balanced tree similar to a B-tree with index records in the leaf nodes containing pointers to data objects. It does adapt for the efficient access of spatial data. The B-tree stores one-dimensional data of character or number, while the R-tree keeps two (or more) -dimensional data of spatial objects. There is no order relationship between R-tree nodes. Each node is composed of several entries. Each entry includes a minimal bound rectangle (MBR) and a pointer. The format of an entry in a leaf node is (I，*obj-id*). The I is the MBR and *obj-id* is a pointer to address the spatial object in database. The format of an entry in a non-leaf node is (I，*child-pointer*). The I covers all rectangles in the lower node's entries and *child-pointer* is the address of a lower node in the R-tree. We assume M be the maximum number of entries in one node and m be a parameter specifying the minimum number of entries in a node. An R-tree satisfies the following properties. The root has at least two children unless it is also a leaf node. Each non-root node has between *m* and *M* children. All leaves appear on the same level.

2.2. Spatial Join

Spatial join operation was proposed in the past as many kinds of the method such as spatial-merge join [10]. Brinkhoff *et.al*. [2] proposed five methods to perform spatial join for R-tree. It used the depth-first search to traverse all the nodes. Each node must be checked to determine whether it overlaps with other nodes. Thus, only local optimization is performed. Later, Hung [5, 6] proposed the method of Breadth-First R-tree Join (BFRJ) with the feature of global optimization which is the optimization of memory, buffer management and the order of overlap data among non-leaf nodes.

BFRJ adopts breadth-first search to traverse nodes from the top of two R-trees level by level to achieve global optimization. The technique of search pruning is used to reduce the number of node-pair checking. BFRJ uses several tables, called intermediate join indexes (IJI), to save pairs of overlapping nodes. Each entry in an IJI includes two fields to record two overlapping nodes belonging to different R-trees.

3. Spatial-Insert Operation

In this section, we purpose of spatial-insert operation to describe how to process some objects in one R-tree can be inserted into another R-tree at the same time. Assume that there are two groups of compatible spatial objects associated with two R-trees, R and S, as shown in Figure 1 and Figure 2, respectively. Figure 3 shows the overlap condition of the two groups of spatial objects. Spatial-insert operation is composed of two phase. The first phase is using the spatial-join concept to find the objects and the relevant leaf nodes in two R-trees. The second phase is using multi-object-insert concept to take out the objects, found in first phase, from S and to insert into the relevant leaf nodes in R.

3.1. The first phase of spatial-insert

We must first find the overlapping objects that belong to R or S. With the concept of spatial-join [6], we can finish the above requirement without IJI tables. Instead, we use a queue, called Spatial Join Queue (SJQ), and a data structure, called Overlap Pair of Nodes (OPN), to save the overlap pair-nodes. SJQ is used to save OPN structure. The OPN structure is composed of four fields. The fields parentR and parentS denote a pair of overlap parent nodes that belong to two R-tree, respectively. The field childR and childS represent a pair of overlap child nodes or objects that belong to parentR and parentS, respectively.

Our spatial-join concept is starting from the roots of the two R-trees, with top-down direction to check pair of nodes at each level whether they are overlap or not. If two nodes have an overlap, they are stored as an OPN record to SJQ. A table, called PATH, is used to record each ancestor node (in each level) of each object (in R) which overlaps objects in S. These ancestor nodes can be referenced when node-split and/or MBR-adjustment propagate upward. Each row, called branch, in PATH is composed of two fields. The filed nodeP denotes a certain node of R which overlaps a certain node N in S. The field nodeC denotes a certain child node or object of N. The process of fetching an OPN record, examining overlap nodes, producing new OPN records, and storing OPN records to SJQ is repeated until all related nodes of two R-trees are checked. Figure 4 shows the results of SJQ and PATH after the first phase.

3.2. The second phase of spatial-insert

After node-pair checking of two R-trees, the SJQ would store the OPN records which had overlapped nodes and objects. However, some of these OPN records are invalid because of the following two cases. First, the same object may overlap the objects in different leaf nodes at the same time. The same object may be repeatedly inserted into different leaf nodes. Second, the same object may overlap different objects in the same leaf node at the same time. The same object may be repeatedly inserted into the same leaf node. Therefore, these invalid OPN records in SJQ must be erased.

3.2.1. Deletion of invalid OPN records in SJQ

To erase the invalid OPN records in case 1, only one of the different leaf nodes must be reserved. The reserved leaf node is the one that contains an object which has the largest overlap area with the combined object. Resolve ties by choosing the one with fewer entries. The remaining OPN records in case 1 must be deleted after the reserved leaf node is determined. For example, object s9 overlaps object r11 in leaf node R4 and object r17 in leaf node R6, respectively, as shown in Figure 4. We must decide that s9 should be inserted into R4 or R6. Since the overlap area of objects r17 and s9 is larger than that of objects r11 and s9, as shows in Figure 3. In SJQ, the 11th OPN record is retained while the 1st OPN record is deleted. To erase the invalid OPN records in case 2, all the records, except one, must be deleted if these records have the same values of parentR and childS. For example, the 2-4 OPN records in Figure 4 indicate that object s4 will be inserted into leaf node R7 three times. Thus, only one OPN record is kept, others must be deleted. The same way is also applied to records 5-7, records 8 and 12. The final result of SJQ is show in Figure 5.

3.2.2. Preparing enough leaf nodes to contain objects

It is possible to insert a lot of objects into one leaf node for the spatial-insert operation. The leaf node may split many times if many objects are inserted one by one. The more number of node-split, the less the performance of R-tree. To erase redundant node-splits, we prepare enough extra leaf nodes to contain the inserted objects at the same time. The number of prepared leaf nodes can be computed as follows. Suppose the maximum number of entries of a leaf node N in R-tree R is M_R, the possession of entries is M_{RC}, and the number of objects to be inserted into N is M_{SC}. There are two conditions can be considered. First, if $M_R \geq M_{RC} + M_{SC}$, all the M_{SC} can be inserted into N directly. No extra leaf node is needed. Second, if $M_R < M_{RC} + M_{SC}$, one or more extra leaf node is needed. Otherwise, more than two extra leaf nodes are regained. The number of enough leaf nodes is $X = \lceil (M_{RC} + M_{SC}) / M_R \rceil$. According to the node-split technique [4], the $M_{RC}+M_{SC}$ objects must be divided into X groups to distribute to the X leaf nodes, respectively. These X leaf nodes later should be inserted into the parent node P of N upward. If P also overflows, the same idea is applied to P until P or one of P's ancestor does not overflow.

3.2.3. Multi-objects-insertion

The multi-objects insertion is described as follows. First step, we take out several OPN records with the same parentR value R_i from SJQ. The objects identified by the childS values of these OPN records are inserted into the leaf node identified by R_i. Similar processes of inserting several objects into a leaf node each time are repeated until SJQ is empty. Second step, if the leaf node overflows, then several extra leaf nodes are allocated to store these inserted objects. These extra leaf nodes later are also inserted into the parent node of the original leaf node. Besides, a branch record for each extra leaf node is added to PATH. Third step, the MBR of the original leaf node must be adjusted in its parent node and the adjustment must be propagated upward. If the insertion of extra leaf nodes makes the parent node of the original leaf node overflow, the node-split action also needs to propagate upward. If node-split propagation makes the root split, create a new node as the root. Figure 6 shows the final R-tree R after the insertion of the objects in R-tree S.

4. Conclusions

In the tradition, the data access operations of R-tree include search, insert, delete, and update, aim at a single object. In real applications, the user may need to process large number of objects together. It is necessary to develop special operate to process several objects at the same time. Therefore, we propose the spatial-insert operation to combine two groups of objects together. The spatial-insert has some characteristics. The OPN structure can be extended dynamically to keep information for user's demand such as adding a field to record the overlap area value of two objects. Traditional object insertion may lead to many times of node-splits and MBR-adjustments that decreases the database performance. We solve the problem by generating enough extra leaf nodes to contain all inserted objects once. The overflowing node has only one node-split and/or MBR-adjustment.

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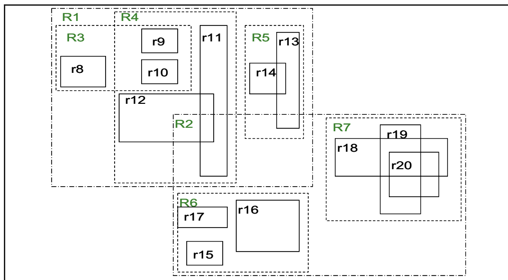

Figure 1(a) The spatial objects indexed by R-tree R.

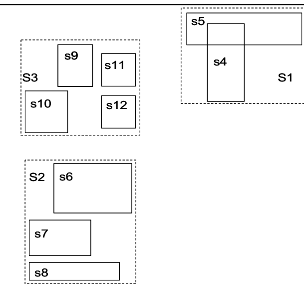

Figure 2(a) The spatial objects indexed by R-tree S.

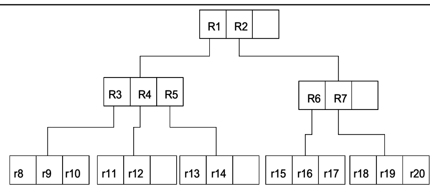

Figure 1(b) The structure of R-tree R.

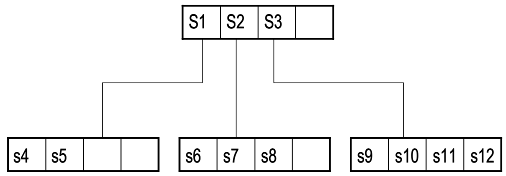

Figure 2 (b) The structure of R-tree S.

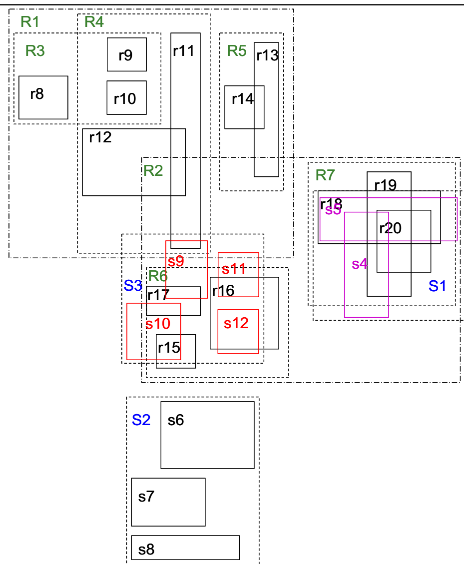

Figure 3 The overlap condition of the two groups of spatial objects.

Level 1 SJQ

parentR	childR	parentS	childS
Null	R1	Null	S3
Null	R2	Null	S1
Null	R2	Null	S3

PATH

nodeP	nodeC
Null	R1
Null	R2

Level 2 SJQ

parentR	childR	parentS	childS
R1	R4	S3	s9
R2	R7	S1	s4
R2	R7	S1	s5
R2	R6	S3	s9
R2	R6	S3	s10
R2	R6	S3	s11
R2	R6	S3	s12

PATH

nodeP	nodeC
Null	R1
Null	R2
R1	R4
R2	R7
R2	R6

Level 3 SJQ

parentR	childR	parentS	childS
R4	r11	S3	s9
R7	r18	S1	s4
R7	r19	S1	s4
R7	r20	S1	s4
R7	r18	S1	s5
R7	r19	S1	s5
R7	r20	S1	s5
R6	r15	S3	s10
R6	r16	S3	s11
R6	r16	S3	s12
R6	r17	S3	s9
R6	r17	S3	s10

PATH

nodeP	nodeC
Null	R1
Null	R2
R1	R4
R2	R7
R2	R6
R4	r12
R7	r18
R7	r19
R7	r20
R6	r15
R6	r16
R6	r17

Figure 4 The contents of SJQ and PATH at each level.

parentR	childR	parentS	childS
R7	r18	S1	s4
R7	r18	S1	s5
R6	r15	S3	s10
R6	r16	S3	s11
R6	r16	S3	s12
R6	r17	S3	s9

Figure 5 The SJQ contents after deleting 5 OPN records.

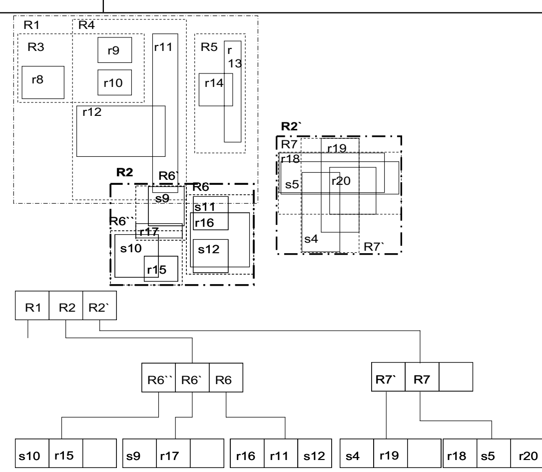

Figure 6 The final result of objects insertion.

Multimedia Streaming Over IP with QoS and Access Control

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Abstract

The paper describes a system to manage the distribution of multimedia content over IP with the support of QoS and fine grained access control. It relies on visual languages to simplify the specification of complex access control and QoS policies in distributed multimedia streaming services. QoS is based on the RSVP protocol, whereas access control is provided based on the RBAC model. In particular, the system translates the visually specified policies into the XACML format, which also embeds the QoS parameters that will be successively used in RSVP negotiations.

1. Introduction

The growing availability of broad band internet connections has made it possible to provide many new challenging services. Among these, multimedia streaming services have been among the most appealing ones. They have raised many important problems and critical issues, such as compression, content based retrieval, real time transmission, etc. Moreover, as commercial organization have started exploiting the internet for distributing multimedia contents, new concerns have been raised regarding security issues.

Traditional access control mechanisms lack in abstraction, and do not provide fine grained access control. The definition of fine grained privileges in multimedia applications and their assignment to the end user is an extremely appealing feature. In this paper we present the PRACSY (Path Reservation Access Control System) system supporting access control in distributed multimedia streaming applications. It is based on the RBAC model[4], and the RSVP protocol[2]. PRACSY provides a visual front-end allowing a service administrator to use a metaphor oriented graphical language to easily specify the policies through which a user can enjoy the multimedia contents over the network, possibly based on the level of service that s/he has previously bought. Policies can specify a combination of constraints at different granularity levels such as time, quality of service, number of uses, quality of media, and many other characteristics ruling the fruition of accessible multimedia resources. The system automatically translates the visually specified policies into the XACML format[8], an XML based language to represent access policies. Other than the visually specified access constraints, the generated XACML file also embeds the transmission channel requirements necessary to guarantee the specified QoS. Such requirements will be forwarded to an RSVP daemon to enforce the bandwidth reservation on the underlying network infrastructure[10].

From the user perspective, PRACSY provides a web-based client application to enforce the fruition of multimedia streaming services according to the specified policies. This module is written in JSP based on the Struts framework[3]. The latter implements the Model View Controller (MVC) design pattern [5], which enables the generation of web applications separating the control logic from the business and the presentation logic. In particular, we integrated our access control logic in Struts at control level, implementing a Policy Enforcement Point (PEP). This PEP intercepts user access requests, and interacts with a Policy Decision Point (PDP) through web-services in order to determine whether the user has rights to access a given resource (video/audio content), and under which conditions (Bandwith, time constraints, billing, etc).

The paper is organized as follows. Section 2 presents related work, Section 3 briefly overviews the technologies underlying PRACSY, and Section 4 shows the system architecture, detailing its components and user interfaces. Conclusions and Future perspectives are analyzed in Section 5.

2. Related Works

RBAC-XACML specifies a profile for the use of the XACML language to meet the requirements of the RBAC model[1, 4, 8]. This specification begins with an explanation of the building blocks from which the RBAC solution is constructed. A full example illustrates these building blocks. The specification then discusses how these building blocks may be used to implement the various elements of the RBAC model. Finally, the normative section of the specification describes compliant uses of the building blocks in implementing an RBAC solution.

A PCIM-based framework for storing and enforcing RBAC policies in distributed heterogeneous systems is presented in[9]. PCIM (Policy Core Information Model) is an information model proposed by IETF. It defines a vendor independent model for storing network policies that control how to share network resources. PCIM is a generic core model. Application-specific areas must be addressed by extending the policy classes and associations proposed by PCIM. In order to represent network access policies based on the RBAC model authors propose a PCIM extension, called RBPIM (Role-Based Policy Information Model), and an RBPIM implementation framework based on the PDP/PEP (Policy Decision Point/Policy Enforcement Point).

An XML-based framework for distributing and enforcing RSVP access control policies for RSVP-aware application servers is proposed in[10]. Policies are represented by extending XACML. Because RSVP is a specific application domain, it is not directly supported by the XACML standard. The authors present an XACML extension required for representing and transporting the RSVP access control policy information. In the latter work the XACML-based framework is proposed as an alternative to the former IETF PCIM-based approach, also providing a comparison between the two approaches.

A policy management system and a policy enforcement point integrated into the Globus Toolkit middleware is described in [7]. The system enables the specification and modification of resource policies by administrative parties through a graphical user interface, and the secure association and transport of these policies to the policy decision components.

3. Underlying Technologies

As said above, PRACSY has been built by implementing new visual languages upon several standard technologies and frameworks, such as XACML, RSVP, MVC, and Struts. In what follows we briefly revise them in order to provide a clear description of our architecture.

3.1. The RSVP Protocol

The Resource Reservation Protocol (RSVP) is a network-control protocol enabling Internet applications to achieve different quality of service (QoS) for their data flows. Some applications require reliable delivery of data, but do not impose any stringent requirements for the timeliness of delivery. Conversely, time constraints are crucial for many modern distributed multimedia applications, including videoconferencing and IP telephony: Data delivery must be timely but not necessarily reliable. Thus, RSVP was intended to provide IP networks with the capability to support the divergent performance requirements of different application types.

In RSVP, a data flow is a sequence of datagrams that have the same source, destination (regardless of whether that destination is one or more physical machines), and quality of service. QoS requirements are communicated through a network via a flow specification, which is a data structure used by internetwork hosts to request special services from the internetwork. A flow specification describes the level of service required for that data flow.

RSVP is designed to manage flows of data rather than to make decisions for each individual datagram (Figure 1). Data flows consist of discrete sessions between specific source and destination machines. A session is more specifically defined as a flow of datagrams to a particular destination together with the transport layer protocol to be used. Thus, sessions are identified by the following data: destination address, protocol ID, and destination port.

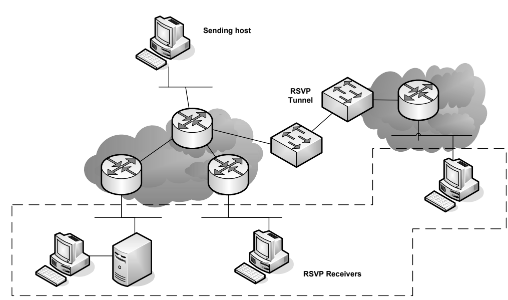

Figure 1. In RSVP, Host Information Is Delivered to Receivers over Data Flows

To initiate an RSVP session, a potential sender starts sending RSVP path messages to the IP destination address. The receiver application receives a path message and starts sending appropriate reservation-request messages specifying the desired flow descriptors using RSVP. After the reservation request message returns back to the sender, this starts sending data packets.

Under RSVP, resources are reserved for simple data streams (that is, unidirectional data flows). Each sender is logically distinct from a receiver, but any application can act as a sender and a receiver. Receivers are responsible for requesting resource reservations. Figure 2 illustrates this general operational environment.

During the resource reservation setup, two local decision modules evaluate an RSVP request: the ”policy control module” and the ”admission control module”. The

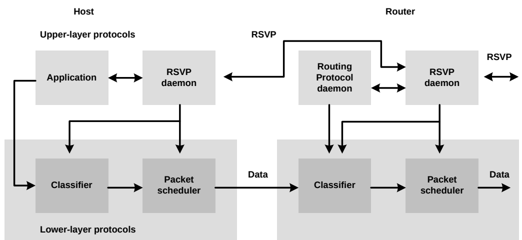

Figure 2. The RSVP Operational Environment Reserves Resources for Unidirectional Data Flows

admission control module determines whether the node (host or router) has sufficient resources available for satisfying the QoS request. The policy control module determines whether the user has administrative permission for obtaining the reservation. The parameters for policy and admission control are not defined and controlled by the RSVP. The protocol merely transports the parameters to the appropriate module for interpretation. According to the RFC2205[2], the sender application must specify the type of service that is more appropriate for its requirements of transmission by passing the related information to the RSVP daemon in the host machine. After being invoked, the RSVP daemon inquires the local decision modules, verifying resources and authorizations necessary to initiate the exchange of RSVP messages with the nearest network element in the path to the receiver.

In Pracsy we have implemented a new mechanism for configuring access control policies ("authorization control") and QoS reservation for RSVP-aware application servers. It uses a visual specification approach for XACML, i.e., the policy control is implemented only by the application server. However, in this proposal we also supply the information for defining the Tspec and Rspec parameters transported in the PATH and RESV messages. Therefore, the XACML policy also provides the information used for "admission control" by the network elements along the path between the transmitter and the receiver.

3.2. XACML

XACML is an XML-based language, or schema, conceived to create access policies, automate their use in the management of access control for generic devices, and support interoperability among different systems and frameworks[8]. It was designed to replace existing, application-specific, proprietary access-control mechanisms. Previously, every application vendor had to create its own customized method for specifying access control, and these typically could not talk to one another.

XACML specification describes both a request/response language for expressing queries about whether a particular access should be allowed, describing the answers to those queries, and an access control policy language (which allows developers to specify who can do what and when).

In a typical XACML based scenario, in order to undertake some action on a particular resource a user submits a query to the entity protecting the resource, named Policy Enforcement Point (PEP). Using the XACML request language, the PEP prepares a request based on user attributes such as action, resource, and other relevant information. The request is sent to a Policy Decision Point (PDP), which examines the request, and retrieves policies written in the XACML policy language that are applicable to this request. The PDP also determines if the access can be granted according to the request. That answer is returned to the PEP, which allows or denies user access. It is worth noting that the answer returned to the PEP is expressed in the XACML response language.

3.3. Apache Struts framework

Apache Struts is an open-source framework for developing J2EE web applications[3]. It uses and extends the Java Servlet API to encourage developers to adopt an MVC architecture.

This framework enables the design and implementation of large web applications to be handled by different groups of people. In other words, page designers, component developers, and other developers can handle their own part of a project, all in tandem and in a decoupled manner. It features I18N (internationalization), a powerful custom tag library, tiled displays, and form validation. It also supports different presentation layers, including JSP, XML/XSLT, JavaServer Faces (JSF), and Velocity, as well as a several model layers, including JavaBeans, and EJB.

3.4. MVC Architecture

Model-view-controller (MVC) is a software architecture that separates the application's data model, the user interface, and the control logic into three distinct components so that modifications to one component can be made with minimal impact to the others.

In other words, constructing an application using an MVC architecture involves defining three classes of modules:

Model: The domain-specific representation of the information on which the application operates. The model is another name for the domain layer. Domain logic adds meaning to raw data (e.g. calculating if today is the user's birthday, or the totals, taxes and shipping charges for shopping cart items).

View: Renders the model into a form suitable for interaction, typically a user interface element. MVC is often seen in web applications, where the view is the HTML page, and the code gathering dynamic data for the page.

Controller: Responds to events, typically user actions, and invokes changes on the model and perhaps the view.

Although MVC comes in different flavors, control flow generally works as follows:

1. The user interacts with the user interface in some way (e.g., user presses a button).
2. A controller handles the input event from the user interface, often via a registered handler or callback;
3. The controller accesses the model, possibly updating it in a way appropriate to the user's action (e.g., controller updates user's shopping cart).
4. A view uses the model to generate an appropriate user interface (e.g., view produces a screen listing the shopping cart contents). The view gets its own data from the model. The model should have no direct knowledge of the view.
5. The user interface waits for further user interactions, which begin a new cycle.

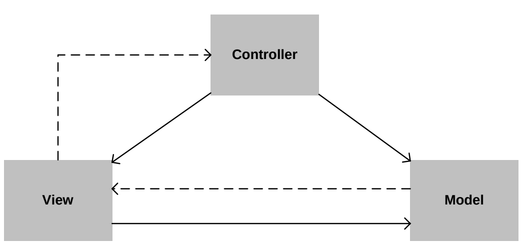

Figure 3. Relationship between Model, View, and Controller.

In figure 3, relationship between Model, View, and Controller is shown. Notice that the solid lines indicate a direct association, whereas the dashed line indicates an indirect association (i.e. Observer pattern).

4. System Architecture

The system architecture is shown in Figure 4. It is composed of the following four autonomous components interoperating through the HTTP protocol and through web-services:

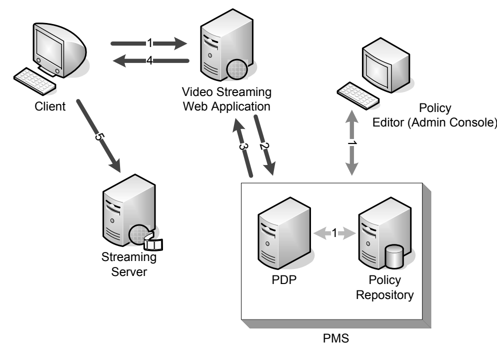

Figure 4. Overall architecture of PRACSY.

- The Streaming Server, a standard streaming server deploying Multimedia content.
- The Policy Management Server, a java server offering authorization control services, policy evaluation, and policies management services.
- The Visual Policy Editor, a tool enabling the user to draw policies in a visual way; policy created will be translated in XACML format, and deployed through the policy management server.
- The Video Streaming WEB application, a web based application, written in JSP and Struts, to give the user the ability to stream media content.

4.1. Policy Management Server

The Policy management server consists of a PDP and a PEP. Once policies have been generated by the VPE, they need to be managed. To this aim an XACML scenario based on a Policy Enforcement Point (PEP) and a Policy Decision Point (PDP) has been developed. PEP aims at protecting the resources from unauthorised subjects. To achieve access to a particular resource a subject has to submit a query to the PEP before undertaking any action.

The PEP software module uses the XACML language to prepare a request based on user attributes such as action, resource, and other relevant information. This request is then sent to the PDP, which examines it and retrieves XACML based policies that apply to this request. Once the PDP has determined whether the access can be granted, a response is returned to the PEP, which allows or denies user access. The communication between PEP and PDP is carried out trough the exchange of XACML messages.

Figure 5 shows the UML Deployment Diagram describing the distributed software architecture used to manage XACML access polices. The Application Module node contains only the Generic Functionality, which represents a generic software component that invokes the PEP component to access a particular software resource. In the proposed architecture the PEP component plays the role of a gatekeeper that decides whether or not a user can access a software resource with the support of the PDP.

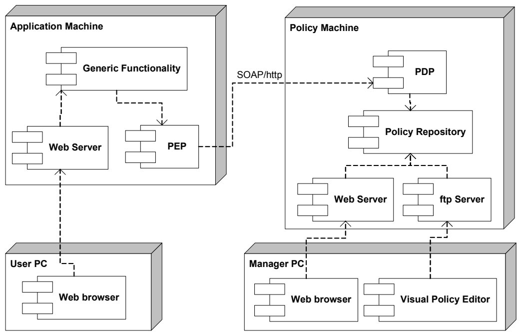

Figure 5. Network Distributed Architecture.

Currently, the PEP is implemented as a servlet, whereas the PDP as a Web Service. Thus, the communication between these two software components is enabled through the SOAP protocol over HTTP.

4.2. Visual Policy Specification and XACML translation

The visual policy editor implements the suite of visual languages defined in[6]. It allows the policy manger to generate XACML access and control policies starting from the policy visual specification. The first proposed visual language is the Role Diagram (RD), which allows us define the roles and their hierarchic relations. Then, the Permission Diagram (PD) allows us to define access permissions for a resource and to associate them to a role.

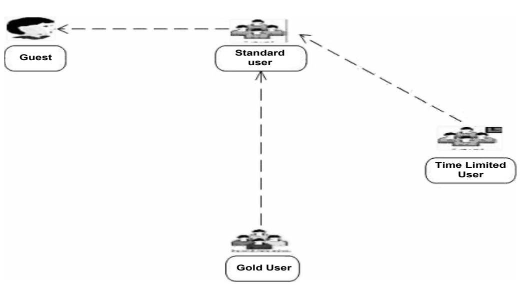

Figure 6. Role Diagram.

The visual sentence showed in figure 6 and 7, are translated in XACML code like in figure 8.

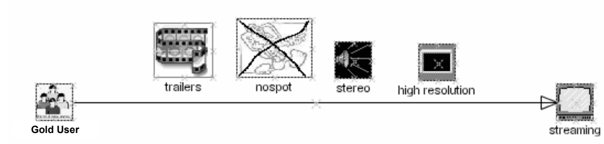

Figure 7. Permission Diagram.

Policy Description
Subject
Resource
Action

```
<?xml version="1.0" encoding="UTF-8"?>
<Policy  PolicyId="PPS:Gold:role"
RuleCombiningAlgId="urn:oasis:names:tc:xacml:1.0:rule-
   combining-algorithm:permit-overrides">
   <Description>The user is enabled to streaming </Description>
   <Rule RuleId="AccessIfInGroup" Effect="Permit">
    <Target> <Subjects> <AnySubject/> </Subjects>
    <Resources><Resource>
       <ResourceMatch
MatchId="urn:oasis:names:tc:xacml:1.0:function:string-equal">
       <AttributeValue
DataType="http://www.w3.org/2001/XMLSchema#string">
           streaming </AttributeValue>
        <ResourceAttributeDesignator
DataType="http://www.w3.org/2001/XMLSchema#string"
           AttributeId="urn:oasis:names:tc:xacml:1.0:resource:resource-id"/>
    </ResourceMatch></Resource></Resources>
   <Actions><Action>
      <ActionMatch MatchId="urn:oasis:names:tc:xacml:1.0:function:string-equal">
      <AttributeValue DataType = http://www.w3.org/2001/XMLSchema#string >
streaming
      </AttributeValue>
      <ActionAttributeDesignator
DataType="http://www.w3.org/2001/XMLSchema#string"
        AttributeId="urn:oasis:names:tc:xacml:1.0:action:action-id"/>
      </ActionMatch>
     </Action></Actions></Target></Rule>
  </Policy>
```

Figure 8. Permission Policy in XACML.

4.3. Video Streaming WEB Application

The client interacts with a video streaming web application written in JSP and Struts. The Access control logic is embedded in the control layer of the struts framework, and it consists in a pure invocation of the web services evaluating the user request on the PMS. Then, the application translates the user-interaction in an XACML request, and transmits it to the PMS. In what follows, we show some screen-shots of the PRACSY system: Figure 9 show the login page, Figure 10 show the search page, and Figure 11 the streaming page.

Figure 9. Login Page.

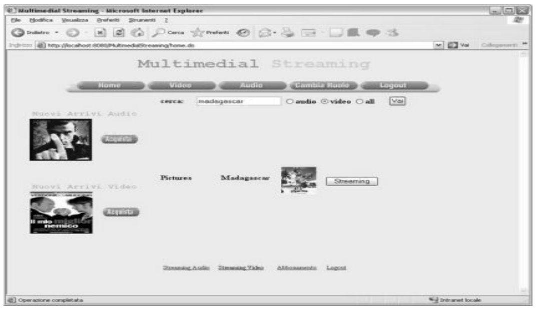

Figure 10. Search Page.

Figure 11. Streaming Page.

5. Conclusion and Future Work

We have presented the PRACSY system enhancing multimedia streaming services over IP. The system exploits visual language technologies to reduce the complexity of specifying fine grained access control policies on multimedia contents. Policies are successively implemented into the XACML language, which would be difficult to directly manage without our visual front end. Thus, PRACSY can be used by a broader class of users. The target XACML specification also addresses QoS parameters, which will be used to start an RSVP based negotiation to perform the bandwidth reservation on the underlying network infrastructure.

The ideas underlying the PRACSY system can be used to extend the RSPVP protocol in order to directly support policy based access control mechanisms. In fact, the fruition of multimedia services over IP is often characterized by the level of services that the user has bought.

We have used the PRACSY system experimentally in the context of video on demand applications using thin clients such as mobile phones and palm computers. In the future we plan to perform further experiments in the context of large distributed multimedia databases and services. Moreover, we plan to perform thorough usability experiments, and to verify the possibility to plug PRACSY as a component of multimedia DBMSs.

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SVD-BASED TAMPER PROOFING OF MULTI-ATTRIBUTE MOTION DATA

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ABSTRACT

Repositories of motion captured (MoCap) data can be reused for human motion analysis in physical medicine, biomechanics and animation related entertainment industry. MoCap data expressed as a matrix $M_{m \times n}$ can be subject to tampering from shuffling of its elements or change in element values due to motion editing operations. Tampering of archived motion data intentionally or due to machine/human errors, may result in loss of research, money and effort. The paper proposes singular value decomposition (SVD) based methodology for tamper proofing motion data. This tamper proofing methodology extracts reference patterns in the form of right and left singular vectors of motion data matrix M. These patterns are used to verify and trace the pattern of tampering. The use of first Eigen vectors for tamper detection reduces storage and computation complexities to $O(m + n)$ and makes the solution scalable.

1. INTRODUCTION

The advent of Motion Capture systems such as Vicon [16] has brought in applications like

- *Physical Medicine and Rehabilitation:* Analyzing different body segments/joints for different motions aid in better diagnosis of the problem(s) that a patient might be facing.
- *Biomechanics and Physiology*: Researchers investigating the interplay of bone and muscle in leg movement benefit from the 3D map of human body motions.
- *Reusability in Animation:* Motion captured data is reusable and it can help build entertainment related animations, by using software such as Motion Builder [8].
- *Quantifying the effects*: of certain diseases such as the effect of spasticity on knee movements.

These applications can benefit from having a large repository of 3D human motions. Motion data archived in a repository can be subject to tampering due to malicious actions or human/machine related faults. The tampering of motion data may result in loss, in terms of valuable information, money, and time spent for recording. Moreover, incorrect information can be misleading from the application's perspective.

MoCap data is multi-attribute, and can be described as $M_{m \times n}$ matrix (see Figure 1 and Figure 2) (for the comma separated value (*.csv*) format of Vicon IQ [16]), with columns representing rotational and positional data of skeleton joints, and rows representing the changing values over time. The varying lengths of frames make the data bulky. Adversaries can use motion editing techniques [16] such as motion cropping, mapping and concatenation to tamper data. These techniques alter the trajectory of joints by changing values or shuffling rows, columns, row elements, and column elements. There could be combination of these attacks or it could be a random attack. The tampering methodology should be capable of verifying and tracing the pattern of such kind of attacks.

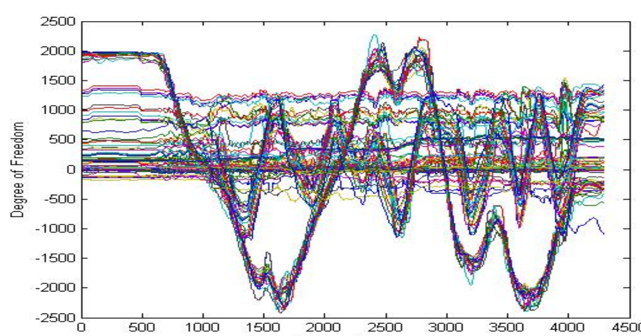

Figure 1. Motion Data representation

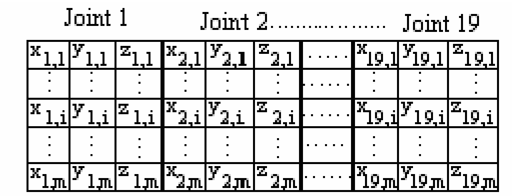

Figure 2. Motion Data Representation I matrix format with positional information

Tampering can be avoided by using tamper proofing mechanism, such as fragile watermarking. Fragile watermarking [2-13] can be achieved by embedding a watermark inside a target data. Tampering is recognized whenever during an extraction process, a sub-part of the embedded watermark is found corrupt. The sub-part points to the spatial location of corruption and serves as an evidence for tampering. Watermarking techniques alter the original data, resulting in distortion, which eventually can alter the meaning of the data. Recent research in watermarking motion data [14, and 15] uses private watermarking schemes for copyright protection. These schemes are private and are storage inefficient (not scalable), since the original data has to be stored for tamper verification. Therefore, in order to achieve tamper proofing, we need to design a novel scheme that can detect errors, without distorting the original data, and must be storage efficient.

1.1 Proposed Approach

The paper proposes singular value decomposition (SVD) based tamper proofing scheme. The scheme is not a watermarking methodology, as it does not incorporate information hiding. The idea is to extract the reference patterns using SVD, and use them for tamper proofing. The reference patterns are recognized as right and left Eigen vectors of the SVD of a motion data matrix *M*. During the detection process, we take the SVD of the target matrix *M′* and compare its left and right Eigen vectors with that of *M*. The proposed method is shown to verify and trace the pattern of attacks, such as row tampering, column tampering, row-column tampering, and random attack.

The reference patterns are Eigen vectors with non-zero Eigen values. This helps in reducing the size of information required to be stored for verification, and as a result makes the solution scalable. The use of Eigen vectors and thresholds help us determine the exact position in *M* that has been tampered. Experimental results aptly demonstrate the effectiveness of our approach.

The rest of the paper is organized as follows:
Section 2 discusses the attack patterns and methods developed using SVD to verify and trace these patterns. In addition, we suggest ways to optimize the methodology and advantages over watermarking are mentioned. Section 3 gives experimental proof of the attacks and helps visualize the advantage of the proposed technique. The paper ends with Sections 4 describing the future work and conclusion. Table 1, gives a list of notations used in the paper.

RT	Row tampering
RS	Row shuffling
RES	Row element shuffling
CT	Column tampering
CS	Column shuffling
CES	Column element shuffling
RCT	Row column tampering

Table 1. Table of Notations

2. TAMPER PROOFING METHODOLOGY

The tamper proofing methodology is applied on MoCap data (.csv format) acquired from Vicon IQ [16] (*120* frames/sec). As discussed earlier, this data can be expressed as a matrix $M_{m \times n}$ ($m > n$), where columns represent the joints of the human skeleton. The joints are represented as rotational and translational information, with varying values per frame (row). The attacks on a matrix *M* can be categorized as follows:

- **Row tampering (RT) attacks:** This attack is restricted to row tampering only, such that column elements of *M* stay invariant. Mathematically, if *A* is modified to using row tampering then $A_{mxn} \neq B_{mxn}$ such that $\bigcup_{k=1}^{m} a(k, i) = \bigcup_{k=1}^{m} b(k, i)$, for all i ($1 \leq i \leq n$), and $\bigcup_{k=1}^{n} a(j, k) \neq \bigcup_{k=1}^{n} b(j, k)$, for j ($1 \leq j \leq m$). This attack can be realized either by column element shuffling (CES) or row shuffling (RS). CES exchanges the row elements, and does not alter the column element set. RS does not alter column elements, but shuffles the rows. These attacks are further categorized as combinations of {CES}, {RS}, {CES, RS}.
- **Column tampering (CT) attacks:** This attack is restricted to column tampering only, such that rows elements of *M* stay invariant. Mathematically, if *A* is modified to *B* using column tampering then $A_{mxn} \neq B_{mxn}$ such that $\bigcup_{k=1}^{n} a(i, k) = \bigcup_{k=1}^{n} b(i, k)$, for all i ($1 \leq i \leq m$), and $\bigcup_{k=1}^{m} a(k, j) \neq \bigcup_{k=1}^{m} b(k, j)$, for j ($1 \leq j \leq n$). This attack can be realized either by row element shuffling (RES) or column shuffling CS. RES exchanges the column elements, and does not alter the row element set. CS does not alter row elements, but shuffles the columns. These attacks are further categorized as combinations of {CS}, {RES}, {RES, CS}.
- **Combined row-column tampering (RCT) attacks:** This attacks results in tampering of row and column element set, such that element set of A and B are the

same. The tampering can be due to combinations of row and column tampering attacks.

- **Random Attacks:** This kind of attacks result by adding random noise signals to motion data. This attack is different from the above attacks, since the element set of *A* and *B* is not similar. In other words it is a combination of row and column tampering, such that element set of $A \neq$ element set of *B*.

The above attack patterns will result in joint motions following different patterns from their original. Since human body motion is described by motion information of joints, it will change as a consequence of the above attacks. The paper develops a singular value decomposition (SVD) based tamper proofing technique to handle such attacks.

2.1 Background on SVD

As proved in [1], any real $m \times n$ matrix M has a SVD (M) = $U.S.V^T$, where $U = [u_1, u_2 \ldots u_m] \in R_{m\times m}$ and $V = [v_1, v_2 \ldots v_n] \in R_{n\times n}$ are two orthogonal matrices, and S is a diagonal matrix with diagonal entries being the singular values of M: $s_1 \geq s_2 \geq \ldots \geq s_{min(m, n)} \geq 0$, where s_1 is significantly larger than other Eigen values. Column vectors u_i and v_i are the i^{th} left and right singular vectors of M respectively. The left singular vectors have length equal to the number of time frames, that vary with each individual motion data file. The right singular vector has a constant length depending on the number of joints considered. The singular values of matrix M are unique, and the singular vectors corresponding to distinct singular values are uniquely determined up to the sign, or a singular vector can have opposite signs.

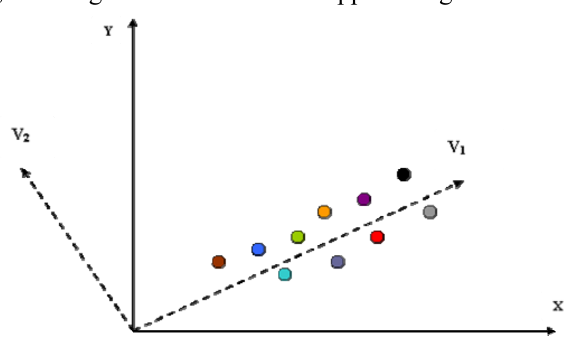

Figure 3. Geometric structure of a matrix exposed by its SVD

SVD exposes the geometric structure of a matrix *M*. It has orthogonal bases. It transforms the matrix from one vector space to another. The components of SVD quantify the resulting change between the underlying geometry of these spaces. Along the direction of the first right singular vector, the row vectors in *M* have the largest variation, and along the second right singular vector direction, the point variation is the second largest, and so on. The singular values reflect the variations along the corresponding right singular vectors. Figure 1 illustrates a 10 x 2 matrix (2D (x, y)) with first and second right singular vectors V_1 and V_2 (orthogonal vectors). The 10 points in the matrix have different variations along different directions; hence have the largest variation along V_1. We observe that elements of the matrix *M* can be expressed using a set of linear combination of elements of the matrices *U*, *V* and *S*.

The SVD (M) = $U.S.V^T = U.(S.V^T) = \{M(i, j)\}$ where $1 \leq i \leq m$, $1 \leq j \leq n$, $m > n$. $M(i, j)$ can be expressed as follows:

$M(i, j) = [U(i, 1)\ U(i, 2) \ldots U(i, m)]\ [S1.V(j, 1)\ S2.V(j, 2) \ldots Sn.V(j, n)\ 0\ 0 \ldots 0]^T$

The tamper proofing mechanism consists of *extraction phase* and *detection phase*. During the extraction phase reference pattern are extracted from matrix *M*. The second phase is the detection phase, where attacks are detected. We take SVD (M) = $U.S.V^T$, and for non-zero Eigen values *S* store the corresponding left and right Eigen vectors U and *V*. Here *V* and *U* are the reference patterns that will be used to identify and trace the attack pattern.

2.2 SVD Based Detection

Once the attack has been identified it traces the pattern used for the attack. The tamper detection process can be realized as follows:

Step1: *SVD (M') = U'.S'.V'*^{T}
Step2: *DiffU = U' – U, DiffV = V' – V*
Step3: *if DiffU and DiffV are zero matrices*
No tampering;
Else If (DiffV is zero matrix only)
RS attack or CES attack or {RS, CES} attack;
Else If (DiffU is zero matrix only)
CS or RES or {CS, RES};
Else
Random attack or RCT;

In the above checking process we consider vector till *k*, since first *k* Eigen values are non-zero. The remaining *(n- k)* Eigen values are zero and their contribution to *M* is insignificant. The process of tamper detection is done by taking considering the difference (*DiffU* and *DiffV*) between Eigen vector matrix of *M* and *M'*.

The above steps can be understood as verification of attack and tracing the attack pattern. The following subsection discusses the reasons behind the verification and tracing of attacks:

2.2.1 Verification and tracing of Row Tampering (RT) attacks

The following theorem, an extension of the theorem mentioned in [1], helps us prove that row tampering is related to change in left Eigen vector only.

Theorem 1: Given matrix $A_{mxn} \neq B_{mxn}$ such that $\bigcup_{k=1}^{m} a(k, i) = \bigcup_{k=1}^{m} b(k, i)$, for all i ($1 \leq i \leq n$), and $\bigcup_{k=1}^{n} a(j, k) \neq \bigcup_{k=1}^{n} b$

(j, k), for j $(1 \le j \le m)$, then SVD $(A) = U_1.S.V^T$ and SVD $(B) = U_2.S.V^T$.

Proof: Given SVD $(A) = U.S.V^T$, the right singular vector V can be determined from $A^T.A = V.S^2.V^T$. Let $C = A^T.A$, where $c(i, j) = \sum_{k=1}^{m} a(k, i).a(k, j)$ => the condition $\bigcup_{k=1}^{m} a(k, i) = \bigcup_{k=1}^{m} b(k, i)$, for all i $(1 \le i \le n)$, and $\bigcup_{k=1}^{n} a(j, k) \ne \bigcup_{k=1}^{n} b(j, k)$, for j $(1 \le j \le m)$ makes no difference to C. As a result, V and S are same for A and B. However since $A \ne B$ => SVD $(A) = U_1.S.V^T$ and SVD $(B) = U_2.S.V^T$

As a consequence of the above result, we can assume that whenever there is a row tampering attack, there is a change in left Eigen vector of matrix M. The following theorem helps us realize that it is possible to trace the rows of M where the tampering has occurred.

Theorem 2: If B is derived from A, by row tampering a set of rows $\{r_i$: $1 \le i \le m\}$, then rows of left Eigen vectors of A and B are different by the same set $\{r_i$: $1 \le i \le m\}$.

Proof: For a given matrix A, with SVD $(A) = U.S.V^T$, U can be determined from $A.V = U.S$. It can be easily be shown that $u(i, j) = s_j^{-1} \sum_{k=1}^{n} (a(i, k).\ u(k, j))$. By Theorem 1, we know that $V_1 = V_2$ and $S_1 = S_2$. If rows of A $\{r_i$: $1 \le i \le m\}$ are tampered => Set of rows $\{r_i$: $1 \le i \le m\}$ will be different for the left vectors of A and B.

So, by theorem 2 we can say that the non-zero rows of $DiffU = |U - U'|$ will indicate the set of rows $\{r_i$: $1 \le i \le m\}$ that were tampered. Since rows of U change in the same pattern as modified M, it is possible to trace the presence of RS. *DiffU* will point out the rows that have been shuffled. The shuffle pattern can be identified by sorting the left Eigen vectors, and observing the mapping between the rows of the sorted vectors. In case of a CES, *DiffU* will point out the rows, but not the exact shuffled column elements. Hence, it is not possible to trace a CES or {CES, RS} as opposed to RS.

2.2.2 Verification and tracing of Column Tampering (CT) attacks

The following theorem helps us prove that column tampering is related to change in right Eigen vector only.

Theorem 3: Given matrix $A_{mxn} \ne B_{mxn}$ such that $\bigcup_{k=1}^{n} a(i, k) = \bigcup_{k=1}^{n} b(i, k)$, for all i $(1 \le i \le m)$, and $\bigcup_{k=1}^{m} a(k, j) \ne \bigcup_{k=1}^{m} b(k, j)$, for j $(1 \le j \le n)$, then SVD $(A) = U.S.V_1^T$ and SVD $(B) = U.S.V_2^T$.

Proof: Given SVD $(A) = U.S.V^T$, the right singular vector U can be determined from $A.A^T = U.S^2.U^T$. Let $C = A.A^T$, where $c(i, j) = \sum_{k=1}^{n} a(i, k).a(j, k)$ => the condition $\bigcup_{k=1}^{n} a(i, k) = \bigcup_{k=1}^{n} b(i, k)$, for all i $(1 \le i \le m)$, and $\bigcup_{k=1}^{m} a(k, j) \ne \bigcup_{k=1}^{m} b(k, j)$, for j $(1 \le j \le n)$ makes no difference to C. As a result, U and S are same for A and B. However since $A \ne B$ => $SVD(A) = U.S.V_1^T$ and SVD $(B) = U.S.V_2^T$.

As a consequence, we can assume that whenever there is a column tampering attack, there is a change in right Eigen vector of matrix M. The following theorem helps us realize that it is possible to trace the columns of M where the tampering has occurred.

Theorem 4: If B is derived from A, by column tampering a set of columns $\{c_i$: $1 \le i \le n\}$, then rows of right Eigen vectors of A and B are different by the same set $\{c_i$: $1 \le i \le n\}$.

Proof: For a given matrix A, with SVD $(A) = U.S.V^T$, V can be determined from $U^T.\ A = S.V^T$. It can easily be shown that $v(i, j) = s_i^{-1} \sum_{k=1}^{n} (u(k, j).\ a(k, i))$. By Theorem 3, we know that $U_1 = U_2$ and $S_1 = S_2$. If a set of columns of A $\{c_i$: $1 \le i \le n\}$ are tampered => similar set of rows $\{c_i$: $1 \le i \le m\}$ will be different for the right Eigen vectors of A and B.

So, by theorem 4, we can say that the non-zero rows of $DiffV = |V - V'|$ will indicate the set of rows $\{c_i$: $1 \le i \le m\}$ that were tampered. Since rows of V change in the same pattern as modified M, it is possible to trace the presence of *CS*. *DiffV* will point out the rows that have been shuffled. The shuffle pattern can be identified by sorting the right Eigen vectors, and observing the mapping between the rows of the sorted vectors. In case of a RES, *DiffV* will point out the rows, but not the exact shuffled row elements. Hence, it is not possible to trace a RES or {RES, CS} as compared to CS.

2.2.3 Verification and tracing of Row-Column Tampering (RCT) attacks

As seen from Theorem 1 and 3, left and right Eigen vectors help us realize the presence of attacks. Therefore, we can intuitively say that a combination of row and column tamper attacks will affect the right and left Eigen vectors of A. As a result we get non-zero *DiffU* and *DiffV* and can verify the presence of a row-column attack.

Row and column tampering can occur in any order and any number of times. Say, we have row tampering (RT) order $<rt_1, rt_2 \ldots rt_n>$ and column tampering (CT) order $<ct_1, ct_2 \ldots ct_n>$. Row column tampering occurs such that order of rt_i and ct_i is not compromised. For such cases, theorem 5 helps us prove that it is possible to determine final outcome of <$rt_1, rt_2... rt_n$> and <$ct_1, ct_2 ... ct_n$>.

Theorem 5: Given row tampering (RT) and column tampering (CT) pattern, the order of application of tampering to a matrix is independent of the resultant matrix.

Proof: Given matrix A where SVD (A) = $U_1S_1V_1^T$. By theorem 1 RT on A results in B where SVD (B) = $U_2S_1V_1^T$. By theorem 3, CT on A results in matrix D where SVD (D) = $U_1S_1V_2^T$. We have two orders of attack <RT, CT> and <CT, RT>.

Case <RT, CT>: By theorem 1, RT on matrix A will result in B, such that SVD (A) = $U_1S_1V_1^T$, SVD (B) = $U_2S_1V_1^T$. Since the row information is invariant, then by theorem 3 CT on matrix B will result in matrix C, such that SVD (C) = $U_2S_1V_2^T$

Case <CT, RT>: By theorem 3, CT on matrix A will result in B, such that SVD (A) = $U_1S_1V_1^T$, SVD (B) = $U_1S_1V_2^T$. Since the column information is invariant, then by theorem 1 RT on matrix B will result in matrix C, such that SVD (C) = $U_2S_1V_2^T$. Since both the cases give the same result, we can say that the order of application of tampering to a matrix is independent of the resultant matrix.

As observed above, the order of application of RT and CT are independent of each other, the net resultant left and Eigen vectors of the final matrix are same as those corresponding to row tampering order <$rt_1, rt_2... rt_n$> and column tampering order <$ct_1, ct_2 ... ct_n$> applied to M. If RT and CT corresponded to row and column shuffling only, then it is possible to predict the shuffling pattern. In other cases we restricted to finding the columns and rows where attacks took place. In such cases we assume that the attack to be a random attack and can trace the pattern of attack as shown in subsection 2.2.4.

2.2.4 Verification and tracing of Random Attack

Values of M (i, j) are changed randomly. By equation 1, any change in the j^{th} column elements of M is reflected in the j^{th} row of V, and any change in the i^{th} row of M is reflected in the i^{th} row of U. As a result, we have both *DiffU* and *DiffV* non-zero. Therefore, the indication that *DiffU* (i, k) and *DiffV* (j, p) change is non-zero, points that M (i, j) has changed due to random attack. The elements changed in M will give us the random attack used to tamper motion data.

2.3 Optimizations

The number of non-zero Eigen values determines the number of computations involved in tamper detection and information required for tamper detection. This will be significant while considering the case for scalability. The following discussion describes the optimizations that can be considered to aid scalability and reduce computations.

It can be observed from equation 1, the contribution of left U_k and right V_k vectors to the matix M is determined by their corresponding Eigen value s_k. As observed in section 2.1 the Eigen values can be ordered as $s_1 \geq s_2 \geq . . . \geq s_{min (m, n)} \geq 0$, where s_1 is significantly larger than other values. This implies the contribution of V_1 and U_1 is significant as compared to other vectors. Therefore any change ($M' – M$) will be reflected in $DiffU_1$ and $DiffV_1$. If we keep only the first left and right Eigen vectors, we can save computations and storage as follows:

- **Computation Reduction:** Initially we had n left and right Eigen vectors for comparison. We have m elements in left vector and n elements in right vector. As a result, we have O (n ($m + n$)) comparisons. By restricting it to first vectors, we now have O ($m + n$) comparisons. Therefore we save computations are O ((n -1) ($m + n$)).
- **Storage Reduction:** When we are storing U and V for n Eigen vectors, then storage required is O (n ($m + n$)). However, once we use first Eigen vectors storage is reduced to O ($m + n$). The reduction is identified as O (($n – 1$) ($m + n$)).

2.4 Advantages

The advantages of the scheme are described as follows:

2.4.1. Computational and Storage Advantages over Private Watermarking

Private fragile watermarking schemes use the original matrix M to extract the watermark. This will require the O ($m.n$) original data to be stored in the databases and during computations analysis of O (mn) elements in ($M – M'$). The proposed methodology used O (m) first left Eigen vector and O (n) first right Eigen vector. As a result it used only O ($m + n$) space and requires analysis of O ($m + n$) elements. Therefore, we save space and computations by O ($m.n – m – n$). Since $m > n$ (see section 2.1), for motion data we can have large reduction in space.

2.4.2 Better Accuracy over Existing Error Detection Methods

Error detection is a well studied topic with techniques [10] such as cyclic redundancy check (CRC), parity bit checking, and checksums. Schemes such as CRC and checksum are storage efficient and faster than our proposed scheme, as they do not require O ($m + n$) space. However, they are not capable of locating the errors in the matrix. Therefore, the proposed scheme is more efficient in terms of accuracy of error detection.

3. EXPERIMENTS AND DISCUSSION

All the experiments are carried out on angular motion data (Euler angles). This data was obtained in a *.csv* format created by Vicon IQ [16] MoCap system (Motion Capture facility at University of Texas at Dallas). The data consists of joint information of a skeleton, expressed in terms of rotational (Euler angles) and translational (co-ordinates) data. The motion clip used in these experiments can be expressed as *225 x 57* matrix, where frames = *225* and *19* skeleton joint rotational data (3 Euler angles) values.

3.1. Analysis of Attack Patterns

Attack patterns can be detected in automatically by our technique, and this detection can be visualized in this subsection. In Figure 4, CS and RES attack can be perceived on a joint. It shows the original trajectories for a joint, and also the attacked data for the same. It can be seen that one of the angles is shuffled with some other column, resulting in totally different data. This causes the joint to behave abnormally. The spikes in the figure depict the row element shuffling attacks, which can be seen in case of all the three angles. Figure 6 shows the effect on first right singular vector due to CS and RES attacks. The circled parts are the change in values due to row element shuffle (RES) attack. The other changing values are due to a column shuffle attack. The left singular vectors remain unchanged in these 2 cases as seen in Figure 8.

Figure 5 shows one Euler angle over the entire time duration before and after a RS and CES attack. The spikes (circled values) represent the CES attack. Figure7 shows the first left singular vectors before and after the attack (circled spikes represent CES values). The first right singular vectors do not change during a RS and CES attack, as observed in Figure 9.

Random attack affects left and right Eigen vectors. These effects can be visualized Figure 10 and Figure 11. Figure 10 corresponds to the comparison of first right Eigen vectors. Figure 11 shows first left Eigen vectors of original and attacked data. The dissimilarity between the Eigen vectors serve as evidence for tamper detection.

4. CONCLUSION

The paper proposed singular value decomposition (SVD) based technique to detect tampering of archived motion data. It has been shown that this method is capable of verifying and tracing the attack patterns on motion data matrix $M_{m \times n}$. The proposed scheme supports addition of copyright based watermarks. The information and computation required for tamper detection for a *(m x n)* matrix is reduced from $O(m.n)$ to $O(m+n)$, making the solution scalable.

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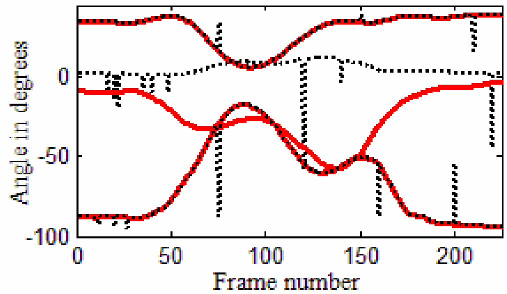

Figure 4: Effect on trajectories of a joint due to CS and RES attack

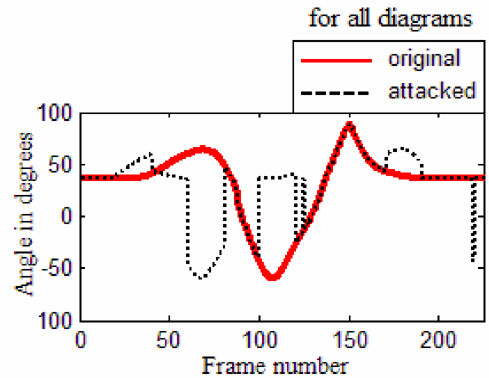

Figure 5 : An Euler angle value over the entire duration upon RS and CES attack

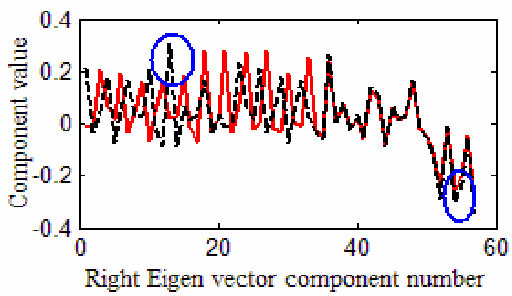

Figure 6: First right singular vector upon a CS and RES attack

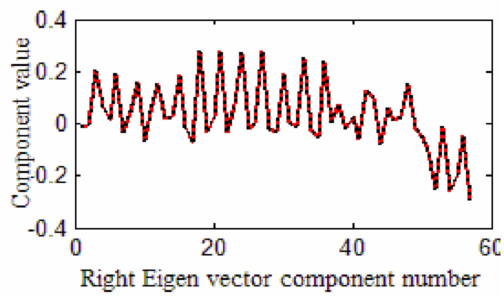

Figure 7: First left singular vectors upon RS and CES attacks

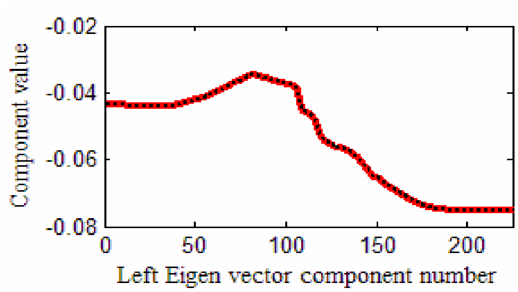

Figure 8: First left singular vector upon a CS and RES attack

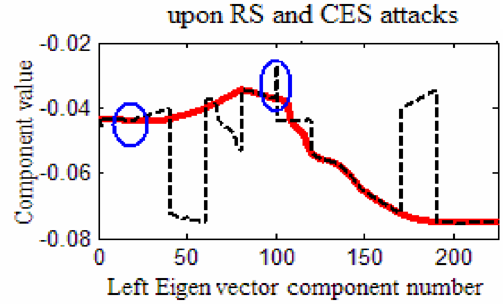

Figure 9: First left singular vectors upon a RS and CES attack

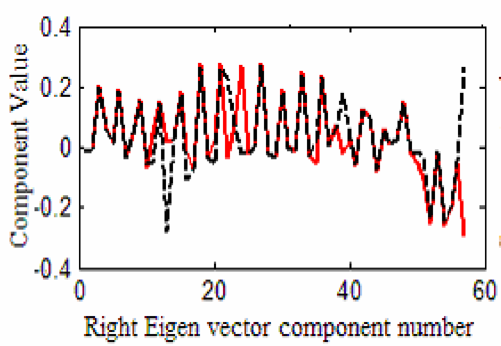

Figure 10: First right singular vector upon a random attack

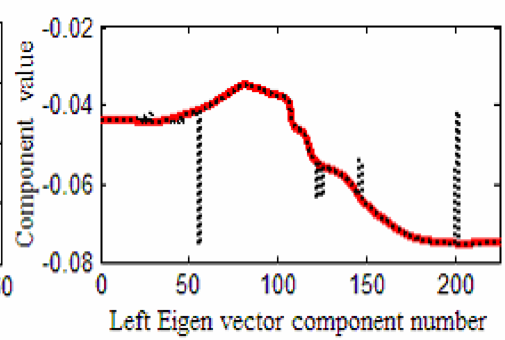

Figure 11: First left singular vector upon a random attack

Uncertainty: An extra layer of security For Unauthorized traffic based Web Services

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ABSTRACT

Distributed web services are under constant threat of being attacked from nodes, internal or external to the system. Internal attacks may result from hijacking of trusted web servers, resulting in loss/corruption of information, and Denial of Service (DoS) to clients. External attacks can occur from hijacking of trusted clients or malicious nodes leading to DoS to clients. The paper focuses on building an attack resistant framework for web services based on unauthorized traffic. Unauthorized traffic is a consequence of query driven session less HTTP-request/response message based web service applications, such as google.com. Dictionary.com etc. Unauthorized traffic based web service applications are supposed to have low response time. Unfortunately current mechanisms show lack of support for this traffic, since they add extra delay due to processing at intermediate nodes. The paper proposes a framework that optimizes the use of secure overlay services for unauthorized traffic. We add an extra layer of security around the web servers, which introduces uncertainty in the adversary's actions and is achieved by introducing dummy servers to the existing system, which appear as real servers to the clients or adversaries. The dummy servers act as traps if an adversary attacks assuming them to be real servers. Secure strategies have been proposed to implement the dummy servers. These strategies reduce the risk of hijacking and DoS attacks, minimize the changes to external infrastructure, can be easily integrated with existing security systems, do not promote ISP collaboration, and helps in scaling the system.

1. INTRODUCTION

Web services are under constant threat of being abused by attacks such as the following:

- **Denial of service attack:** These attacks can be launched by sending flash crowds to web servers. Such flash crowds can be generated by concatenating distributed hosts across the network; hence the name distributed denial of service (DDoS) attack. DDoS attack can be launched in an unsophisticated way by running "rootkits" and worms [6] on these malicious nodes. The source of the flash crowds can be internal trusted nodes or external trusted/distrusted nodes. The trusted nodes are made to act malicious by hijacking them.
- **Information corruption:** Nodes internal to the system can be hijacked. Once hijacked, these nodes can disrupt the information at the system, and also send malicious information to the client side.

The malicious nodes are either internal or external to the system, hence the name internal and external attacks. In order to subvert such attacks we need to design framework that protects different kinds of web services. We identify web services on the basis of traffic generated by web applications as follows:

- **Unauthorized traffic:** This can be generated from query driven web services such as search engines (google.com), online dictionary (dictionary.com, word.com), map service (mapquest.com) etc. The interaction between client and server are HTTP-request and HTTP-response messages and do not require authentication mechanism prior to any information exchange. Such kind of traffic has low response times since the user expects quick responses.
- **Authorized traffic:** This can be generated from web-applications such as email service (gmail.com), e-commerce website (amazon.com) etc. These applications involve authentication mechanisms prior to information exchange. Such kind of traffic can have delay tolerance since authorization mechanisms involve identification processing.

Recent work on resistance against DDoS [1, 2, 3, 4, 5, 6, 7, 8, and 10] has focused on filtering traffic at the intermediate nodes. The filtering criteria can be traffic from unauthorized/illegitimate clients or absence of expected information in the message sent by the clients. Techniques such as [4] filter illegitimate traffic at the routers whenever the client identifies an attack being done using such a traffic. Similar techniques [5, 6, 7, and 10] have been developed to identify illegitimate traffic as weapons for launching DDoS attacks. Unauthorized traffic is based on short lived HTTP sessions that use TCP connections that tear down after each use. Subjecting the unauthorized traffic to such mechanisms would increase the response time, which is not a valid feature for such kind of applications. However, we observe that such solutions are more suited for authorized traffic based web applications since they are delay tolerant at the cost of security.

Frameworks that are based on Secure Overlay Services (SOS) [1, 2, 3, and 6] are suited for prevention against internal and external attacks. However, it is not suited for unauthorized and authorized traffic, as a result of the following problems:

- **Lack of traffic Support:** SOS-based techniques do not provide support for unauthorized traffic and filter such traffic assuming it to be a weapon to launch DoS attack. Therefore, we cannot rely on methods that support authorized traffic and use unauthorized traffic as a means to filter out an attack.
- **Hop Delay:** We could depend on techniques such as Secure Overlay Services (SOS) [1] to protect web services that support unauthorized traffic based applications. However, SOS has a potential problem for query driven application that requires fast responses. SOS adds hop-delays that will result in increase in response time.
- **Points of failure:** A node belonging to SOS can serve different web services. When such a node comes under attack, it malfunctions and affects all such systems. We need to remove such dependencies and points of failure, in order to secure the web services.

The above rationale motivates the design of secure framework for web services (supporting unauthorized traffic based applications) and is derived from an optimized SOS architecture. This paper contributes by proposing such a framework with the following design scope:

- **Risk Reduction:** Reduce the risk involved in hijacking and DoS or DDoS attacks by increasing the probability of failure of the adversary, which will act as the de-motivating factor for the adversary.
- **Minimal Change to existing Infrastructure:** The change in the system should least impact the external system such as the internet and transport protocols, and the routers. This also includes end-host, inter-ISP and intra-ISP cooperation.
- **Co-existence with existing security features:** The new layer of security should not impact the existing security features.
- **Support Scalability of the existing system:** The addition of the security feature should have minimal impact the scalability of the system
- **Fast Query responses:** The response time of the system should not be affected by the addition of security features.
- **No external cooperation:** The framework should result in increase in traffic due to cooperation between end-host/ISP, inter-ISP, and intra-ISP cooperation [4].
- **Ease of customization:** The framework requires minimal effort in customizing it for existing web service architectures [12], such as cluster-based, virtual clusters and locally distributed servers.

The proposed design introduces a set of dummy nodes/servers that are mapped to the real nodes/servers. The clients communicate either directly with the real servers or indirectly via the dummy servers. However, the clients assume direct communication with the real server. The mapping between the real and dummy servers is a secret and introduces uncertainty in launching internal or external attacks. We have shown the probability of failure of the adversary increases as the number of dummy servers is made equal to the number of real servers. Our design introduces (<) 1-hop delays which is an improvement over SOS design. Moreover it does not have points of failure since we do not use an infrastructure such as SOS.

2. DESIGN RATIONALE AND ASSUMPTIONS

The following assumptions are considered for our design:

- Servers within the system can communicate with each other over secure reliable high bandwidth links using their synchronization protocols.
- Any system node is capable of identifying a DoS attack and raises an alarm.
- During a node crash, the system will bring up another identical node with same IP address.

SOS hides the true identities of servers by introducing hidden paths to the target nodes. These paths are like levels in security. In case a web service uses a SOS, the target nodes are the web servers. Therefore, the web servers are hidden behind the SOS. We introduce an extra layer of nodes, similar to SOS, before the web servers. This layer is defined by dummy servers that are not used by the system for processing requests. We assume that the adversary views the dummy servers as real servers and will try to attack them. Therefore the dummy servers will act as traps and as a result the probability of its failure of the adversary will increase.

Figure 1 illustrates the interaction between client and N servers. We introduce K dummy servers to form the extra layer of security. N- K servers communicate directly and considered exposed and vulnerable to attack. Meanwhile K servers communicate indirectly with the real servers via the dummy servers.

We need the following features to implement the extra security layer:

- **Transparency:** The client nodes should visualize the dummy servers as real servers. In order to achieve such transparency we need mechanisms wherein the dummy servers should be able to process the client requests.
- **Secrecy:** In order to break down the system the adversary should be in a state to distinguish between dummy and real servers. In order to counter such an act, we need to maintain the identities of real and dummy servers a secret.

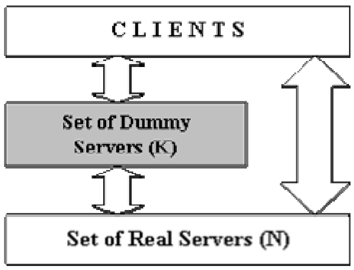

Figure 1 Client-Server Interaction

3. STRATEGIES TO SUPPORT THE DESIGN

The following section tries to explain strategies that can be used to maintain transparency and secrecy.

3.1 Transparency-based Strategy

Each dummy server is mapped to a real server. Clients communicate with the real server via the dummy nodes. In this case, the HTTP requests are received at the dummy nodes and forwarded to the real nodes. Similarly the HTTP response is received from the real server and forwarded to the client. HTTP uses TCP at the transport layer and hence would require two separate TCP sessions, referred in figure 2 as TCP1 and TCP2. Whenever the clients send out requests represented by TCP1-Req, the dummy server establishes a TCP connection with real server represented by TCP2-req. The real server responds with TCP2-reply and this is conveyed to client as TCP1-reply. It should be observed here that the TCP1 and TCP2 are different, and TCP2 represents TCP1 to the real server.

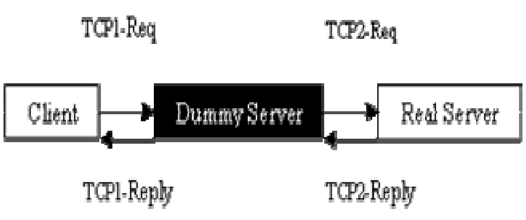

Figure 2 TCP traffic handling

The connection is made transparent since TCP2 is hidden from the client and it always assumes interaction with the real server. It is can be observed from Figure 2 that the HTTP requests and response over TCP1 and TCP2 stay invariant and are referred as TCP1-Req/TCP21-Req and TCP1-Reply/TCP2-Reply respectively. The client always visualizes interaction with the real server. We assume that, whenever a dummy server is under attack, all the current connections can be redirected to a back-up dummy server.

3.2 Secrecy-based Strategy

We add a set of dummy servers say K (≤ N, number of real servers). Each dummy server is mapped to a real server. The number K and the mapping is kept secret and can vary with time. Therefore the adversary will be unable to distinguish between the real and dummy servers. The IP address of the real and dummy servers is made public and is used by the clients for communication. Since the mapping secret we say that it is an *extra secret layer*. The secret in this layer results in uncertainty in the adversary's decision to attack the system.

In this approach we only have one-to-one mapping between the real server and the dummy server; in case there is a compromise of the dummy server, the identity of at most one server is revealed, leaving rest of the system safe.

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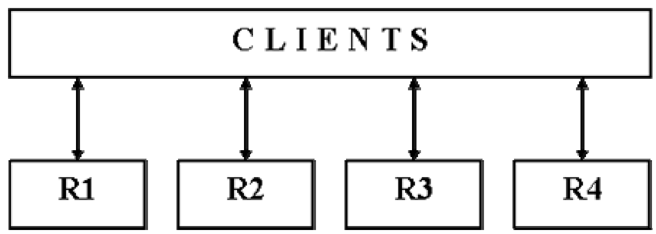

Figure 3 (a) Insecure System

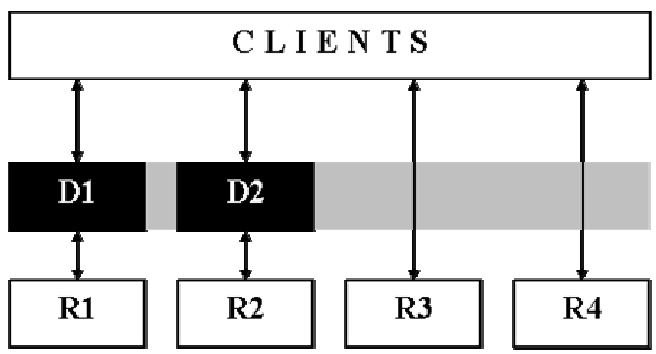

Figure 3 (b) Secret Extra Layer for Figure 3 (a)

Figure 3(b) represents a secrecy-based strategy for Figure 3(a). In this case we introduce two dummy servers with mapping (D1, R1) and (D2, R2). The client's perspective remains the same since the number of servers does not change. The following sections try to answer questions related to the use of secrecy-based strategy.

4. ATTACKS AND COUNTER MEASURES

The following subsections explain the attacks and their counter measures.

4.1 Internal Attack

Adversaries can capture servers and use the information stored at the server to attack other servers. Compromised servers can collude to attack and obtain the identity of other servers. As a result, compromise of servers can lead to attacks that compromise the remaining servers.

In order to make the system robust, we make the real servers incapable of discriminating between real and dummy servers. This can be achieved by following the secret-based strategy mentioned in section 3.2. The clients in this case are the servers themselves. Every real server is given a set S of IP address of servers they can communicate to, for synchronization purpose. The set S contains a combination of IP addresses of real servers or dummy servers. A real server by itself is unable to discriminate between the IP addresses of real and dummy servers. It assumes communication with all the real servers. In case the IP address of the dummy server is being used, communication with the real servers happens via the dummy server. During an attack, an adversary may compromise the real server. However since the real server is incapable of discriminating between the real and dummy servers, it will give no clue to the adversary.

4.2 External Attack

Adversaries can capture trusted clients and launch attacks on web servers that trust these clients. The following sub-sections explain as to how the security strategy can help prevent these attacks.

4.2.1 Delay Pattern Attack

The adversary may try to pin point a dummy server by observing the 1-hop delay added due to the routing process. In order to handle this situation we can add random delays to responses to the requests that do not come from the dummy servers. So that the adversary will not get an exact knowledge about the real servers, thus defeating the adversary's purpose.

4.2.2 All node Attack

A consequence of the combination of secret and transparency strategies is a layer of uncertainty that protects the real servers. However, some of the real servers are always exposed to the Internet. In order to overcome the uncertainty, an adversary may attack all the servers. We assume that the dummy servers are capable of recognizing such an attack and will raise an alarm to overcome such an attack. As a result, we will be able to protect the exposed real servers.

As long as the adversary is unable to distinguish between the true and dummy servers, the element of uncertainty always confuses the adversary. Therefore, the adversary is incapable of launching attacks [6] such as probing, adaptive flooding, and request attack. Prevention against external and internal attacks helps reduce the risk of DDoS by unauthorized traffic. The reduction in risk is evident in section 6.

5. CUSTOMIZATION FOR WEB SERVICES

A web service can be organized a locally distributed set of servers [12], which can be defined as cluster-based, virtual web-cluster and geographically distributed. The following schemes customize our solution to distributed web servers:

- **Cluster-based:** In such a scheme, we have a web-switch that acts as the router to the incoming and out-going requests/responses. The IP address of the web-switch is the publicly known to the clients. An attack can be launched on such a system by overtaking the web-switch. Since the web-switch has full knowledge of the IP address of all the servers, it will come under attack. Such an attack can be dissuaded by making the web-switch unable to distinguish between the real and dummy servers. It can be easily observed that the dependence on a single web-switch makes the system vulnerable to central point of failure. We can overcome this problem by assuming the web-switch is the target address for SOS. As a result, the clients observe the IP address of these SOS as the contact point to the web service. It has been shown in [1] that SOS offers significant guarantee against failures due to denial of service attack. Therefore in our improved design we observe the use of SOS in combination with our technique.
- **Virtual web-cluster:** In such a scheme, the web servers have the same IP address. We can customize this design to our solution by adding dummy servers with the same IP address. A significant advantage of such an approach can be triangular routing where the connection requests route from dummy to real servers. However the response and further communication takes place with the real server.
- **Locally Distributed servers:** In such a distribution, the IP address of the web servers is publicly known. We customize this scheme to our idea by adding the IP addresses to the pool of publicly known IP addresses. The IP addresses of the real servers that pair with the dummy servers are hidden. So the publicly known IP addresses consist of IP addresses of the dummy and real servers. It should be observed here that our original scheme does not hide the IP addresses of the real servers.

It can be observed that in the above customizations, that we do not change the existing web server systems. This is evident from the fact that the IP address remains invariant. It is the mapping between real and dummy servers that will determine the difference. However, this is not influenced by web service architecture. Thus we induce minimal changes and add ease in customization to the existing system. The following system analyses hop delay and risk of the proposed design.

6. ANALYSIS

This section is aimed at analyzing the framework in terms of reduction in risk and average hop delay.

6.1 Analysis of Risk

The probability of failure of the adversary indicates the effectiveness in security of our system. The following analysis calculates such a probability, where for a system of N servers with K dummy servers, the adversary attacks J servers without being able to distinguish between the real and dummy servers. Probability of failure of the adversary is (${}^{K}C_{J}/{}^{N}C_{J}$).

N=5	K= 1	K=2	K=3	K=4	K=5
J =1	0.2000	0.4000	0.6000	0.8000	1.0000
J =2	0	0.1000	0.3000	0.6000	1.0000
J=3	0	0	0.1000	0.4000	1.0000
J=4	0	0	0	0.2000	1.0000
J=5	0	0	0	0	1.0000

Table 1 Probability of failure for (N=5, varying J (1 to 5), K (1 to 5))

Table 1 illustrates different values of probability of failure, given N = 5 for different values of K (1 to 5) and J (1 to 5). We can observe from table 1 that in order to have probability of failure (> .5) we need higher number of dummy servers in the system. For K = 5, we can guarantee 100% failure of the adversary. It can be observed that in order to attack the system, uncertainty will prevail for probability of failure (> .5). If the number of dummy servers being operated is made a secret, the probability of failure is a secret. Thus, uncertainty will prevail by maintaining such secret and will dissuade adversary. Therefore, when designing the web services framework we need not require the condition N = K. Therefore, we can claim that the SOS based extra layer of security can be *optimized*.

N =4	K= 1	K=2	K=3	K=4
J =1	0.2500	0.5000	0.7500	1.0000
J =2	0	0.1667	0.5000	1.0000
J=3	0	0	0.2500	1.0000
J=4	0	0	0	1.0000

Table 2 Probability of failure for (N=4, varying J (1 to 4), K (1 to 4))

Table 2 illustrates risk analysis for Figure 3(b), with different values of probability of failure given, N = 4, K (1 to 4) and J (1 to 4). We can observe that the probability of failure for figure 3 is represented in column K =2. As observed in table 1, table 2 also shows us that for larger values of J, we need higher number of dummy servers to keep the probability of failure (> 0.5).

6.2 Analysis of average hop delay

The average hop delay [11] (for K dummy servers, N real serves, Average Traffic) can be calculated as follows:

$$\text{Average Hop Delay} = \frac{\sum_{i=1}^{K} AverageTraffic}{\sum_{J=1}^{N} AverageTraffic} \quad (1)$$

$$= \frac{K * AverageTraffic}{N * AverageTraffic} \quad (2)$$

$$= \frac{K}{N} \quad (3)$$

It can be observed from equation 3, that the average hop-delay is (K/N < 1) for (K < N), and hence is an improvement over SOS where average hop-delay is > 1. For figure 3(b), K = 2, N = 4 and the average hop delay is (2/4 = 0.5 < 1).

7. DISCUSSION

This section discusses our design in terms of advantages; the disadvantages with their counter measure, and compare our design to SOS.

7.1 Advantages

The advantages are listed as follows:

- **Handling DDoS attack:** Our design is capable of handling DDoS attack as it dissuades the adversary from launching internal and external attacks (see section 4).
- **Reduction in risk:** As we increase the dummy servers in the system, the likelihood of an adversary attacking a dummy server increases (see section 6). The idea of secret strategy will act as a dissuading factor to the adversary. Thus we might be able to avoid external and internal attacks.
- **Co-existence with existing security strategy:** Our idea can work in conjunction with SOS by registering the IP addresses of the dummy and real servers to the SOS. In such a case, our system introduces uncertainty in attack to a compromised SOS node.
- **No change in external system:** We do not make any major changes to the external protocols such as UDP, TCP or routers. Hence our design has minimal impact on the Internet infrastructure.
- **No External cooperation:** The design does not assume any end-host, inter-ISP and intra-ISP cooperation. Thus making the system free of signal exchange.
- **Reduced Response time:** In SOS where hop delay is a problem. However, the introduction of only a single layer adds a 1-hop delay. Since some of the servers are

directly exposed the 1-hop delay is not present. As a result, the response time will be reduced as compared to SOS technique. It can also be observed since no prior authentication is requires, we reduce the response time.

- **Ease of customization:** It has been shown in section 5 that our framework does not require any major changes in existing web service architectures.

7.2 Disadvantages and Counter-measures

Scalability at increased cost: As the number of requests of the clients increase, the load at the dummy servers will increase. This can be handled by increasing the computation power and memory capacity at the dummy servers. Since companies are willing to invest and the requisite hardware is getting cheaper, scalability is possible.

7.3 Comparison with Secure Overlay Services

Secure Overlay Services (SOS) hides the true identities of servers by introducing hidden paths to target servers. These paths are like levels in security. An attack on a node at a given level can be handled by removing the node from the SOS, and rerouting the traffic through another SOS node. In case a web service uses a SOS, the target nodes are the web servers. Therefore, the web servers are hidden behind the SOS. It has been shown in section 5 that the probability of failure of an adversary for SOS is 100%. However, by re-using the SOS ideas of hiding some of the servers in our own system, we introduce uncertainty in the adversary's desire to attack a web service (see section 5). We can compare SOS with our technique in terms of the following:

- **Traffic Support:** Our technique provides this support, and can also work in conjunction with techniques such as SOS to provide support against DDoS attacks.
- **Hop Delay:** Removing the extra layers and leaving certain servers directly exposed can reduce the overall delay. This evident from subsection 6.2 where it has been shown that the average hop delay (< 1).
- **Points of Failure:** The extra layer of dummy servers are system dependent, the points of failure are removed. A failure of a dummy server will not affect another web-application.

8. CONCLUSION

In this paper, we develop a secure framework for web service applications that generate traffic which does not require authentication as a pre-condition for communication. The design of the framework is derived by optimizing Secure Overlay Services (SOS). However, it does not suffer from the fundamental drawbacks of the SOS such as hop-delay, and lack of unauthorized traffic support. The paper proves that the framework avoids DDoS and information corruption attacks from nodes (external/internal) that are either acting malicious or have been compromised. The framework can be easily integrated with existing frameworks such as SOS, scalable at increased cost, does not require any change in external (internet protocols), requires no ISP collaboration and can be easily customized for existing web service architectures.

ACKNOWLEDGEMENTS

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A Framework for Pre-Rendered Virtual Worlds Navigation Through Motion Tracking Based Interface

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ABSTRACT - *Virtual reality (VR) is today mostly used for applications ranging from entertainment to interactive simulation and scientific visualization, but it can also play an important role to implement new paradigms for cultural heritage fruition and dissemination. In this paper we present a framework aimed to navigate and to interact with 3D photo-realistic virtual worlds populated by believable characters through an advanced interface exploiting wireless 6 DOF (degrees of freedom) head and hand motion tracking. The proposed approach does not rely on real-time rendering but is based on high resolution stereoscopic pre-rendered content instead. In this scheme, to navigate through the environment and to interact with its object and characters basically means to visit a graph. This methodology, though limiting in term of action freedom could be effectively used for VR applications in fields such as Edutainment and Cultural Heritage. We show the proposed framework applied to the virtual reconstruction of the Colosseum during gladiator fighting in imperial Rome.*

1. INTRODUCTION

Tridimensional computer graphics represents a challenging research area of information technology, whose commercial and industrial applications are continuously growing. Technical achievements in modeling, rendering and animation, have been vastly exploited in fields like design/prototyping, cinema digital effects, scientific and architectural visualization, videogames and Virtual Reality (VR). Thanks to the revolution operated by Graphical User Interface (GUI) based operative systems, the above mentioned applications were empowered by (and partly responsible for) continuous innovation in both hardware (graphics boards, local/high speed buses, vector processing capable CPUs, multi-pipelined GPUs, etc.) and software (3D engines, VRML, OpenGL and DirectX graphics libraries, etc.). Indeed, vast diffusion of graphics based applications has been one of the main reasons (at least from a technical point of view) for research and development of many architectural enhancements which characterize most computers today, as shown by the most used PC or workstation benchmarks which are usually based on 3D intensive tasks like polygonal based rendering. Even if this scenario suggests that today any user could expect photo-realistic 3D VR applications on PC or even just on dedicated hardware, this is not exactly true, at least not yet.

Surely most advanced videogame engines coupled with the latest CPU and GPU technology can produce stunning graphics, but if polygonal detail and image resolution exceed a certain amount, like in large screen visualization for example, the illusion vanishes. Even highly expensive dedicated hardware, such as multi-GPUs based solutions suited for real-time flight or astronomical simulation could not address highly detailed complex characters and environments rendered at cinema-quality by the most sophisticated shading, lighting and animation techniques.

So, though certainly the next generations of specialized hardware will bring even more processing power to VR applications, at this moment a trade-off in terms of visual quality and/or scene complexity is still necessary. This study presents a VR framework offering virtually unlimited visual quality at the cost of a constrained interactivity, and results best suited for edutainment and cultural heritage applications like virtual museums, for example. It is based on a pre-rendered approach which relies on scalable, not dedicated hardware technology and on motion tracking technology to provide a more friendly and intuitive way to navigate and to interact. We applied this framework to the virtual reconstruction of the Colosseum in Rome as it is supposed to be near the first century a.C.. Different kind of fighting gladiators, including highly detailed weapons and armors, have been digitally replicated too (see Fig 1.).

This paper is organized as follows. In section 2 main approaches to VR are presented. In section 3 the proposed framework is presented in detail and applied to the case study. In section 4 the proposed methodology and its implementation is compared to other approaches. The paper concludes in section 5.

Figure 1. Thracian gladiator helmet. A sample of one among many highly detailed 3D models built for the case study presented. It features aging shaders and dynamically simulated feathers which would be hard to compute and realistically render in real time.

2. MAIN APPROACHES TO VR

Virtual Reality paradigm is to provide user a visually believable experience in a virtual environment, interacting within it with objects and characters. In a classic geometry based approach to VR, the interaction requirement asks for a high frame rate real time rendering, while the visual realism requirement asks for high image resolution, fine geometry detail and sophisticated rendering algorithms.

Other typical VR options include stereoscopic and/or multi-screen visualization, which are even more demanding in terms of processing load. Though technology is rapidly changing the horizon with fast paced announcements of new and more powerful vector processing units or multi-pipelined architectures for parallel vertex and pixel processing, to achieve at the same time a high level of interaction and cinematographic visual quality is still not possible. The result is that, except for the entertainment domain (videogames), real-time based VR often does not live up to its promise of realism. With a completely different approach, Apple Computer Inc. released in the '90s the Quick Time Virtual Reality (QTVR) Application Program Interface as an extension of its QuickTime video compression technology [2]. In this Image Based Rendering (IBR) method, tri-dimensional visualization of an environment, is obtained projecting a panoramic view of it onto a cylinder (or a sphere or even a cube). This environmental map can be produced through image processing of actual wide angle photos stitched together or even by properly rendered synthetic images. Limited navigation option such as constrained camera rotations and movie branching are supported, so it is possible to build a virtual world and within some extents to explore it, but the main limitation is that the scene has to be static, meaning that moving objects or characters are not allowed unless they are rendered into the scene in real time from conventional geometry based models. Other more sophisticated IBR approaches have been developed since then to model and render environments and particularly architectural scenes [3], even combining geometry based and image based approaches [4]. They proved to be very suited to real-time navigation in visually rich static worlds. IBR techniques have been also proposed to improve realism of complex object (statues, monuments, even characters) when they do not need to be seen closely [7], or just to reduce the geometry processing load in real-time engines. While these methods can effectively contribute to enrich real-time navigation in virtual environment, they can not yet address effectively animated environments with complex characters. The aim of the "pre-rendered" approach to VR is to realize a virtual experience through a vast collection of pre-rendered video clips accessed on-the-fly according to user interaction. This idea is not new, indeed in the past, different technologies were proposed for interactive video content fruition when real-time rendering was simply not an option. The Interactive Video Disk (IVD), presented in the first half of '80s was the first optical support to allow the storage of a big amount of visual data either as still images or broadcast quality video.

The IVD capability to randomly access a particular frame or video clip within a fraction of a second, was responsible for its usage as interactive video platform in a few entertainment applications as well as for training and educational purposes implementing a simple interaction on digitized footage [6]. Since one of the most stable IT trends in the last decade has been price reduction of mass storage coupled with a huge increment in both memory space and performances, we have now the opportunity to revisit the IVD concept of video interaction overcoming many of its original limits. Indeed, is now possible to record and play hours of uncompressed high definition video content, even stereoscopic, accessing any point of a given clip randomly without any noticeable lag, simply through a head and/or hand motion. So, for applications in which visual realism is critical, while complete freedom of action is not a strict requirement, pre-rendering could represent an interesting alternative to real-time VR. This is the idea behind the system described in the following section.

3. PROPOSED FRAMEWORK

The main aim of the proposed framework is to allow the interactive fruition of rich virtual worlds making content creators free to exploit even the most realistic (and computing expensive) techniques for modeling, animation and rendering, without any constraints in terms of scene or character complexity. On the other hand, since a pre-rendering based approach limits interactivity, we want to reduce this disadvantage through effective system design and an intuitive interface, using smart techniques derived from videogame development. The whole system is exposed in the following subsections 3.1 to 3.4.

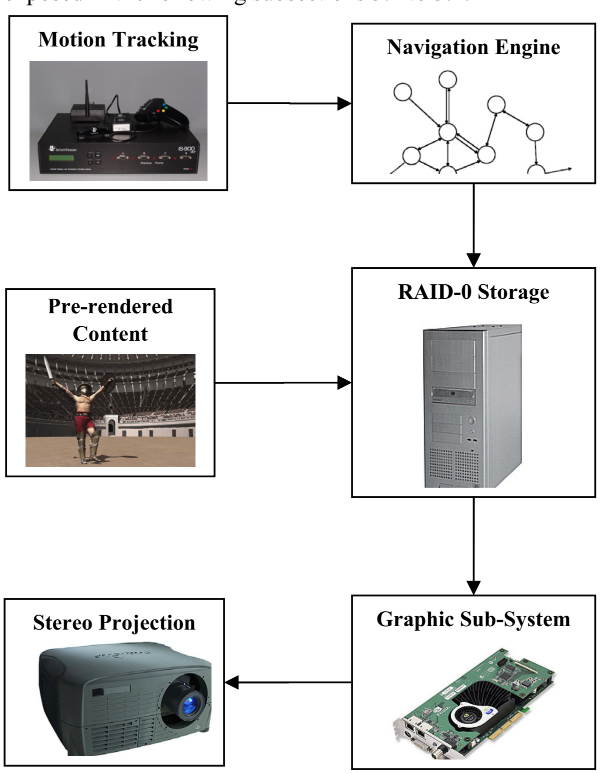

Figure 2. Schematic view of the proposed architecture.

3.1 Graph Based Navigation

The foundation of our proposal is the development of a pre-rendered virtual world in which user can navigate following pre-built paths and performing available actions through a context sensitive motion tracking based interface.

In Fig. 2 a schematic view of system's architecture is shown. The entire virtual world, is a collection of video clips stored on a high performance server, including every scene, eventually viewed from any allowed angle, and every path from one scene to another. In other terms such a virtual world can be visualized as a graph whose nodes represents scenes and whose oriented arches represent available paths which lead user from scene to scene. Any node or arch is uniquely identified with a tag pointing to the start frame of the corresponding clip. There can be various types of scene-nodes and various type of path-arches as shown in Fig. 3. Solid circled nodes, represent scenes in which user's point of view is fixed, dash circled nodes represent scenes in which the camera can rotate along one axis, while in scene corresponding to dot circled nodes the camera can rotate along two axis. Every arch coming out from a scene-node equals to an action available to user at that precise point of the virtual experience.

Mono-directional arches only allow to move from source node to destination node according to the direction of the arrow, bi-directional arches represent a single clip that can be played in both direction, whereas two parallel mono-directional arches represent that a path is reversible, but only through two different clips. The heart of this system is the navigation engine, implementing a real time video editing application which, based on the virtual world design and on user's input plays the correct video clip for a given context. Thanks to the underlying hardware technology (detailed in the following subsection), clips previously rendered to be jointed at specific time position are seamlessly played. In this way the navigation and interaction results in a pseudo real-time experience. For instance, since the hardware architecture is able to play a video sequence in both direction, user can smoothly change his viewpoint (on a given axis) simply playing a circular seamless pre-rendered animation if that option is available for that particular scene-node.

3.2 Hardware Architecture

The hardware equipments necessary for this architecture to work effectively, are tightly related to the requested image resolution and to the number of clips present in the World-Graph (including all layers if any). Typical system configuration (for an output resolution up to 2K+ pixels) requires a RAID-0 server equipped with an array of SATA or Ultra SCSI hard-disks, each one featuring high RPMs and 8-16 MBytes buffer for more efficient read and write operations. As RAID-0 operative modality implements a parallel access to all mounted drives this results in a single virtual disk whose capacity and transfer rate are the sum of the correspondent values of all physical drives. A total of 2-3 TBytes of storage space is not unusual allowing to play up to hours of high resolution uncompressed content with a sustained transfer rate of up to 300+ Mbytes/sec.. The navigation software run on the video server as it has a very low computing load since images are stored uncompressed, therefore it does not need special hardware or powerful processors. However, as high speed data exchange between storage sub-system and video frame-buffers is crucial for this architecture, 2 GBytes of RAM (used as content buffer) and a fast system bus (PCI-Express) are required.

The graphic subsystem is based on a workstation class graphic board which is not used for polygon processing but for its high pixel fill-rate, driving simultaneously two monitors or projectors in passive stereo, or just one in active stereo through a quad buffered output.

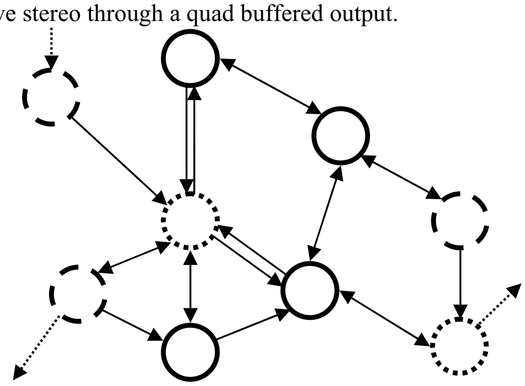

Figure 3. Sample graph fragment of a pre-rendered world. Solid nodes, represent scenes in which user's point of view is fixed, dashed nodes represent scenes in which the camera can rotate along one axis, while in scene corresponding to dotted nodes the camera can rotate along two axis.

3.3 Motion Tracking Based Interface

User interaction is accomplished through a motion tracking system, which detect the hand and/or head position in 3D space, plus their rotation on three axis for up to 6 degrees of freedom. In our experiments we used the IS 900 ultrasonic based motion tracking hardware from Intersense corp. (see Fig. 5), able to precisely acquire and process motion data coming from each of two wireless devices the user can wear: an head tracker and a joypad. The keypad features programmable multi button interface and an analog joystick which can be used to trigger specific actions. In our implementation we developed an iconic context dependent graphical interface showing either actions or camera options available at a given stage of navigation.

These icons appear as an overlay drawn in real time over the video content (see Fig 5a), and allow the user to visualize not only which option is available (to change the viewpoint, to move forward or backward, to choose a new path, etc.) but even how to select it. In fact the user can select the desired action simply moving the head toward the corresponding icon and confirming the selection via the wireless keypad (a color based button-icon correspondence and an animated confirmation simplify this task).

Figure 4. A frame from case study showing a realistically rendered crowd of spectators inside Colosseum.

3.4 The Framework at Work

The proposed system has been used for the virtual reconstruction of the Colosseum in Rome. Thanks to the information provided by archaeologists, we realized a richly detailed digital replica of architecture, gladiators, armors and weapons. Gladiators' faces where reconstructed starting from craniometrical data, according to recently developed methodology [1]. We exploited some of the most advanced CG techniques like sub surface scattering for skin rendering, particle based hair, virtual garment design and simulation. About 40,000 animated villains have been positioned on Colosseum's seats (see Fig. 4), while real fighting actions has been recorded during various motion-capture sessions involving specifically trained actors. As we did not need real-time performance, we were free to use even the most demanding lighting algorithms like radiosity. The project has been optimised and rendered for active stereoscopic visualization.

4. DISCUSSION

It is reasonable to imagine that in the next few years real-time CGI will deliver virtual experiences at near cinema quality with almost comparable content richness. If we look at the most recent videogame titles, we could conclude it is just beginning to happen. So it could seems a step back to propose a non real-time VR system in a time in which there is a lot research work about real time solutions. But in the end VR is just the art of producing a believable illusion, no matter on what approach it is based on, so it is meaningful to consider other available alternatives. It is reasonable to think that if real time CGI does not match the expectations, at least for some applications the interactivity alone could not be enough to capture user's interest. But, on the other side, it is true that interactivity is what make VR experience potentially more involving than others, like cinema for instance. So, until technology will not be ready to offer the best of both worlds, a trade off has to be accepted, and it could also be on user's freedom of interaction.

Table 1. A brief comparison of main approaches to VR

Main Features	Approaches to VR		
	Real-Time	**QTVR/ IBR**	***Proposed***
Visual Quality	limited by hardware	high in static scenes	*virtually unlimited*
Interactivity	virtually unlimited	almost none	*limited by scene design / storage space*
Allowed Viewpoints	virtually unlimited	limited by source images	*limited by scene design / storage space*
Animated Objects or Characters	any, but performances are affected	no	*no limitation*
Large/Multi Screen Visualization	yes, but cost and performances are affected	yes	*yes*
Stereoscopic Visualization	yes, but performances are affected	yes	*yes*
Dedicated Hardware Cost	directly related to resolution / performances	none	*low, does not affect content quality*
Dedicated Hardware Obsolescence	fast, due to rapidly changing technology	No dedicated hardware required	*Slow*
Content Longevity	Directly Related to HW/SW	high	*high*

Probably, the term "freedom of interaction" itself is misleading even if it is referred to a genuine real-time simulation, because even in videogames each action the user can perform (to open a door, to run, to shot, etc.) in a given moment has been carefully planned from level designers, and usually can happen only under precise circumstances. What real-time VR really leave up to user's will (tough there are some exceptions) is the freedom to move inside the environment looking everywhere he likes at almost any angle and zooming in and out. To this regard QTVR and IBR could produce photo-realistic visualization with a minimum hardware required, but they lack other form of interaction (i.e. to open a door is a very challenging task) and they are not suited for character animation. They could be used in a hybrid approach together to a real time system to partially overcome their limits while reducing the geometry necessary for the backgrounds. In Table 1 there is a resume of some of the characteristics featured in the three approaches to VR presented in section 2. As the comparison shows, real-time VR provides without doubt the highest level of interaction, but visual quality is directly related to rapidly changing specialized hardware, and cost can be prohibitive for large screen productions.

Moreover the obsolescence of required hardware and software is much faster resulting in a correspondent obsolescence of the content developed. With the proposed pre-rendered approach instead, content development is decoupled from hardware characteristics (except for image resolution and clips duration) and can even be integrated later simply adding new clips (new nodes and arches to the world graph). Indeed, new powerful video synthesis techniques like graph cuts [5] could be exploited to seamlessly blend new and previous video clips, or to generate new navigation paths, as the cost of dedicated hardware is really low and is going to further reduce itself.

As for a real-time VR application the level of optimization required in every aspect of high quality content development is much greater then for pre-rendering, even the cost of the development can be higher.

On the other side, the production of hours of pre-rendered content implies the use of render-farms or cluster of hundreds of pc, a number that is almost doubled in case of stereoscopic visualization. To this regard new IBR techniques have been recently proposed to reduce considerably the extra time needed for ultra high resolution stereo rendering [8], making this option more attractive than ever. In the end, pre-rendered VR can be effectively exploited in many contexts like virtual museums, or virtual reconstruction of historical characters, which not necessarily need the advanced interaction and fast feedback of pure entertainment simulations, but could greatly benefit from unparalleled visual realism.

5. CONCLUDING REMARKS

We presented a framework for pre-rendered VR, in which to navigate through the environment and to interact with its object and characters basically means to visit a graph. In this sense, nodes represent pre-rendered video clip of a scene in the virtual world, while oriented arches represent available paths, which seamlessly lead (through the appropriate animation) from one scene to another. This approach is aimed to maximize visual quality, allowing any kind of high end modelling, animation, rendering and visualization techniques to be used for content production.

Adaptivity to user's age or interests is another advantage offered by the proposed architecture, as the whole graph can be layered to satisfy different preferences.

The intrinsic limit of this approach, related to the pre-defined number of actions or viewpoints available in a given moment of the virtual experience, can be considered a well tolerable constraint in many applicative contexts and can be mitigated, adding new clips as, today, storage cost and space is not a bottleneck anymore.

Figure 5a-5b. (a) The framework at work in the VR laboratory of DMI. The ceiling of this facility is equipped with ultrasonic based motion tracking emitter/receivers from Intersense Corp.. The retro-projection system support active stereoscopy. Navigation icons are displayed in the upper side of the screen. (b) The user wearing IR-controlled LCD Shutter Glasses, 6DOF head motion tracker (wired to a pocket wireless transmitter), and 6DOF hand motion tracker plus wireless joypad.

The proposed framework produced interesting results on the case study, proving this approach to be really suited for (but not limited to) applications like virtual museums and historical reconstructions. Therefore, even if we believe real-time rendering is the future of VR, there are still many interesting things we can do with pre-rendering meanwhile.

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Multimedia Conference System Supporting Group Awareness and Remote Management

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***Abstract*— We developed a multimedia conferencing system using IPv6/IPv4 multicasting for real-time distance education that enables video, audio, and pointing information to be shared. It supports multiple telepointers that provide group awareness information and makes it easy to share interests and attention. In addition to pointing with the telepointers, it allows users to add graphical annotations onto video and share these with one another. It also supports attention sharing using video processing techniques.**

The system includes a sender application, a receiver application, a multipoint viewer, a recording/replaying/relaying tool and a voting application, along with the remote control tools for these. A modular design enables the system to adapt flexibly to various configurations with different numbers of displays and different resolutions at multiple sites. Moreover, the remote control applications help the chairperson or conference organizer to simultaneously change the settings of a group of applications distributed at multiple sites.

***Index Terms*— Awareness, collaborative work, remote management, flexible configuration, multimedia communication**

I. INTRODUCTION

The National Institute of Multimedia Education (NIME) operates a multipoint videoconferencing system, for education and research using satellite communications, called the Satellite Collaboration System (SCS) [11], which is based on H.261. SCS has one hub station at NIME and 150 VSAT stations at universities and research institutes across Japan. We are working to develop the next-generation IP-based system for large-scale distance education.

Conventional videoconferencing standards using IPs, such as H.323 [5], are widely used, and commercial videoconferencing products based on H.323 are widely available. Microsoft NetMeeting [12], GnomeMeeting [13], and other video conferencing software systems can also be used on personal computers. These systems can be used in SCS; however, they are inadequate and inefficient to enable large-scale distance education. In the following, we will explain why conventional systems are inadequate and inefficient for large-scale distance education, especially through satellite communications.

Conventional videoconferencing systems do not provide group-awareness information to participants. Group-awareness information allows participants to understand the situations and intentions of others. There are various methods of providing such information. We think that pointing and attention sharing are important in distance education. Pointing involves the use of telepointers, and attention sharing involves the use of either telepointers or video processing. Conventional videoconferencing systems only support one telepointer or none at all. The telepointer can be shared among multiple users but it is usually only controlled by one user at a time. For someone else to control the telepointer, the current user has to transfer control. In collaborative environments, transferring control is time-consuming and slows down communications. Therefore, multiple telepointers should be supported.

Systems compliant with H.323 or SIP [10] are designed for point-to-point connections. These systems can thus use neither the broadcast capabilities of satellite communications nor the multicast-capability of IPv6/IPv4 networks. They are not efficient for large-scale distance education.

Moreover, as large numbers of people can join remote lectures in distance education, differences in the settings of the system between participants can often be a problem. Instructing participants individually about the settings using video and audio is tedious and time-consuming. Remote control functions are necessary to smooth the preparation and management of remote lectures. Although general-purpose remote control software tools are available, they cannot handle multiple sites simultaneously. Remote operation functions for groups are needed in a multipoint conferencing system.

Conventional videoconferencing systems restrict display and window configurations and cannot adapt to differences in environments well. They usually support only one display. Some conventional systems are based on ITU recommendation H.239 [6], which defines dual video stream functions, such as People+Context, and data collaboration. They support one main display and another display, but the use of dual video stream functions requires two displays at all sites. Some sites with only one display cannot participate in a conference using dual videos in the same manner. Some sites, on the other hand, have more than two displays. Multiple displays cannot be fully utilized by conventional systems even when multiple sites send and receive videos simultaneously. A conventional video conferencing system usually uses a multipoint control unit (MCU), which composes one video stream from multiple video streams and sends the composed video to receivers. The resolutions for multiple videos on the composed video with this method are inferior to the resolutions of the original videos. We think that all displays should be effectively used when multiple displays are available and multiple videos are received even if display resolutions may be different at different sites. Conventional videoconferencing systems usually display a video as a full screen or in a window. They do not allow the users to view multiple videos as multiple windows on one display. In other words, they lack flexibility in their display configuration.

Because conventional systems are inadequate and inefficient for large-scale distance education, we developed a multimedia conferencing system that supports multiple telepointers and other attention-sharing techniques, based on a videoconferencing tool called FocusShare [9]. The tool enables video, audio, and telepointers to be shared using IPv4/IPv6 multicasting and supports some attention-sharing techniques using video processing techniques. We enhanced its functionality and added new tools for distance education. The combinations of the tools and the functions efficiently support flexible display configurations.

Alkit Confero [2] is a multimedia collaboration software tool that supports synchronous audio, video, and text communication. It also supports both point-to-point and multipoint communication. Multipoint communication uses either IP multicasting or an RTP reflector and mixer. Although Confero has many functions, it does not support multiple shared telepointers, pointer labels, focus-sharing views using video processing, simultaneous display of multipoint videos, or remote control functions, which are all supported by our system. As previously explained, ITU recommendation H.239 defines dual video stream functions but our system's capabilities exceed this recommendation.

II. Tools in System

Our system provides users with real-time collaboration-support functions in multimedia conferencing systems. It allows them to simultaneously send multiple videos, audios, and group awareness information from one site. For example, multi-angle videos can be transmitted. One PC can simultaneously receive multi-angle videos and different PCs can receive videos captured from different angles. Whereas conventional video conferencing software systems such as NetMeeting cannot receive multi-angle videos simultaneously on one PC without the help of video mixing at the MCU because only one instance of the software can be executed on one PC.

We developed our system based on a modular design. It is not a huge unified tool but a tool suite consisting of several small tools. It is comprised of a sender, a receiver with pointer sharing, a multipoint viewer, a recording/replaying/relaying tool, a voting tool that counts pointers for simple surveys or questionnaires, a remote controller application for the sender, a remote controller application for the receiver, and a remote controller application for the multipoint viewer.

Resolution, compression methods, and transmission rates can flexibly be selected in our system. For example, high-definition video and high-fidelity audio can be transmitted. Previously developed basic features are described in detail in [9].

III. Group Awareness Support

Our system supports various techniques that provide group-awareness information.

A. Telepointers

A telepointer is a cursor, such as an arrow, used to indicate where a participant is pointing. It is useful to explicitly and clearly indicate interesting points or areas in question. Telepointer movements can also be used as gestures to communicate with other users. In other words, telepointers are important for sharing information through embodiment, gestures, and coordination in collaborative environments [4]. People involved in synchronous distance education and collaborative work use telepointers to promote group awareness and attention sharing [1].

Our system allows all users to have their own telepointers. They can share multiple-pointer information with other receivers in the same session. The receiver tool can transmit mouse pointer information in a multicast session. The telepointers appear in the video windows on the local receiver and other remote receivers while transmission is in progress.

Most conventional video conferencing systems do not allow users to manipulate a telepointer on a live video although some allow them to only have a telepointer for data sharing applications such as a shared whiteboard based on T.120 [7]. Moreover, most conventional systems do not allow individual users to manipulate their own telepointers simultaneously. Whereas only one telepointer can be utilized by switching users in conventional systems, our system enables the use of shared multiple telepointers on a video. This capability allows us to explicitly show points on a live video being captured with a camera. For example, we can discuss a scene using telepointers on a live video being captured through a microscope in a biology lecture, but this cannot be done with conventional systems.

1) Telepointers with different appearances and labels

All telepointers can have different shapes and colors in our system. In addition to fixed or statically shaped pointers, our system offers dynamically shaped pointers to illustrate points more clearly and attract the attention of participants. A dynamically shaped pointer is similar to the projected image of a laser pointer.

Furthermore, brief labels can be specified for all pointers. As will be described, different shapes, colors, and labels can be assigned to each mouse button state. These differences make it easy to distinguish multiple pointers clearly. A label can be entered by selecting it from the history list of items that have been entered, or by typing it directly in a text field. There is a screenshot with multiple telepointers in Fig. 1.

2) Hand-raising action

Our system supports the action of hand-raising. Pressing one of the mouse buttons will cause a shape representing a hand to appear in the video windows on the receivers. This is done by assigning a different mouse button state to a pointer with a different shape, color, and label. There is a screenshot of the hand-raising action in Fig. 2.

This capability is simple yet effective for attracting attention. Conventional systems do not have this simple but effective capability. Moreover, appropriate labels assigned to buttons can clearly indicate the intentions of users.

3) Telepointer traces

Trace images of pointers can also be used. They can improve the understanding of pointing gestures [4]. When this setting is turned on, trace images of the telepointer appear in the video window on the receivers, as can be seen in Fig. 3. The transparency of the telepointer traces decreases as time passes.

B. Graphical annotation

Our receiver tool also allows lines to be drawn on videos. The lines are shared with all receivers in the same session. This function can be used for simple graphical annotation, as we can see from Fig. 4. Multiple users can draw on videos simultaneously.

When the left mouse button is clicked and dragged while this setting is turned on, trails of the telepointer appear in the video window on the receivers. Clicking the right mouse button can erase the lines. Users can only erase their own drawings but not erase others' drawings.

IV. FOCUS-SHARING DISPLAY TECHNIQUES USING VIDEO PROCESSING

In addition to telepointers, our system supports various focus-sharing display techniques using video processing. Some of these were implemented in the previous version [9], but they have been improved based on user comments. For example, zoomed regions are now enclosed in a line frame to better highlight them. Moreover, partial zooming and a mosaic display capability have been incorporated into the system.

A. Partial Zooming

A region of interest (ROI) in a video is extracted on the basis of the location of the mouse pointer of the sender and displayed on the receiver. There is an example of partial zooming in Fig. 5. The region enclosed by the red rectangular frame in Fig. 5(a) of a sender is transmitted to receivers, and the receivers acquire the image in Fig. 5(b).

B. Linear zooming

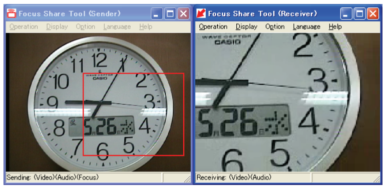
Linear zooming is a kind of Focus+Context visualization technique [3]. An ROI of a video is extracted. The ROI is controlled by using the location of the mouse pointer and is overlaid on the video. There is an example of linear zooming in Fig. 6. The ROI is enlarged, but an overview can also be seen. However, some of the ROI's surroundings are hidden by the ROI and cannot be seen.

Fig. 1 Multiple telepointers

Fig. 2 Hand-raising action with labels

Fig. 3 Telepointer traces

Fig. 4 Graphical annotation



(a) Sender (b) Receiver

Fig. 5 Partial zooming

C. Non-linear zooming

Non-linear zooming is also a kind of Focus+Context visualization technique. An extracted part of a video is displayed at the original resolution in a smaller window. The surroundings of the extracted video are non-linearly reduced and displayed. This type of zooming displays not only the zoomed region but also its surroundings. The non-distorted portion of the video moves depending on the location of the mouse pointer of the sender. There is an example of non-linear zooming in Fig. 7. This display does not hide any regions although there is some distortion.

D. Videos composed of different qualities

This technique provides users with a high-quality ROI and low-quality surroundings. The sender transmits both an overview low-resolution video and a focused high-resolution region of the overview video with this technique. The focused region is extracted on the basis of the location of the pointer. The receiver composes a combined view from these using the pointer location information.

If a codec capable of specifying an ROI and encoding a video appropriately is available, we can use it. However, such codecs are not readily available. Therefore, the sender must encode videos with different qualities and transmit them to the receiver, which can compose one video with a high-quality ROI from two videos. Moreover, different frame rates can be assigned to different regions in our system.

The position of the high-resolution portion of the video varies depending on the mouse pointer location of the sender. This function is used to achieve a Focus+Context display and decrease the necessary bandwidth. Fig. 8 has an example of videos composed of different qualities.

E. Video with mosaiced area

Part of a video can be concealed with a mosaiced area as shown in Fig. 9. The mosaiced area can be controlled by the location of the mouse pointer of the sender.

This function can be used to hide answers in quizzes. Conventional systems allow a window to be hidden but do not support partially hidden windows whose positions can be controlled by mouse movement.

V. Subjective Evaluation of Focus-Sharing Techniques

We conducted an experiment to evaluate the focus-sharing techniques implemented in the system. In this evaluation, we focused on the focus-sharing of a sender and a receiver.

Fifteen subjects took part in the experiment. They read the system's user manual and then used it both as a lecturer at a sender site and as a student at a receiver site, and answered a questionnaire about the techniques. The subjects rated each item on a scale of 1 (strongly disagree) to 5 (strongly agree). In other words, the questionnaire was presented in the form of a five-point Likert scale. The subjects also made free comments about the system.

A. Focus-sharing display techniques using video processing

We first asked the subjects to evaluate focus-sharing display techniques using video processing. The questions are listed in Table 1. Figures 10 and 11 show respective average ratings of subjective evaluations as a lecturer at a sender site and as a student at a receiver site.

The answers to Questions A, B, and C reveal the subjects preferred the focus-sharing techniques used in the system over ordinary video without focus-sharing techniques (without ROI) when they wanted to indicate a region of interest. The scores for Question F indicate that linear zooming was the most preferred technique at the receiver side. The scores also disclose that non-linear zooming was not preferred as much as other zooming techniques and ordinary video without ROI.

Fig. 6 Linear zooming

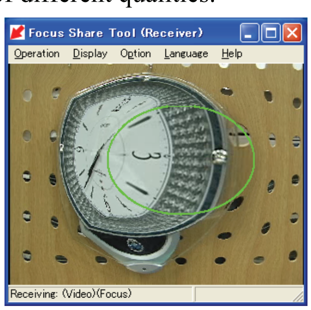


Fig. 7 Non-linear zooming

Fig. 8 Videos composed of different qualities

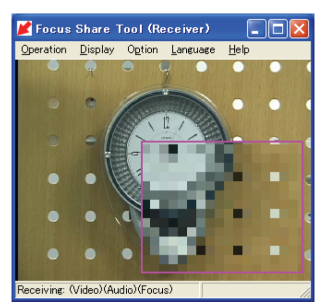


Fig. 9 Video with mosaiced area

Non-linear zooming is considered to be a smart and effective technique for distortion in information visualization, but, in this experimental evaluation, it was not preferred for video communication of actual scenes. One reason is that actual scenes have natural dimensions and any distortion of these is perceived as unnatural. The data for information visualization, on the other hand, does not have natural dimensions and distortion does not affect user preferences.

The technique that received the best score for all questions varied. This indicates that various focus-sharing techniques are necessary to satisfy the various demands users have. The developed system supports various focus-sharing techniques and satisfies user demands more fully than conventional video conferencing systems, which support only one focus-sharing technique or none at all.

Table 1 Questions with respect to focus-sharing display techniques using video processing

Items	Questions
A	Can it indicate ROI quickly?
B	Can it indicate ROI precisely?
C	Can it indicate ROI intelligibly?
D	Can it indicate surroundings for ROI?
E	Can it show overview?
F	Is it good from general viewpoint?
G	Does it result in less fatigue?
H	Are you satisfied with it?
I	Do you want to use it?
J	Is it interesting?

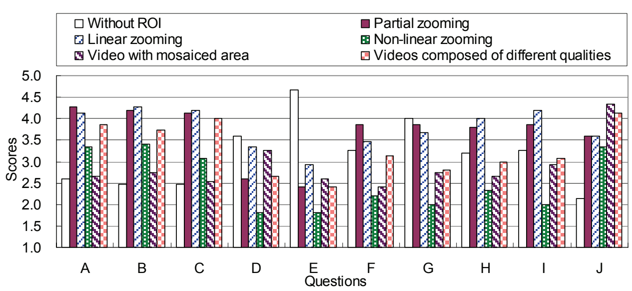


Fig. 10 Average ratings for subjective evaluation as lecturer at sender side

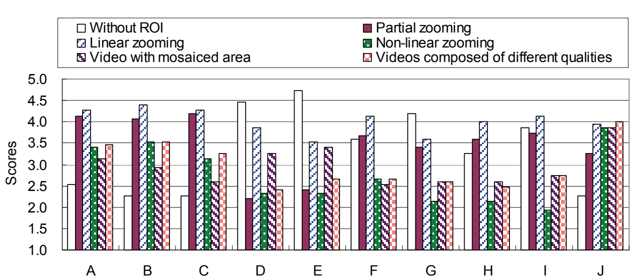


Fig. 11 Average ratings for subjective evaluation as student at receiver side

B. Telepointers and graphical annotations

The subjects evaluated telepointers and graphical annotations as a means to indicate a point of interest (POI). They comparatively evaluated video conferences without telepointers or graphical annotation, with telepointers, and with both telepointers and graphical annotations.

Table 2 lists questions with respect to telepointers and graphical annotations. Fig. 12 shows the average ratings for telepointers and graphical annotations with standard deviation error bars. The results indicate that telepointers were useful for showing a POI, and graphical annotations also contributed to enhance the subjective evaluation.

Table 2 Questions with respect to telepointers and graphical annotations

Items	Questions
K	Can it indicate POI quickly?
L	Can it indicate POI precisely?
M	Can it indicate POI intelligibly?
N	Is it good from general viewpoint?
O	Are you satisfied with it?
P	Do you want to use it?
Q	Is it Interesting?

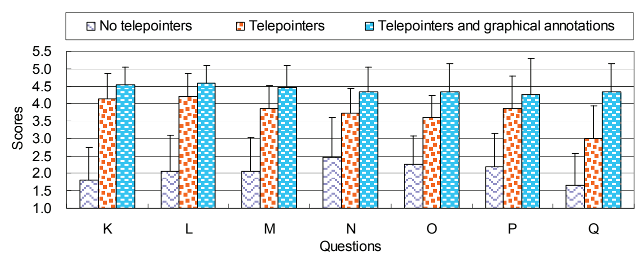


Fig. 12 Average ratings for telepointers and graphical annotations

C. Overall comparison of conventional video conferencing systems and ours

The subjects also comparatively evaluated conventional video conferencing systems and ours. Table 3 lists the questions for overall comparison and Fig. 13 plots the average ratings for answers with standard deviation error bars.

The results demonstrated that our system was evaluated more positively than those for conventional video conferencing. The differences between them with respect to usability, i.e., Question S, were not large. This means that our system has more functionalities than the conventional systems but it is as easy to use as they are.

Table 3 Questions with respect to overall comparison of systems

Items	Questions
R	Is it good from general viewpoint?
S	Is it easy to use?
T	Are you satisfied with it?
U	Do you want to use it?
V	Is it interesting?

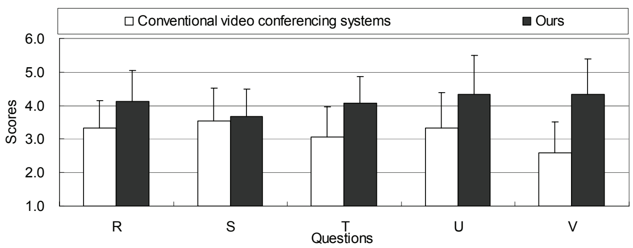


Fig. 13 Average ratings for conventional video conferencing systems and ours

VI. Remote Management and Flexible Configuration Support

This section describes remote management functions and flexible configuration support.

A. Remote control of windows

As explained in the introduction, many general-purpose remote control software tools are available, but they cannot simultaneously control large numbers of clients. By using the remote control function in our system, a lecturer or a chairperson can remotely control client applications at the same time. This function makes managing numerous clients easier. For example, a chairperson can remotely allocate unique shapes and colors to telepointers on multiple sites.

Moreover, a lecturer can control the receiving windows on multiple sites, maximizing them, minimizing them, moving them to the front or the back, or creating other window arrangements, as shown in Fig. 14. This function enables the use of various display configurations even if the sizes of the displays are different at different sites. The regions in each display can be fully used. Let us consider the situation where one display at one site has a different size or resolution from another display at another site and that two receivers' windows are shown on each display. When one receiver's window is moved to the front, the other's window may be hidden by the front window, but a large part or a full region of the other's window can be seen if the display is large and the locations of the windows have been appropriately arranged. It is therefore possible to more fully utilize the region of the display by using our system.

B. Volume Indicator

Sound levels during multipoint conferences are often problems. Because sound cannot be seen, tracking down a sound problem can take a great deal of time. It is therefore useful to visualize sounds to diagnose the causes of problems. Therefore, we incorporated a sound visualization function, or a volume indicator, into our tools.

The volume indicator provides a graphic representation of audio data that have been transmitted or received during a session. In remote conferences, it is difficult to adjust the volume of sounds at all participating sites. This tool can be used to adjust the volume of the audio system before a lecture or a conference. Moreover, lecturers or speakers can confirm the level of their vocal volume during lectures or conferences. There is a screenshot of the volume indicator in Fig. 15. The horizontal axis denotes time, while the vertical axis denotes volume. The scale for time can be changed.

The remote control tools can be used to show the volume indicator at a remote site. This allows users to confirm whether senders/receivers input and output sounds at appropriate levels. This can reduce the time necessary to confirm sound settings at remote sites and solve sound problems.

VII. Additional functions and Tools

This section describes additional tools and functions in our system.

A. Recording/replaying/relaying tool

The recording/replaying/relaying tool can record multiple videos, audios, and pointer information on one PC. It can replay recorded data and transmit them synchronously. It can also select types of data for replay. Moreover, it has a function to transcode received data and to transmit this transcoded data via multicasting in real time.

Fig. 16 has a screenshot of this tool. It will help lecturers save their lectures, including pointer movements, and reuse them. Furthermore, the relay function enables multicast data to adapt to different network environments.

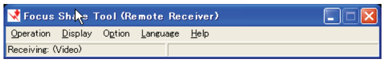
B. Multipoint viewer

The multipoint viewer can receive videos from multiple sites and show them in one application window. It allows users to see multipoint videos in one window.

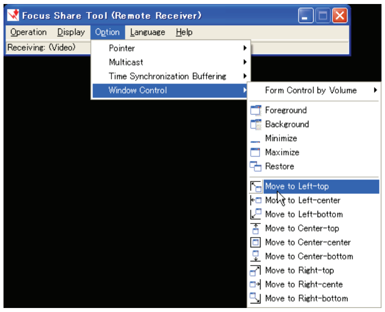
There is a screenshot of the multipoint viewer in Fig. 17. Each video can be displayed in its original size or a fixed size. We plan to enhance this tool so that it works with remote tools for the chairperson to control conferences.

C. Voting tool counting pointers

Our system has voting tool counting pointers that can be used for simple questionnaires or voting. Participants can cast votes by pressing one of the mouse buttons. The number of button presses and pointer shapes can be counted. Appropriate settings for the hand-raising action enable the participants to confirm their own answers visually. The counting results can be displayed in the form of a pie chart or a bar chart. Fig. 18 is a pie chart of voting results.



(a) Remote controller application menu



(b) Window control menu in remote controller application

Fig. 14 Remote controller application for receiver

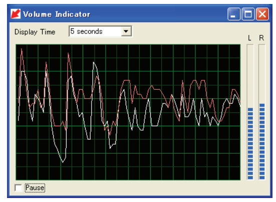


Fig. 15 Volume indicator

Fig. 16 Recording/replaying/ relaying tool

Fig. 17 Multipoint viewer

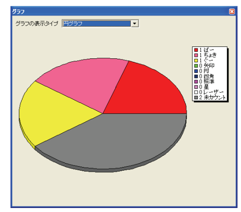


Fig. 18 Pie chart display of voting tool

D. Screen image transmission

Our system enables a user to capture screen images at high resolution and transmit them to others. Dynamic images of the screen can be transmitted. Using an appropriate codec, or a lossless codec, the received images will be the same as the sent images. The frame rate for the captured images can be specified.

This function can be used to transmit screen images showing presentation graphics, such as those in Microsoft PowerPoint, Apple Keynote, or Lotus Freelance. Fig. 19 has a screenshot of a PC running Windows XP. Its screen has a window displaying the captured screen of a Macintosh running Safari browsers.

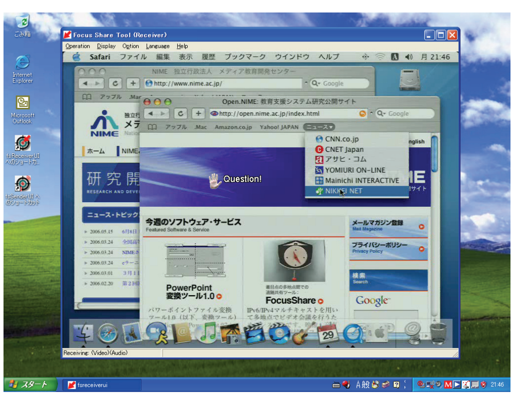


Fig. 19 Received PC screen

E. Sender/receiver status monitor

The tools in our system can monitor and display the status of transmissions. Fig. 20 is a screenshot of a receiver monitor. Monitoring functions are useful for determining the status of networks and diagnosing network problems.

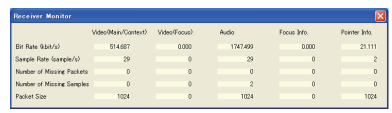


Fig. 20 Receiver status monitor

F. Captions

Our system enables users to easily add captions to pointers and videos. In this subsection, we will describe how captions are added to videos.

When multiple videos are used, captions are useful for distinguishing one video from another. A caption of up to 30 double-byte characters can be specified for each video. The specified caption is then transmitted from the sender to the receiver, where it appears overlaid in the video window on the receiver. It is usually displayed at the bottom-center of the window. There is an example of a video caption on a receiver in Fig. 21.

Because a video caption hides part of the video, our system allows users to turn captions on and off. Furthermore, history functions, which will be described later, allow users to easily revert to previous captions.

Fig. 21 Video with caption

G. Insertion of video and audio clips

The sender tool allows users to insert video and audio clips into transmissions. This function can be used to insert instructional videos, background music (BGM), and other clips.

When a video clip is inserted, the specified clip is input instead of the default video source, which is usually a camera or a screen capture module. After the video clip is viewed, the sender returns to a previously selected video source. Video clips in MPEG and AVI formats can be inserted in the current version of the sender tool.

When an audio clip is selected, sound is transmitted. Users can mix the audio clip with the captured audio feed or play the clip by itself. Repeating a replay of the clip is possible. Mixing a repeating audio clip with a captured audio feed can be useful for combining audio feeds with BGM. WAV and MP3 formats are supported in the current version.

H. History

All the tools have history functions to simplify software operations. Recent operations are saved in the tool history, which is listed in menus. Users can choose menu items to perform previous operations again. This can reduce the need to repeat operations. For example, if a user wants to switch between video captions, they can easily be switched using an operation history item.

I. Internationalization

The tools have a language configuration file allowing user interfaces to be displayed in various languages. The file can customize the way menus are displayed in the selected language. Moreover, the tool provides built-in support for Japanese and English. There is an example of Japanese language settings in Fig. 1, while there is an English language example in Fig. 2.

VIII. Experience

We used the system in several experiments. One experiment was conducted between international institutes using satellite communications [8]. Four institutes took part in the experimental multipoint conference: the Institut Teknologi Bandung in Indonesia (ITB), the University of the South Pacific at Suva in Fiji (USP), Chiang Mai University in Thailand, and the National Institute of Multimedia Education in Japan (NIME).

The tools were also used for distance education between an indoor room and an outdoor farm using three-dimensional videos. The tools were useful in giving an experimental lecture using three-dimensional videos. Our experiments demonstrated the effectiveness of our system for point-to-point and multipoint conferencing.

IX. Conclusion

We developed a multimedia conferencing system enabling real-time collaboration between multiple sites. It supports group awareness and graphical annotations to permit efficient remote collaboration. The evaluation revealed that the focus-sharing techniques employed in the system are useful in various situations. The system includes various useful tools and remote management functions for distance education and remote collaborative work. Moreover, it can adapt to various configurations flexibly. Our system can assist in advancing synchronous distance education and collaborative learning.

We plan to incorporate new tools to allow remote collaboration that will enhance our system's functions. We also intend to evaluate all of its features more extensively.

X. Acknowledgements

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Some versions of FocusShare can be downloaded at Open.NIME (http://open.nime.ac.jp/) or http://www.nime.ac.jp/~osawa/focusShare/index-e.html.

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Log-Analysis based Characterization of Multimedia Documents for Effective Delivery of Distributed Multimedia Presentations

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Abstract

In a distributed environment, media files have to be downloaded, coordinated, and presented to the clients, according to the specifications given by the authors of multimedia documents. We present a server-side logO *middleware which* learns *the structure of a multimedia presentation only by accessing traces of presentations, and constructs an automaton which captures the dynamic aspects of the evolution of the document, relevant for the optimization of the presentation delivery, prefetching, and scheduling.*

1. Introduction

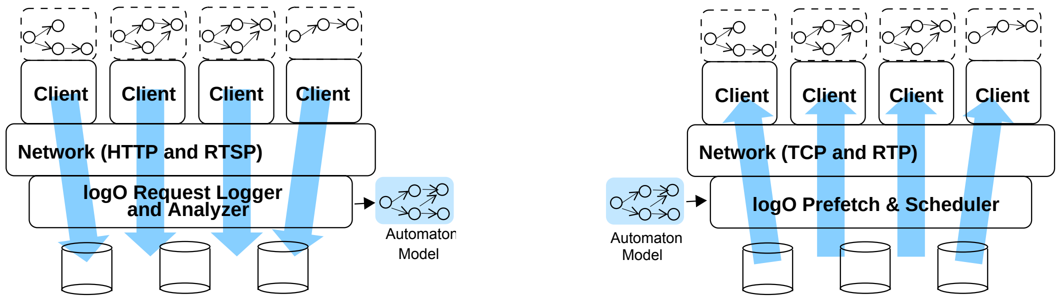
Multimedia documents are collections of media objects, synchronized through temporal and spatial constraints. In a distributed environment, where media servers and clients are dispersed, objects have to be requested, received, coordinated, and presented to the clients. Content servers are largely ignorant of the high-level presentation semantics, but can only observe media les that are requested by and delivered to the client for presentation through lower-level network protocols. These include control protocols, such as Realtime Streaming Protocol (RTSP) and Realtime Control Protocol (RTCP), and transport-level protocols, such as Realtime Transport Protocol (RTP). In particular RTSP [20], an application-level client-server protocol, allows timing and control of multimedia streams. After receiving information about the available media (such as addresses, ports, formats) through a DESCRIBE request and after setting up a session through a SETUP message, the client can request media (or parts of the media) through PLAY requests. The media are then streamed to the client using RTP.

A high-level understanding of the synchronization semantics, on the other hand, can be essential for effective delivery of presentations [19, 24, 22, 9, 6]: improving the delivery of presentations through intelligent scheduling of data accesses to the secondary storage, prefetching and buffering of the media objects, or even adapting/replacing presentation fragments can be possible only if advance knowledge about the presentation speci cations is available. Since this information is not available below the presentation level in the hierarchy, traditional work in this area either (a) assumed that intelligent scheduling is being done at the client level [6] or (b) relied on less-informed access-clustering or popularity-based prefetching (such as [16]) techniques to help improve content delivery.

In this paper, we note that both of these approaches have their shortcomings. The rst approach is naturally more informed than the second one; however, it is limited to only client-side optimizations. Furthermore, such analysis can be extremely dif cult in the presence of documents speci ed according to different reference models. Most importantly, even when presentation constraints are available, when there are alternative presentation plans available to the users, such user preferences can not be directly estimated using the client-side presentation semantics.

We, on the other hand, highlight that there is a third alternative which brings together the best of the approaches: (a) a high-level understanding of presentation synchronization characteristics, (b) capturing user preferences in terms of popularity of alternative presentation pathways, and (c) independence from speci c high-level synchronization models, enabling analysis even if presentations are de ned with different languages. In particular, we propose to *learn* presentation structure and the user preferences directly from its execution traces, observable as RTSP protocol requests.

Contributions. We propose a server-side middleware, *logO*, for log-analysis based characterization of multimedia documents with the ultimate goal of improving the delivery of distributed multimedia presentations (Section 2). Note that, unlike traditional log-analysis approaches used in various application domains, such as web-page delivery, where the goal is to learn the correlation between object requests, the *logO* middleware also has to learn the temporal synchronization characteristics underlying the multimedia presentations. For this purpose *logO* relies on RTSP request logs which contain information about the status of the media objects and the time instants in which changes take place. Then, by using the trace available in the logs, *logO* constructs an automaton capturing the dynamic evolution of a document, relevant for effective delivery (Section 3).



(a) Request event logging (b) Model-based informed delivery

Figure 1. Overview of the *logO* middleware: (a) the request logger and analyzer listens to the RTSP requests that servers are receiving and integrates these requests into a state automaton and collects appropriate statistics, (b) this automaton and the associated statistics are then used for giving intelligent prefetching and scheduling decisions for effective delivery of presentations

A particular challenge *logO* faces is that different executions of the same presentation can vary in their evolution traces. Thus, *logO* first approximates traces by collapsing to the same time instant events possibly occurring at very close, but distinct, times. To identify quite similar, but slightly different executions of the same presentation, *logO* relies on appropriate temporal similarity metrics. Whenever possible, *logO* merges the paths that are the same up to a certain state and introduces non-linear alternatives whenever different evolutions are identified.

2. Overview of the *logO* Middleware

logO is a server-side middleware. In order to learn the presentation structure, it listens to the RTSP requests that servers are receiving and integrates these requests into an integrated state automaton (Figure 1(a)). As it constructs the automaton, *logO* collects appropriate statistics regarding clients' *preferred* access patterns over this structure, to enable effective prefetching and scheduling decisions for improved delivery of presentations (Figure 1(b)).

Presentations can contain static (such as images and text) or streaming objects, which need to be presented smoothly to the user. The objects can be fetched using different transport protocols: static objects can be requested using HTTP and delivered using TCP. Since HTTP requests are not referenced against a timeline, streaming objects (or objects that need to be synchronized against a timeline), on the other hand, are generally requested using RTSP and delivered using RTP. A sample RTSP request is presented below:

```
PLAY rtsp://aria.asu.edu/audioobj RTSP/1.0
     CSeq: 715
     Session: 12567
     Range: npt=10-25;time=20060324T164800Z
```

Here, *CSeq* is a counter incremented for each distinct request, *Session* is the session ID for this request, and *Range* states that the server will play seconds 10 through 25 of the media. The *Time* entry specifies when the server should start the playback (in this case at 16:48 on 03/24/2006). Therefore, by listening to the requests, *logO* can observe the timing characteristics of the multimedia presentations.

The *logO* middleware needs to accommodate for the facts that (a) some media objects in the presentation may be requested by the client through other sources that are not being logged by *logO* and (b) request traces can vary due to user interactions or dynamicity of the system states. The first issue is naturally handled by *logO* in that the automaton created using available logs will reflect the portion of the media presentation that need to be delivered from relevant servers. The second issue, on the other hand, requires an automata merging mechanism which can handle variations in request traces (Section 3.2).

3. Learning Presentation Structures

Without getting into the details of the HTTP and RTSP request formats, let us consider a simplified log format, where each entry is a record of the form $\langle t, m, ev\rangle$. Here, t is a (middleware) time instant, m is a media object, and $ev \in \{st, end\}$ is an event[1] that has occurred, possibly changing the state of the media m. As an example, consider the following event trace:

Example 3.1 (Event Trace)

```
15:11:03:863 intro st     |  15:29:07:019 descr end
15:11:03:891 logos st     |  15:29:07:052 image1 st
15:14:05:129 intro end    |  15:29:07:059 image2 st
15:14:05:133 logos end    |  15:35:07:021 image2 end
15:14:05:150 artist st    |  15:35:07:128 image1 end
15:19:06:997 artist end   |  15:35:07:400 concl st
15:19:07:016 descr st     |  15:40:08:638 concl end
```

- The record `hh:mm:ss:ms m st` means that media m has started at time instant `hh:mm:ss:ms`.
- The record `hh:mm:ss:ms m end` means that presentation of the media m has ended at time instant `hh:mm:ss:ms`.

Events are *simultaneous* if they occur at the same time instant. Unfortunately, the sequential nature of the request

[1] For simplicity of discussion, in this paper, we ignore complex events, such as the distinction in RTSP between *termination* vs. *pause*.

processor can associate distinct request time instants to events, even when they need to occur at the same time instant according to the synchronization specifications. Thus, the event traces are generally interpreted at a lower granularity (a system parameter) than the millisecond level log entries. *logO* treats as simultaneous all events whose recorded times are within the granularity threshold.

In the above trace example, the time instants refer to the middleware's internal clock. Naturally, to extract a uniform, normalized representation of the presentation dynamics, *logO* associate times 0 to the starting instant of any presentation, and shifts all the time instants accordingly.

3.1. Trace Finite State Automata

To represent the information obtained from the trace, *logO* introduces the notion of *state of the presentation at any point in time*. A presentation's state represents the set of media that are active (i.e., being delivered) at a given time instant. Thus, state changes occur when at least one active media ends or one new media starts; i.e., they occur as a consequence of at least one media event in the trace.

Given an event trace for a presentation P, the states and state transitions form a trace automaton. To associate events to their media we use the functional notation: $ev(m)$ represents the fact that the event ev occurs on the media m.

Definition 3.1 (Trace Automaton) *Let log_P be the* normalized *log file tracing the events of a multimedia presentation. Its associated trace automaton is the 5*–tuple $AUT(log_P) = \langle S,\ s_0,\ S_f,\ \mathcal{TR},\ next\rangle$*. In the automaton* **(i)** *S is the set of possible states of the presentation - each state is a pair $\langle id, \mathcal{AM}\rangle$, where id is a globally unique identifier and $\mathcal{AM}$ is a set of active media;* **(ii)** *s_0 is the initial state, $s_0 = \langle id_0, \emptyset\rangle$;* **(iii)** *The set of final states is the singleton $S_f = \{s_f = \langle id_f, \emptyset\rangle\}$;* **(iv)** *$\mathcal{TR}$ is the the set of symbols that label possible transitions.* $\mathcal{TR} = \{\langle ev(m),\ inst\rangle \mid \text{the record } \langle inst, m, ev\rangle \in log_P\}^2$. **(v)** *$next : S \times \mathcal{TR} \rightarrow S$ is the transition function. Given a state $s = \langle id, \mathcal{AM}\rangle$, a set of events ev, and a time instant $inst$, $s' = next(s, \langle\{ev\}, inst\rangle) = \langle id', \mathcal{AM} \setminus \{m \in \mathcal{MI} \mid end(m) \in \{ev\}\} \cup \{m \in \mathcal{MI} \mid st(m) \in \{ev\}\}\rangle$;*

Intuitively, the new state s' reflects the items which have terminated or have been stopped at time instant $inst$ (and are deleted from the set of active media, accordingly) and the items which are starting at the same time (and thus, are inserted in the set of active media).

The states of the trace automaton are implicitly associated with a timeline: each state is entered at a specific time instant associated with the events that cause the transition from the previous state to it and is exited when the next set of events (if more than one, simultaneously) occurs.

[2] We denote *simultaneous* events with a unique compact transition $\langle\{e_0(m_0),\ldots, e_n(m_n)\}, inst\rangle$, where $\{e_0(m_0),\ldots, e_n(m_n)\}$ is the set of all the simultaneous events occurring at the same time instant $inst$.

Example 3.2 *The automaton for the trace in Example 3.1 has the following media sets and durations:*

$\mathcal{AM}_0 = \emptyset$			$\mathcal{AM}_1 = \{intro, logos\}$	$d_1 = 182$
$\mathcal{AM}_2 = \{artist\}$	$d_2 = 31$		$\mathcal{AM}_3 = \{descr\}$	$d_3 = 600$
$\mathcal{AM}_4 = \{img1, img2\}$	$d_4 = 360$		$\mathcal{AM}_5 = \{concl\}$	$d_5 = 300$
$\mathcal{AM}_6 = \emptyset$				

In a sense, the trace automaton describes the evolution of the delivery as consequence of events in the trace.

Theorem 3.1 *The automaton associated to a single (normalized) trace log_P recognizes exactly one word,*

$$\langle e_0(m_0), inst_0\rangle \ldots \langle e_n(m_n), inst_n\rangle,$$

which is a compact representation of the event trace log_P. Compactness comes from associating to a single transition, the multiple events at the same normalized time instant.

3.2. Merging Trace Automata

The trace automaton defined above is a chain of states which reflects the information extracted from the trace of a **single** presentation. Thus it recognizes a single word, which is exactly the sequence of records appearing in the given trace. Effective prediction for multimedia delivery, on the other hand, requires knowledge from multiple execution instances. Therefore, for proper modeling of the overall structure of a multimedia document and for capturing the *popularity* of alternative execution plans, we need to be able to merge related trace automata. In general, *logO* relies on two alternative schemes for merging.

History-independent merging: In this scheme, each state in the original automata is considered independently of its history. Thus, to implement history independent merging, an equivalence relation ($\equiv_{log}$), which compares the active media content of two given states, s_i and s_j, is sufficient for deciding which states are compatible for being merged. The merge algorithm produces a new automaton in which the media items in the states are (representatives of) the equivalence classes defined by the $\equiv_{log}$ relation. The label of the edge connecting any two states s_i and s_j includes (i) the event that induced the state change from a state equivalent to s_i to a state equivalent to s_j in any of the merged automata, (ii) the duration associated to the source state, and (iii) the number of transitions, in the automata being merged, to which (i) and (ii) apply. The resulting automaton may contain cycles. Note that the transition label includes the counting of the number of logged instances where a particular transition occurred in the traces. The count labels on the transitions provide information regarding the likelihood of each transition. In a sense, the resulting trace automaton is a *timed* Markov chain, where the transitions from states have not only expected trigger times, but also associated probabilities. Therefore, given the current state, the next state transition is identified probabilistically (as in Markov chains) and the corresponding state transition is performed at the time associated with the chosen state transition.

History-dependent merging: In this scheme, two states are considered identical only if their active media content **as well as** their histories (i.e., past states in the chains) are matching. The equivalence relation, $\equiv_{log}$, compares not only the active media content of the given states, s_i and s_j but also requires their histories, $hist_i$ and $hist_j$, to be considered identical for merging purposes. In particular, to compare two histories, *logO* uses an edit-distance function. Possible temporal similarity functions have been described in [25]. Unlike history independent merging, the resulting trie-like merged automaton will not contain any cycles and the same set of active media can be represented as different states, if the set is reached through differing event histories.

4. Use of Merged Automaton for Prefetching

Supposing that the playout of the interactive multimedia presentation has reached a state s in this probabilistic automaton; to determine which objects may be needed in the future, *logO* must look ahead in the automaton and estimate what the probabilities of possible execution paths are and which objects are contained in these paths (and when). Reachability and state likelihood analysis for caching and prefetching is commonly done for Markov chains [12]. In trace-automata used in *logO*, however, one has to consider not only the state transition probabilities, but also (a) the *temporal* aspects of the transitions as well as (b) the fact that multiple states can contain the same object. Thus, *logO* cannot rely on traditional Markov chain analysis techniques.

Once a trace-automaton is identi ed, *logO* uses the probabilistic prefetching framework we introduced in [7]. In particular, it computes j-bounded object appearance probability, where if we "look ahead" j state transitions in the automaton then the probability that an object o will be needed in those j levels is the sum of the probabilities of all paths containing object o. Based on this, *path prefetching* and *object prefetching* strategies are developed: in the former case, the middleware fetches as many objects along the most probable paths in the trace trie as will t into the prefetch buffer. In the later, *logO* prefetches those objects that will most probably be required (within the limitations imposed by the size of the prefetch buffer). The experiment results showed that object-based prefetching (though is more expensive to compute) can provide better hit ratios.

5. Related Work

Temporal models include instant-based [11, 5] and interval-based [2, 13] models. Timed Petri nets are used to describe interval-based compositions [14, 8]. Automata based approaches to temporal modelling are presented in [4, 3]. [10, 19, 24, 22, 9, 6, 15] show that knowledge about the temporal characteristics of presentations can lead to signi cantly better request and delivery schedules. Yet, since they assume direct knowledge of the presentation characteristics, these schemes are not directly applicable in *logO*. Also most schemes for prefetching and buffering of audio/video streams [17] rely on the assumption that clients will follow a linear sequence. Existing analysis-based schemes (for web pages, documents, or database objects) consider object reference and access patterns [16, 1, 12, 18]. But, they do not capture the underlying temporal structures.

6. Conclusions

We presented a server-side middleware, *logO*, for log-analysis based characterization of multimedia documents. *logO* constructs a probabilistic automaton, capturing the dynamic evolution of the presentation for effective delivery.

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A Teleconference System by High Definition Omni-directional Video Transmission over IP Network

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Abstract

In this paper, a flexible middleware system for omni-directional video transmission for various teleconferencing applications is introduced. The omni-directional image has more advantages in that it provides a wider view than a single directional camera and able to flexible realize TV conferencing even between remotely separated small rooms. In this paper, we describe system architecture and functions of the middleware for high-definition omni-directional image control and effective video transmission system using DV and HDV (1080i format)[4]. The MidField system which we have developed so far is used for video stream transmission over IPv4/IPv6 networks. The prototype system of a TV conference is constructed to evaluate our suggested high-definition omni-directional middleware. Through the functional and performance evaluation of the prototyped system, we could verify the usefulness of our proposed system.

1. Introduction

Recently high-power personal computers have been commonly used for TV conference system with high quality audio and video. Since those TV conference systems usually use one directional video camera with limited angle, it is very difficult to realize the TV conference with many participants particularly in a small room and to capture wide range of the inside area in real time.

In this paper, in order to overcome those problems, we introduce a new teleconferencing system and middleware system by omni-directional camera which can capture a view of 360 degree angle in real time. In the middleware system, the MidField system [1] which we have developed so far is used for video stream transmission over IP network. Then the quality of the panorama and expanded video images can be controlled and guaranteed by considering the computer and network resources. A prototype system of bi-directional TV conference with omni-directional camera is constructed to evaluate its function and performance. As result, we could verify the usefulness of our proposed system.

Both DV[5] and HDV omni-directional video transmission systems were introduced and evaluated.

In the followings, a system configuration of bi-directional TV conference system based on the omni-directional image is precisely described in section 2. A middleware system and its system architecture of suggested TV conference are explained in section 3. The Midfield system [1] which realizes a basic function of video stream transmission over IP network is explained in section 4. The video stream control method and QoS control method for TV conference system are precisely explained in section 5. The implementation and prototype system is introduced in section 6. The section 7 discusses conclusion of our suggest system and our future research.

2. System Configuration

The system configuration of our TV conference system as shown in Fig.1 is consisted of client and server PCs. The server using a HDV or DV camera with a omni-directional lens, so called PAL lens, as shown in Fig. 2 captures 360 degree ring-shaped image and audio sound. Those image and audio are taken into the server PC through IEEE 1394 interface.

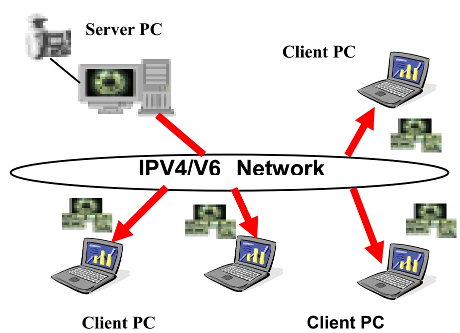

Fig. 1 System Configuration

PAL Lens **HDV camera**

Fig. 2 Omni-Directional Camera

In typical, at the server, the captured ringed image and audio are transmitted over IPv4 or IPV6 based network as RTP video streams to the client. At the client PC, the ringed image is converted to the equivalent panorama image, expanded and displayed on the screen together with audio sound. Then any specific area selected by client user is calibrated and output.

When the network bandwidth is limited and not enough to transmit the HDV or DV video stream or the client PC power is not enough to process the ringed image, the ringed image is compressed using various image coding methods and sent to the client to reduce the required bandwidth.

In order to realize bi-directional TV conference, a set of client and server are simultaneously used at each location. Since omni-directional video provides 360 degree image, the user can view wide range of captured image and freely select any specific part he wants to watch and can expand the desired part of the panorama image by mouse operations. The user's viewpoint can freely control in both vertical and horizontal directions and zooming as if he could control the angle of an ordinal one-directional camera.

The captured ringed image is encoded and decoded to the DV, MPEG-2/4, or M-JPEG, H. 264 compressed video formats on either the server or client depending on the CPU loads and network resource condition and transmitted using MidField which is a middleware system to transmit various formatted video streams over IP network and will be precisely explained its functionality in the following section.

3. System Architecture

The system architecture of the proposed omni-directional TV conference system consists of five layers including Application layer, Omni-directional development layer including Panorama, Expanded and Calibrated Image sub-layers, Synchronization layer, Session layer and Midfield layer as shown in Fig. 3.

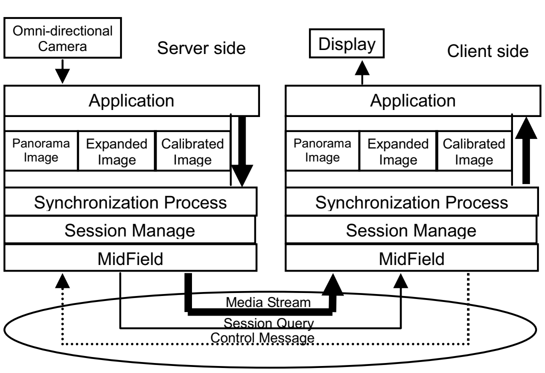

Fig. 3 System Architecture

In the application layer, sampling the ringed video image and audio sound and displaying those on the monitor and speaker for TV conference are performed. In the omni-directional development layer, image development from the ringed image to the panorama, expanded and calibrated images are processed. In the synchronization layer, audio and the panorama, expanded and calibrated image are synchronized. In the session layer, a TV conference session by those images and audio is managed. In the Midfield layer, those videos and audio are transmitted as a stream in real time over IP network.

4. MidField System

As shown in Fig. 4, the MidField system is located between the application and the transport layer. The system is constructed by 3 layers and 4 vertical planes and offers multimedia communication functions to the application layer. Stream Plane is constructed by synchronization, data transform and media flow control layer, and performs multimedia stream processing. Session Plane performs management of communication sessions. System Plane monitors network traffic and CPU rate in the local host, and performs admission tests for QoS requirements from system user. Event Process Plane processes various events that are created in the system.

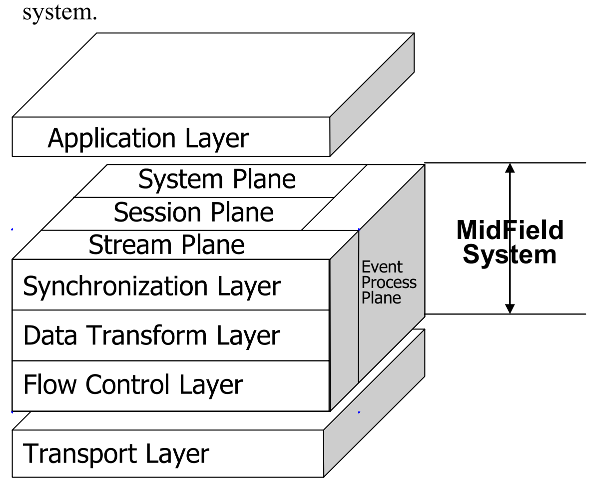

Fig. 4 MidField System

In the Session Plane of MidField System, information of both participants and media streams is handled. It should be considered that some new functions for handling this information are required by various session types. Therefore if both these information and the handling functions can transfer to intermediate node that performs to transcode, the system will have flexibility for updating new management functions for new session types. In addition, if there are no suitable functions to

process media in local computer system, the system should have some functions to get required media processing functions from the other systems.
The system is able to construct intercommunication environment on computer networks dynamically according to the environment of users and QoS requirements from users. Fig. 5 shows an abstract of MidField Session. A MidField Session consists of at least one multicast session and offers peer-to-peer communication to system users. In Fig. 5, three system users (MF1, MF2 and MF3) join to a MidField Session. At this point, both MF1 and MF2 have enough communication environments to transmit DV stream. On the other hand, MF3 can't transmit DV stream because the environment doesn't have enough bandwidth and computing power to handle DV stream. Therefore MF3 requests to use MPEG4 stream to join the MidField Session. In such case, MidField System locates required transcoding functions into suitable node on computer networks to communicate with each other. In this example, both MF4 and MF5 transcode from DV stream into MPEG4. By using transcoding functions, MF3 can join to the MidField Session.

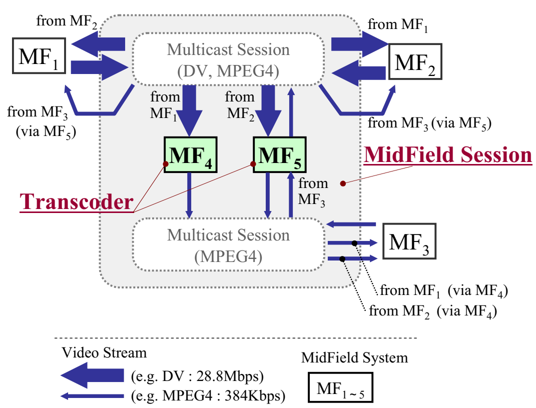

Fig. 5 MidField Session

5. Video Process and Control of Streaming

5.1 Omni-directional Video

There are several kinds of omni-directional cameras [2]. In our research, we apply a combination of commercially available video camera and omni-directional lens, so called PAL lens as previously shown in Fig. 2. Using the omni-directional camera, the ring-shaped image with the 360 degree angle can be taken into the server PC through IEEE1394 interface. The captured ringed image includes 720X480 pixels as a resolution and 30 fps as a frame rate from -20 to 40 degree of a vertical view angle using a DV camera. The resolution using a HDV camera is 1440x1080 pixels. This ringed image is processed by the middleware in the server to the panorama image to be easily understood by user. Since the panorama image by PAL lens can not be zoomed by optical way, the any specific part of the panorama image is expanded by digital zooming method. However, digital zooming makes the image coarse as the enlargement rate increases. Therefore, the enlargement rate is limited within 3 to 5 times.

The image calibration for the expanded image from the selected area is carried out to remove the image distortion by PAL lens and to reconstruct the corrected image as if it were taken from the conventional one-directional camera.

5.2 Variation of omni-directional image

The image taken through the PAL lens is called ringed circle image. Three kinds of images shown below from this ringed circle image are generated, as shown in Fig.6.

- Panorama image which is converted form the ringed circle image taken through the PAL lens of 360 degree.
- Expanded image which is clipped and expanded at arbitrary position from the panorama image.
- Calibrated image which is removed distortion of omni-directional image from the expanded as taken from the regular one-directional camera.

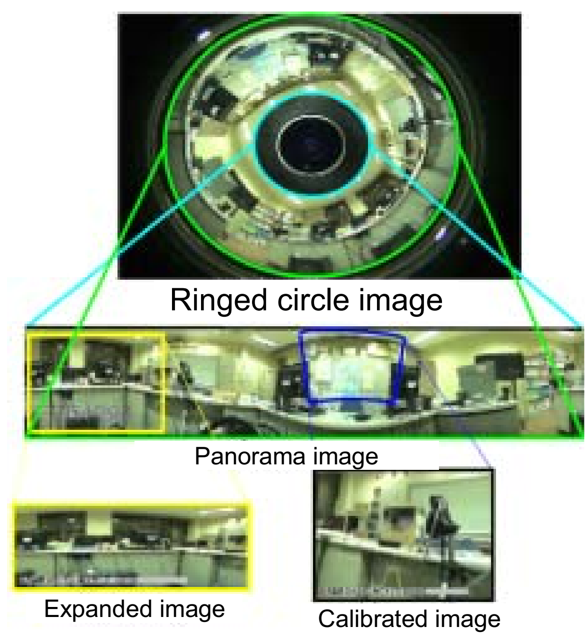

Fig. 6 Variation of omni-directional images

5.3 Omni-directional image development process

The development process from the ringed image to a panorama image is carried out in the following procedure as shown in Fig. 7.

1) Making a coordinate conversion table
2) Calibration of ringed image
3) Image development of panorama, expanded and

calibrated images
4) Image interpolation

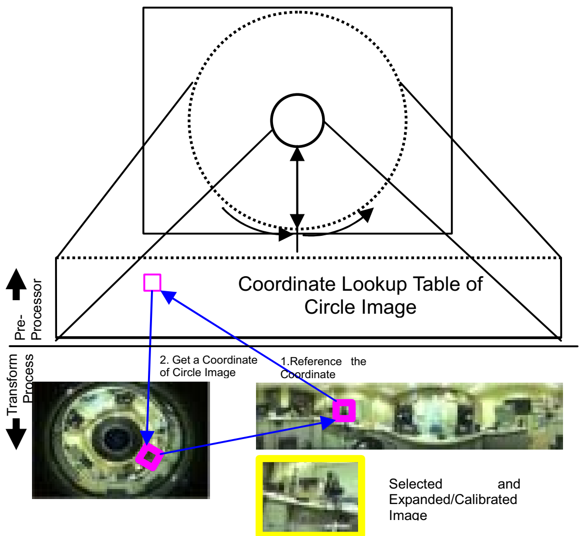

Fig. 7 Omni-directional Image Processing

At the 1st step, since the image development of the ringed image is realized based on polar coordinate conversion, the computation time of image processing, particularly for addressing of memory location for a panorama image is very large. For this reason, the coordinate conversion table form polar axis to x-y axis is produced based on the size of ringed circle image and visual angle of lens in advance to reduce the computation time for image conversion.

At the 2nd step, since the ringed image is captured and processed in the DirectShow filter in MS Window operating system, its shape is not completely circle but oval. This is because the aspect ratios of the circle ringed image acquired from the camera differ from the image after filtering. A true circle is made by carrying out expansion processing of the ringed circle image so as to be adjusted to the original aspect ratio. After adjustment of the ringed circle image. its image resolution becomes 720x540 pixels for DV format and 1920x1080 pixels for HDV format.

At the 3rd step, by referring the coordinate conversion table, the panorama, expanded and calibrated images for the specified area can be extracted from the ringed circle image.

At the 4th step, the extracted image is interpolated to be smoothly displayed on the monitor. The surrounding 4 neighbor pixels of any points are interpolated by linear filtering or 2 dimensional spatial FFT or sub-band filtering methods [3]. By repeating from the 1st step through the 4th step, the original raw ringed image can be changed to desired images.

5.4 Stream Control

In our system, there are two streaming control methods between client and sever, including client based type and server based type.

In the client based type, which is normally used, as shown in Fig.8, the ringed images captured form DV/HDV camera on the server side are multicasted to the client side by DV/HDV video stream using Midfield. On the client side, the multicasted ringed DV/HDV format image is received at client and processed to the panorama image, the expanded image and calibrated image for the selected area depending on the user's selection.

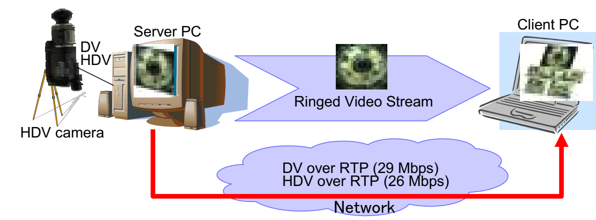

Fig. 8 Client Based Type

Using this client based type system, the ringed image is freely processed on the client and any area in the panorama image can be expanded on each client. Also since there is no use of image compression, higher quality image can be displayed. On the other hand, since DV/HDV format image have to be processed on the client side, more powerful CPU is required for client PC. Also, since DV and HDV format stream requires 29 Mbps and 26 Mbps per one stream respectively, larger network bandwidth is required.

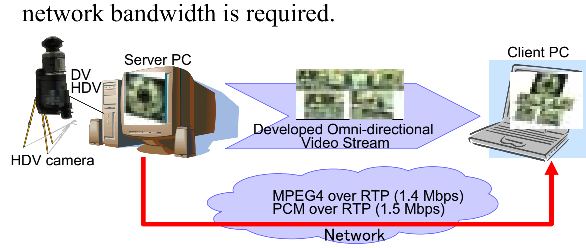

Fig. 9 Server Based Type

In the server based type, on the other hand, as shown in Fig. 9, the ringed image captured form DV/HDV camera on the server side is first converted to the equivalent panorama image, expanded and calibrated for the specific area selected by some client and transcoded to various video formats including MPEG-2/4 M-JPEG, H.264 by Midfield, and then multicasted to the client.

The client receives the multicaseted stream and decodes to display on the monitor. Using this server based type, an image conversion from the ringed image to panorama image can be skipped on the client. Therefore, the relatively low powered PC can be used to obtain sufficient quality image on the client side. The network bandwidth required is also saved to about 1.4 Mbps when the MPEG-4 format is used. However, since all of image conversions and format generation are executed on the server, the CPU load on the server increases. The control of the viewpoint to all of the clients is also limited.

By combing those two methods, the more flexible and proper omni-directional video stream transmission according to the user's environment can be attained.

5.5 QoS Control

In addition to those stream control methods, QoS control based on the client and server CPU load and network traffic is introduced in this system. By introducing QoS control, more proper and precise quality of video and audio can be provided depending on the user's environment.

When the CPU load on the client and/or server increases, the frame rate of the video stream degreases. When the number of the high quality video streams such as HDV streams increases, the packet loss may increases. Since the load condition such as CPU occupation rate or CPU load average on the client and server can be observed, the image size and frame rate of the omni-directional image can be controlled.

On the other hand, the required network bandwidth varies depending on the size of the image and its video formats and compression rate. Therefore, by controlling the size and frame rate of the transmitted video stream according to the dynamically available network bandwidth, the omni-directional video image can be adjusted to user's environment.

6. Prototyped System and Evaluation

In order to evaluate the usefulness and effects of our suggested omni-directional video transmission system, a prototyped TV conference system was constructed on the local area network as shown in Fig. 10.

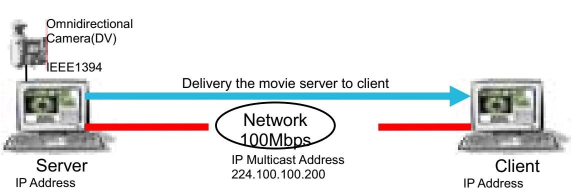

Fig. 10 Prototype System

The prototyped TV conference system consists of client and server PCs with HDV camera attached and connected over 1 Gbps Fast Ethernet. This HDV camera (SONY HDR-CH1) can switch to the DV mode or HDV mode. As the specification of both server and client PCs, Hyper-Threading Pentium 4 processor with 3.4GHz clock including 1.5GBytes as main memory is used. The HDV camera with PAL lens was connected to server by IEEE 1394. The middleware system of omni-directional video transmission was developed using C++ (Microsoft Visual C++ .NET 2003) language and DirectX 9.0b (DirectShow) for video and audio processing and their managements. Although the prototype provides bi-directional TV conference facility, the only one-directional audio and video streams transmission were carried out to evaluate its performance.

As the video format of omni-directional image, 1) the ringed image with DV/HDV format video images were multicasted to the client PC and converted to panorama images, expanded image and calibrated image, or 2) the ringed images were converted to panorama image, expanded image and calibrated images at the server. Then those three different images were encoded to MPEG-4 images, then multicasted to the client. On the client PC, those encoded images were decoded and displayed on the PC monitor. The control data for the view point from the clients were also transmitted to the server. The selected area based on the client viewpoint was extracted by First Come First Service base. As performance evaluation, the audio stream with 1.5 Mbps transmission rate and 16 bits sampled by 48KHz and the DV (720 x 480 pixels) with 29 Mbps as the ringed images were transmitted from the server PC to the client PC. On the client PC, the ringed circle image was converted to the panorama image (800 x 200pixels), the expanded images (320 x 240) and the calibrated image (320 x 240). In this prototype, we could attain 30 fps for the panorama image, 30 fps for the expanded image and 30 fps for the calibrated images. Processing time per one frame is 24ms for the panorama image, 17 ms for the expanded image and 19 ms for the calibrated images. CPU utilization is each to 47%, 36% and 39%. Those frame rates are enough to smoothly communicate each other between the client and server. See table 1.

The HDV (1440 x 1080 pixels) formats with about 26 Mbps as the ringed circle images were transmitted from the server PC to the client PC. On the client PC, the ringed image was converted to the panorama image (1130 x 360 pixels), the expanded images (640 x 480 pixels) and the calibrated image (640 x 480 pixels). In this prototype, we could attain 13 fps for the panorama image, 15 fps for the expanded image and 14 fps for the calibrated images. Processing time per one frame is 56 ms for the panorama image, 45 ms for the expanded image and 52 ms for the calibrated images. CPU utilization is each to 50%, 51% and 51%. Although the frame rate was stable, time delay of a several hundred milli-second was produced. This is due to MPEG-2 encoding in HDV format. Since video frame rate is fluctuated at the max rate, frame rate reduction into a half is made to be stable, as soon Table 2.

	Frame rate	Process time	CPU utilization
Panorama image	30 fps	24 ms	47 %
Expanded Image	30 fps	17 ms	36 %
Calibrated image	30 fps	19 ms	39 %

Tab.1 The performance of the Omni-directional video at the time of using a DV format

	Frame rate	Process time	CPU utilization
Panorama image	13 fps	56 ms	50 %
Expanded Image	15 fps	45 ms	51 %
Calibrated image	14 fps	52 ms	51 %

Tab.2 The performance of the Omni-directional video at the time of using a HDV format

On the other hand, when DV is used, there is almost no end-to-end delay, and both video and audio can be fully stable as a TV conference system. However, when more than two panorama and calibrated images are processed simultaneously, the client CPU load increases. In this case by reducing frame rate from the server PC, the CPU load degreases, and eventually audio noise could be eliminated.

When HDV is used, clearer omni-directional images can be seen compared with the case of DV. Also the resolution of panorama, expanded and calibrated images by HDV can be increased into twice. On the other hand, the time delay of those images gives influence to real time communication of bi-directional TV conference.

7. Conclusion

In this paper, a middleware for High Definition Omni-directional Video Transmission over IP Network was introduced and its system architecture and functions are precisely described. The video stream transmission of the ringed image over high-speed network based on the Midfield which was previously developed for DV/HDV video and audio was provided. The TV conference system as a prototyped system was constructed to evaluate the performance. As a result, our system could provide the reasonable response time which is almost equivalent to the one by the conventional one directional TV conference system although the resolution was not satisfied.

Currently we are optimizing the HDV video processing to improve performance and implementing QoS control function according to the CPU load on both client and server and network traffic.

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Robust and Redundant Disaster Information System over Japan Gigabit Network

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Abstract

In this paper, a robust and large scale resident-oriented safety information system on the occurrence of the various disasters constructed over a nationwide high-speed network is introduced. The resident evacuated can registered his/her safety information in the local safety information servers in the evacuation area whether he/she can safely evaluated or not using mobile PCs or terminals at the evacuation area or mobile terminals on the way of evacuation. All of the local information servers are connected each other by wireless network and the safety information can be sent an upper-layer database in the district area and finally integrated into a district safety information in that region. In our system some of the damaged local servers due to the disaster can be detected and recovered manually by the upper-layer database server. On the other hand, the upper-layer database servers are backed up by mirror servers located to mutually different locations with long distance to isolate the influence to the same disaster when the some of them were destroyed or disordered. Thus, by introducing two levels of redundancy and backup functions, more large scale and robust safety information database system can be realized.

1. Introduction

Since Japan island is mainly formed by mountain volcano along the entire country, a number of large scale sizes of earth quick, mountain explosion, seismic sea wave, frequently happened in addition to ordinal disasters, such as typhoon, rain flooding and snow-slide since our history has started. In order to save our life from those disasters, more reliable and robust information network for disaster prevention purpose than the conventional information network.

As for the safety confirmation with the residents in the stricken area, it is very important to quickly process the frequent inquiries from the people outside of the disaster area whether the objective residents could safely evacuated or injured. Furthermore, in order to quickly process foods and life supplies, and acceptance of volunteers, information and communication network system in the evacuation places are also important. As the conventional communication means, fixed telephones, mobile phones, and as the information broadcasting, radios and TVs are usually used. However, those telephones are disadvantage that they are seriously influenced by traffic congestion and often destroyed by the disaster and cannot work as communication means. The radio and TV can only transmit the information just only one direction. Therefore, more reliable communication network is required just after the disaster happened.

As advent of Internet and high-seed LAN technologies, various information and communication networks have been used as disaster information transmission means without any restriction for individuals in bi-directional ways. Moreover, most of the people using mobile terminal such as VoIP and PDAs can interactively communicate each other even though the public communication lines are congested and out of order. Under the such background, we have started "Disaster Prevention Information Network Project in Mt. Iwate which is located the center of Iwate Prefecture and anticipated to erupt near future. So far we developed the following systems including

1) Bi-directional Video Communication System[1]
2) Resource Management System[2]
3) Resident Safety Information System[3]

In this paper, we describe the construction of a large-scale disaster information infrastructure which facilitates remote mirroring of safety information database as backup function between the distributed database servers to improve fault tolerance and robustness for the total safety information system.

2 System Configuration

In the previous research, we have developed communication network environment which combined by both wired and wireless LANs and anticipated to erupt near future as shown in Fig. 1.

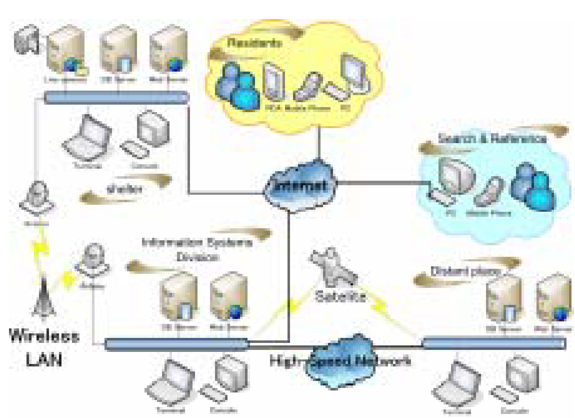

Figure.1 System Configuration

The evacuation places in each cities distributed are interconnected by those wired and wireless LANs and lead to the central disaster center. Each evacuation places and central disaster center include safety information database servers and disaster information Web servers including disaster information as well as ordinal life information. The advantages of using wireless LAN are to be able to achieve relatively high-speed and cost-effective network with 54Mbps and to realize robust and reliable physical connection even though the disaster happened [3]. In addition, even though the disaster provided serious damage to the information network, recovery of the network form the damage can be relatively quickly and simply attained by compensating the damage line by temporal wireless LAN which is installed on the relied vehicle[4][5]. In addition, by combining mobile network by mobile terminals and wireless LAN by personal data access (PDAs), more flexible and effective safety information system is also possible [1][2].

3 System Architecture

It is predicted that not only traffic congestion on the information network by many inquiries for safety information with evacuated residents but also failure and disorder of information servers and networks derive the fatal whole system failure just after disaster outbreak. Therefore, in order to minimize the influence to the whole system functions by system failure or disorder, distributed disaster information system is more suitable than central system.

In general, the evacuation places such as community centers or schools perform a very important role for residents to register his/her safety information to confirm the disaster information or evacuation life information. Therefore, in our system, the safety information database server and web server with the disaster are distributed to the pre -assigned evacuation places. Thus, the safety information with residents is first collected on the safety information database servers on every evacuation place and then sent to the central disaster information center to be totally integrated into totally unified safety information.

Figure 2 indicates system architecture to realize the functions described above. The system consists of 4 components including

1. clients
2. local safety information servers at each evacuation place
3. integration server at the central disaster information center
4. backup servers in remote place

On the other hand, in actual case of disaster occupations, the residents evacuates to the assigned evacuation place, such as community centers or schools. Therefore, it is more suitable to prepare the safety information server collect the safety information with evacuated residents on each evacuated place.

3.1 Local server at evacuation place

The local server is organized by registration module, presentation module, database. The registration module receives a query with safety information from the client and retrieves from database and returns the retrieved results to the client through the network. The registration module newly registers the safety information from the client. The presentation module provides menu so that client can select registration, retrieving, presentation of detail information by HTML format The database based on the RDB stores and manages the safety information to attain the high-speed database retrieving The database manages the safety information with the evacuated residents including evacuation place, current health condition, sexual, location data by GPS.

3.2 Integration server at the central disaster information center

The integration server also includes the same function modules as the local server. In addition, the integration server performs gateway function to the other local servers by showing evacuation places by inquiring to the status management module on all of local server and showing a list of status of the local servers.

The status management module checks whether the local servers have failures or not and whether the daemon process in the Web servers at the each evacuation places. When those servers are out of order, this integrated server performs backup functions. In addition, the integrated server also integrated all the safety information by issuing inquiry to the local server. When the central server has failure, the remote backup server performs backup function by mirroring those information through high-speed network.

3.3 Backup server at remote place

The backup server is always standing by to respond to the failure on the central server by mirroring all of safety information. The backup server consists and performs the same modules and functions as integration server at the central disaster center. When the central server incidentally occurred into a failure, the backup server immediately substitutes as soon as the central server failed. Since the multiple backup

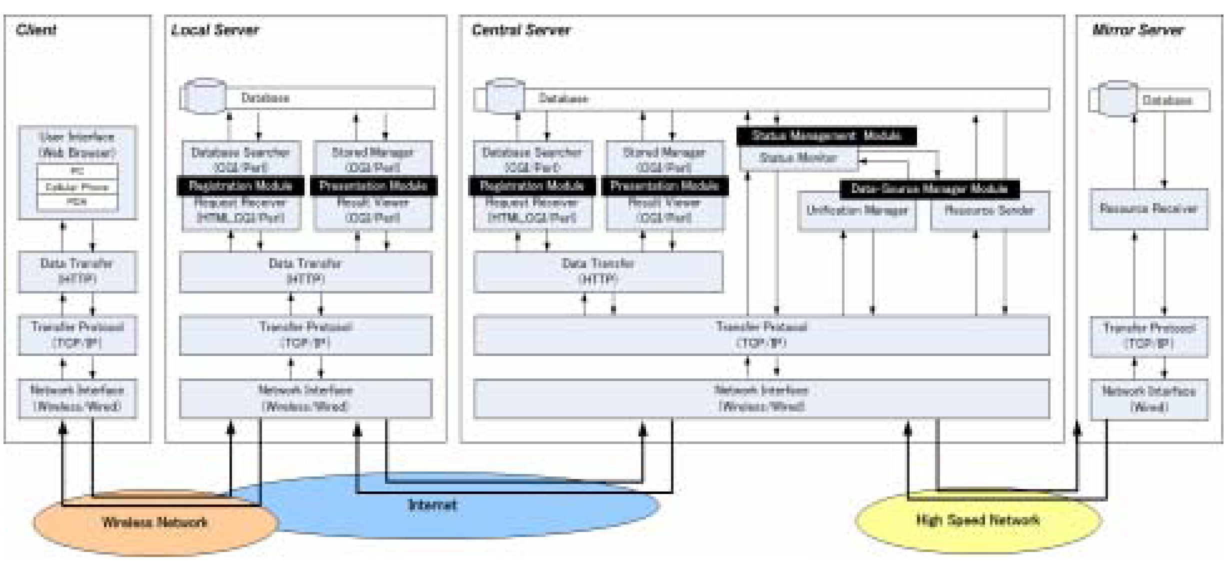

Figure 2 System Architecture

servers are allocated at the remote place far from the disaster area, the probability that both the central server and back up servers failed at the same can reduce as small as possible.

3.4 Network Environment

As network environment, in order to realize more reliable and robust large scale disaster information system, interconnection of both wired and wireless network is introduced. The Internet services are directly taken from the wireless network while the communication between the clients and local servers can be attained on wireless network based on IP protocol. The data communication between the client and server applications such as safety information is implemented using HTTP protocol to directly develop the web based service. Furthermore, the integrated servers on each central disaster centers are connected to the reliable high-speed network such as Japan Gigabit Network which is a national wide area testbed network across the Japan island. Thus, by combining the national wide ultra high-speed network, conventional wired network and wireless network, the any residents can access to the disaster information system using mobile terminals, such as mobile note PCs, PDA, mobile phone as well as desktop PC through Internet environment.

4 Dynamic Reconstruction in a Fault

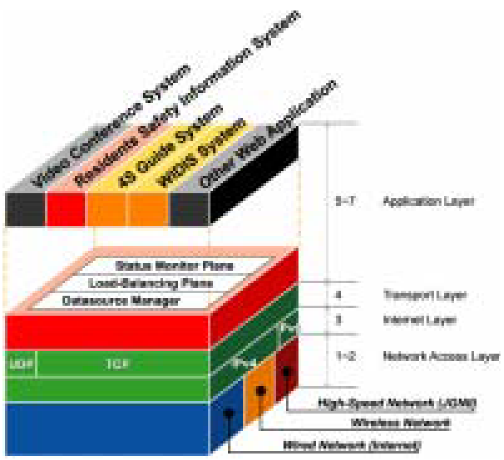

Figure.3 Protocol Stack

In order to realize more robust and reliable disaster information system from the large scale serious damage, the present safety information system is extended by introducing a middleware to deal with dynamic reconstruction of the whole systems distributed over communication network. The middleware is allocated between the application and transport layer as shown in Fig. 3. The middleware system consists of Status Monitor Plane, Load Balancing Plane and Data Source Manager Plane.

4.1 Status Monitor Plane

This Status Monitor performs monitoring function whether server is on normally working or not in case of disaster and the network lines and nodes between server and client and servers are normally working or not. The failed servers and lines and nodes are reduced from the system and the only normal server and network lines and nodes can be reconstructed to perform the minimum function just after transitional disaster period until complete recovery from failure. In previous work, SNMP protocol was used [3]. However, in order to simply implement the detection function in our system, Ping and Heartbeat commands are used to detect the failure points and then the failure server is replicated from the mirroring server.

4.2 Load-Balancing Plane

At the time of large-scale disaster outbreak, it is estimated that the inquiries from the outside of the stricken rush and a lot of disaster information is also registered to the server. However, the system has to endure the processing loads by the update and the reference of the registered information increase.

The backup function by Status Monitor and Data-Source Manager can bring increase of the number of referred databases. As result, the load-balancing in the whole database system can be realized.

By preparing multiple preliminary servers in two more locations and synchronizing data on those servers on the high speed network in the back end, thus inquiries from clients inside and outside can be distributed to those servers. Thus, this redundant database server allocation over high speed network can not only reduce the traffic and processing loads but also improve robustness of whole system. In our system, by dividing the whole referred area into the many sub-areas and statically assigning the server to the specific sub-area, all of the traffic and processing loads for inquiries can be decentralized into the each servers.

The load-balancing is also applied for data mirroring for backup servers. In order to increase the robustness for whole system, the number of backup servers to be mirrored for an original server should be larger as many as possible, but the traffic load by data mirroring increase, eventually leads to network congestion. Therefore, by load-balancing algorithm, the optimal number of backup servers to be mirror is determined.

4.3 Data Source Manager

The Data Source Manager performs backup function from the original server to backup server. The central disaster information server initiates the polling the disaster information to all of the local servers to integrate those information and replicate in the neighborhood local server. As the other function of the Data Source Manager, when the backup server received the notification from the original server which cannot be reached, the Data Source manager initiates the process from stand by state to active state.

The system behavior is precisely explained in Fig. 4 through Fig. 6. The movement of the system is concretely shown based on in the case of when breaking down being assumed.

4. 4 Fault in regional domain network

In normal, a local server is set up at a evacuation place and accumulates disaster and safety information with the residents at the evacuated place in the regional domain network,. The disaster information central server controls the distribution of the reference to each local server in evacuation place at time as shown in Figure 5.

When the local server of each evacuation place broke down, and the central Web sand database servers at the disaster center can perform backup function instead so that the user outside the stricken area can retrieve the safety information and refer equally through the Web server and the application server as shown in Figure. 6. When the automatic forwarding module in the central server detected that the local server of each evacuation broke down, the URL to access to the central database server at the disaster information center offered.

For automatically transmit the URL, the judgment module transmits a TCP packet to the 80th port offering Web service. If packet transmission is responded to 80 th port, the judgment module decides that local Web server is normally working and returns the URL. If not responded, the judgment module decides that the Web server is not working, and returns the URL of the central Web server at the disaster information center.

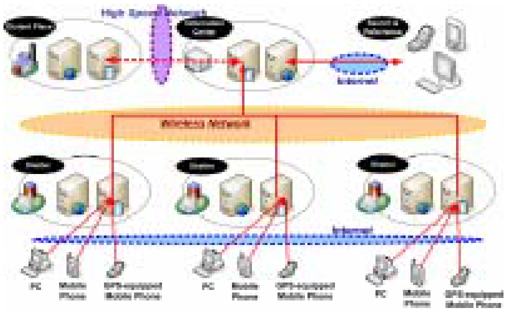

Figure.4 Usually Data Flow

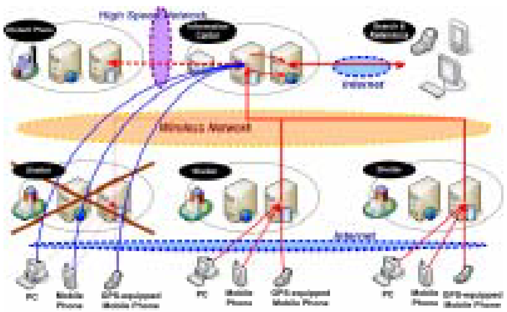

Figure.5 Data Flow when Local Server Broken

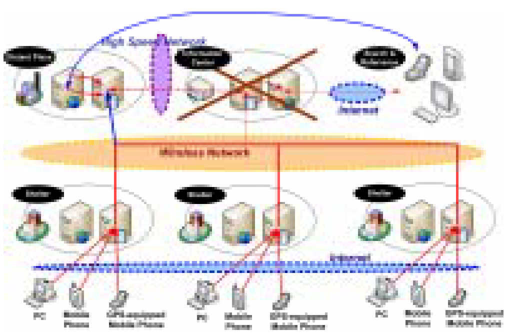

Figure.6 Data Flow when Central Server Down

In this way, by confirming whether Web and database servers can provide or not before accessing in the local servers, the client user can take the disaster information system without manually switching the page.

When a central server broke down, the Status Monitor can detect this failure and one of the remote backup servers at distant place starts data unification work instead and mediates the reference from the outside as shown in Figure. 7.

4.5 Fault in a root server distributed in each place

In order to improve the redundancy of the central servers at the disaster center which integrates all of the safety information and disaster information, the backup servers are allocated the remote place through the reliable and high-speed network such as JGN2. Moreover, by parallel using both JGN2 and ordinal Internet, the total redundancy of the system could be much more improved. As an example as shown in Fig. 7, the five backup servers are set to the remote place which are apart from one another because the probability that all of those five servers broke down by disaster at the same is quite low.

At the disaster information center, the Web server and database server are physically separately. However, when database server broke down, the Web server detects the failure by Status Monitor and redirects the inquiry to the other server, such as the remote backup database server or other local database server in the regional domain network as shown in Figure.8. When the Web server broke down, the database server grasps the failure by Status Monitor, and substitutes the functions of the Web server and navigates to other server in the regional domain network as shown in Figure.9. Thus, as long as at least one server normally alive, the disaster information system can normally keep offering information service.

As result, even though n-1 server in the whole system of out total n server broke down by disaster, this system can provide disaster information service without any dead period as shown in Fig. 10..

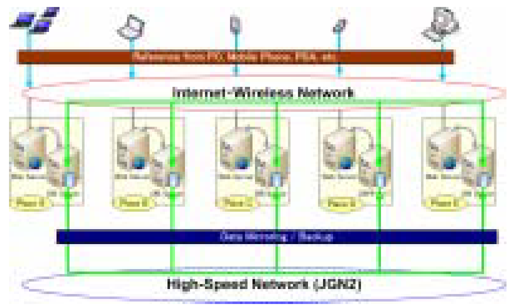

Figure.7 Distributed Root Server

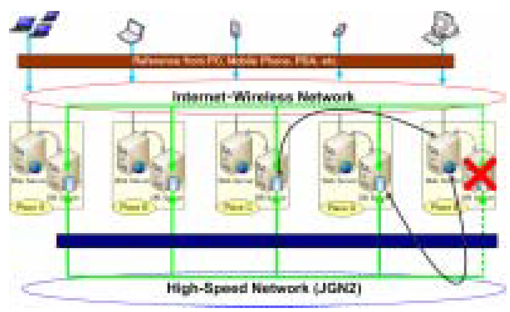

Figure.8 Case of Central DB Server Down

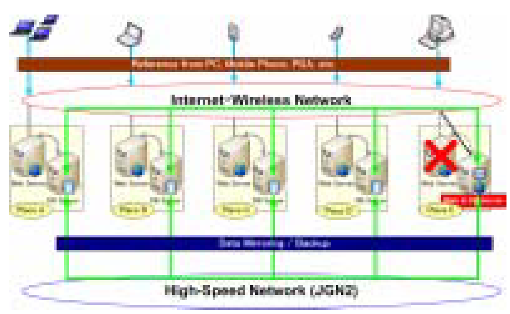

Figure.9 Case of Central Web Server Down

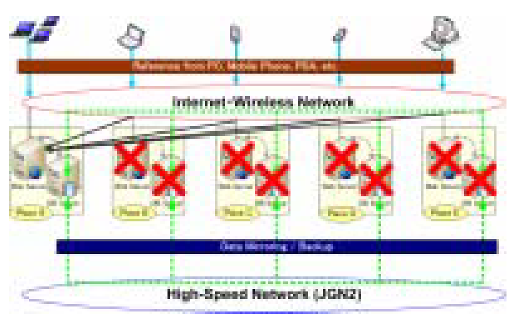

Figure.10 Migration when other place's server down

5 Prototype System

The prototype system is constructed as shown in Fig. 11 to confirm the effectiveness of the suggested system in our research and its function and performance are evaluated. This system used the Web server and the database server and set around the Mt. Iwate at the center of Iwate prefecture. In this disaster information system, we used Apache1.3.27 for a Web server and used Oracle 8 for a database server (RDBMS). We used CGI (ActivePerl 5.6.1) for information extraction from a database. The central server of disasters information center used Windows 2000 Server as operating system. Moreover, an outside refuge through the Internet was assumed, and the server was set up also in the Miyako city office Taro branch located in the Sanriku coast. For the server here, Linux (Kernel 2.4.27) is used and PostgreSQL 7.4.6 was adopted for the database server. We use CGI (Perl) for an application server part treating a safety information demand as well as the Residents Safety Information System. I used Linux (Kernel 2.4.27) for large-scale distributed servers to unify and used MySQL for a database server. The server is set up at NICT Honjo Multi-Media Open Laboratory in Saitama prefecture. Currently its performance is evaluating. The network diagram about Japan Gigabit Network II (JGN II) as the high-speed backbone network in our system is shown Figure 12. In addition, several backup servers are planed to install at University of Shizuoka and NICT IT Open Laboratories in Kitakyushu and Hokuriku to test the experiment on "Wide area Disaster Information sharing system (WIDIS System)" which is collaborative research testbed by universities and public research institutes.

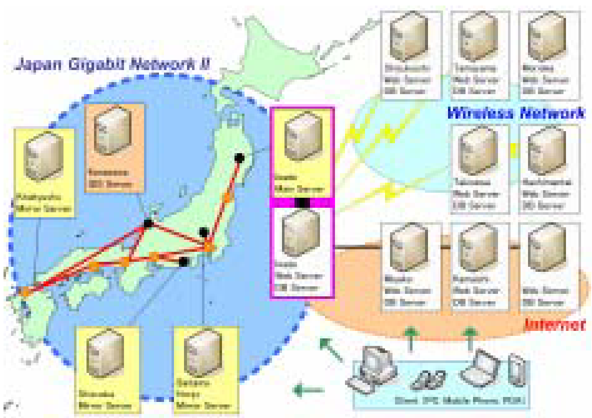

Figure.11 Prototype System over JGN II

6 Conclusions

In this paper, we introduced a large scale distributed resident-oriented safety information system constructed over Japan Gigabit Network II. The safety information with residents is registered to the local database in the evacuated area and integrated into a central database server at the disaster information center in the district area. Those local databases are mutually covered when the some of the databases are destroyed or disordered. On the other hand, the central database servers are located to mutually different locations with long distance to isolate the influence to the same disaster. The backup servers are also mirrored to support when the some of the central database servers are out of order. Thus, by introducing two levels of redundancy and backup functions, more large scale and robust safety information database system can be realized. In this paper, we designed and implemented a prototype system by our introduced method over Japan Gigabit Network to evaluate whether our suggested method is useful or not. Through the functional and performance evaluation, we could verified our suggested resident information system is effective and useful

As future plans, more flexible and simple human interface for children, old age by introducing mobile terminal with GPS function combining with electric map will be developed. Currently we are implementing this human interface. Using this mobile terminal, the user's location information can be easily and simply registered without any operations. Secondly, it is operation by a single domain. Now, two or more servers are used by another domain specifying it. Being examining it now, when the server with IP allocated in the domain in main interface is down, the other server should use that IP dynamically.

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Semantic Categorization of Images for the Intuitive Image Retrieval

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Abstract *In this paper, with the objective to retrieving digital collections more intuitively and flexible, we propose a system architecture of image retrieval to realize the human like image retrieval by the multi-type queries, such as query-by-category, query-by-sample, query-by-words, and the dynamic adjustment of threshold for individual's similarity criteria. For this, the semantic categories are defined based on the human perceptual similarity experiment described in [3], and a method of perception-based feature representation of image and its automatic semantic categorization is proposed. Furthermore, the decision rules for the semantic categorization based on the probability density estimates are described. The experiment results show the effectiveness of the proposed method.*

1. Introduction

Recently, the amount of digital media that has been generated and stored, and which continues to do so at an exponential rate, has already become unfathomable. Under this background, the expectation of retrieving images intuitively and flexible is becoming urgent. In order to avoid the expense and limitations of text annotations on images, there is considerable interest in efficient database access by perceptual and other automatically extractable attributes. However, most current retrieval systems only rely on low-level image features such as color and texture whereas users rather think in terms of concepts. Often relevance feedback is the only attempt to close the semantic gap between user and system.

Recently, there were some researches which were explored to reduce the semantic gap between user and retrieval system by additional techniques to deal with the different levels of abstraction employed by the user and the system. In [3], how human observers judging image similarity was analyzed to get a conclusion that the human observers are very systematic to judge image similarity, following semantic, color, and structural characteristics. Following this conclusion, in [4], the extraction of color features, and the interpretation of these features to five image similarity criteria were proposed. However, it was shown that color could not be used as a single measure to capture the semantic meaning of images. In [6], a concept called "vocabulary-supported image retrieval" was proposed, which allowed the system to translate the user query into an internal query. However, the user query as "Find images with 10-30% of sky" seemed not to be a natural way to present the semantic regarding the images. In [8], a semantic-friendly query language for searching diverse collections of images was proposed. However, same as [6], the query language such as « nature<10 && contrast>800 » seems not to be easy to utilize for modeling the categories. In [5], a scheme of image retrieval system which followed the human perceptual similarity criteria described in [3] was proposed. However, the semantic categorization of images was made manually.

In this paper, we propose a system architecture of image retrieval to realize the human like image retrieval by the multi-type queries, such as query-by-category, query-by-sample, query-by-words, and the dynamic adjustment of threshold for individual's similarity criteria. For this, the semantic categories are defined based on the human perceptual similarity experiment described in [3], and a method of perception-based feature representation of image and its automatic semantic categorization is proposed. Furthermore, the decision rules for the semantic categorization based on the probability density estimates are described. The experiment results show the effectiveness of the proposed method.

2. Multi-type query-based image retrieval

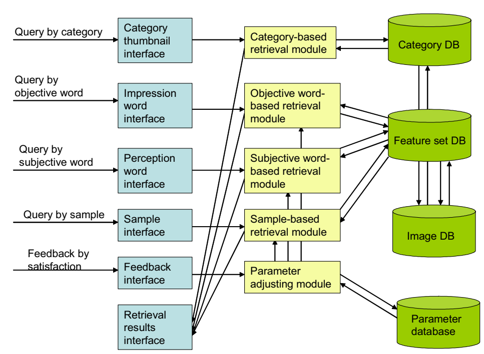

Fig. 1 System architecture

A system of flexible digital collection retrieval by multi-type queries which have the human like performance and behavior is proposed in Fig. 1. The human like query is realized by the flexible combination of the multiple query types that comprise of the query-by-category, query-by-sample, query-by-perception words, or query-by-impression words. The retrieval procedure follows the human judging process regarding image similarity [3], which is the judgment of semantic, color, and structural characteristics regarding images.

The queries of category, words, sample, or the combination of those are inputted by the interface. Let

q_k be the notation of the input data string. k is a index denoting the kth re-query regarding the original query. $q_0 = \{"painting","red"\}$ means that the original query is that retrieving collections of painting with red. $q_1 = \{"painting","red","soft"\}$ means that the first re-query is that retrieving collections of painting with the imagery of red and soft.

The retrieve server determines which retrieval module are executed according to the input data string from interface. For $q_0 = \{"painting","red"\}$, the category-based retrieval module and the objective word-based retrieval module are executed. For $q_1 = \{"painting","red","soft"\}$, the subjective word-based retrieval module is executed to retrieve images from those extracted according to $q_0 = \{"painting","red"\}$.

For the category index DB, the categories are determined by user and images in a category are assigned automatically at advance.

The approaches for the objective word-based retrieval module, the subjective-based retrieval module, the sample-based retrieval module, and the parameter adjusting module have presented in [8]. In this paper, we mainly describe the extraction of perception-based features of images and the semantic categorization for the category-based retrieval module.

3. Extraction of perception-based features

For the color images, we use the SGLD matrices of H, S, V components to extract features due to the perceptual uniformity of HSV color space. Here, H,S,V components are scaled into 16 levels. The SGLD matrix is defined in [1]. That is

$$SGLD, \Phi(d,\vartheta) = [\hat{f}(m,n \mid d,\vartheta)] \quad (1)$$

Let $\Phi_1 = [\Phi(d,\theta)(m,m), m \in [1,16]]$, which is the matrix from SGLD that the information of two pixels with the same separation having gray levels m both occurring is extracted, and let $\Phi_2 = [\Phi(d,\phi)(m,n), m,n \in [1,16], m \neq n]$, which is the matrix that the information of two pixels with the different separation having gray levels m and n both occurring is extracted.

We select the following metrics of Φ_1 and Φ_2 as our perceptual features.

a) Vector space $H : h = \{h_i : i \in [1,I]\}$, where h_i indicates the gray level of hue, and i denotes the rank of element (h_i, h_i) regarding the magnitude in the set Φ_1. I denotes the dimensions of h, which imply the number of dominant hues that the human concerns in acquiring overall impressions on images. $h_1 = 2$ means that the hue component with the value of 2 is in the rank 1 regarding the co-occurrence rates of hue components. Vector H reveals the dominant color distributions of image.

b) Vector space $P_y : p_y = \{p_{yi} : i \in [1,I], 0 < p_i < 1\}$, where p_{yi} indicates the position in vertical direction of the balance of center regarding the hue component, and i denotes the same described in a). The values of p_{yi} are in the range of (0.0, 1.0). $p_{y1} = 0.3$ means that the balance of center in vertical of the hue component which is in rank 1 is 0.3.

c) Vector space $D : d = \{d_i : i \in [1,I], 0 < d_i < 1\}$, where d_i indicates the distribution density of hue component, and i denotes the same described in a). The values of d_i are in the range of (0.0, 1.0). $d_1 = 0.3$ means the density of hue component in rank 1 is 0.3

d) Vector space T:

$t = \{t_k(d,\theta) : k \in [1,15], d = 1, \theta = (0^o, 45^o, 90^o, 135^o)\}$,

where $\{t_k(d,\theta) : k \in [1,5], d = 1, \theta = (0^o, 45^o, 90^o, 135^o)\}$ are the parameters of energy, entropy, correlation, inverse, and inertia of Φ_2 regarding H components, respectively, $\{t_k(d,\theta) : k \in [6,10]\}$ are those regarding S components, and $\{t_k(d,\theta) : k \in [11,15]\}$ are those regarding V components.

The vector H, P_y, D, T compose the feature space which is used to categorize the images, and retrieve the images in a category.

4. Semantic categorization of images

As we know, based on the perceptual image similarity experiments in [3], the images can superimpose onto the space composed of two axes, nature vs. man-made axis and human vs. non-human axis according to the semantics. On the basis of this statement, the images can be classified by the two concepts, nature and human. By the concept of nature vs. man-made, the images are divided into such classes: landscape, sunset, tree & wild flower, interior, patterns of fabrics & woods & papers & others, building, and so on. Such classes are defined as the categories of nature theme, denoted by NC_i, with the index i. Moreover, for these categories, a category may be strongly associated with some other categories. For example, the landscape is strongly associated with the tree & wide flower, and sunset ; interior is done with the patterns of fabrics & woods & papers & others. Such associated categories are called intra-association categories of the category, indicated by NC_{im}. Where, i denotes the current category, and m does the associated categories. However, by the concept of human vs. non-human, the images are divided into such classes: no-face, small images of humans in various settings, and portrait. Such classes are defined as the categories of human theme, denoted by HC_j, with the index j. Similar as the categories of nature theme, the intra-association categories of the category of human theme are denoted by HC_{jn}. Images in the classes of nature theme and the classes of human theme are overlapped on portion. The overlapped images form a new group IC_{ij} called inter-group, with the index *ij,* which has the both concepts of nature and human. As a summary, the semantic categories of images are generalized in Fig. 2.

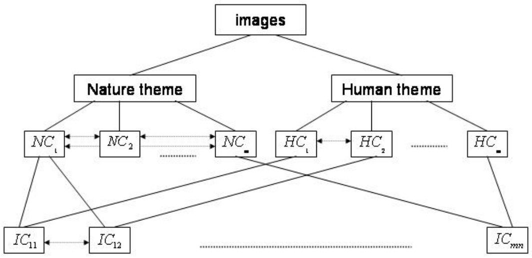

Fig.2 Semantic categories of images

4.1. Categorization of nature theme

Firstly, the feature space $F_1 = (H, P_y, D)$ is used to classify images to the categories of nature theme based on the Bayes' class decision criterion. Assuming there are *m* categories $NC_i (i \in [1, m])$, a feature vector $f_1 \in F_1$ is assigned to NC_k if

$$p(f_1 / NC_k) P(NC_k) > p(f_1 / NC_j) P(NC_j) \quad for \quad all \quad j \neq k \qquad (2)$$

where, $p(f_1 / NC_k)$ is the class-conditional probability density function that f_1 is belongs to NC_k, and $P(NC_k)$ is the prior probability of a image belonging to the class NC_k.

Because the vector space H, P_y, D are independent each other, and h_i, p_{yi}, d_i are also independent each other (*i* indicates the index of feature vector), assuming $P(NC_k) = P(NC_j)$, the criterion (2) can be written in the form

$$\prod_{i=1}^{I} p(h_i / NC_k) \prod_{i=1}^{I} p(p_{yi} / NC_k) \prod_{i=1}^{I} p(d_i / NC_k) > \prod_{i=1}^{I} p(h_i / NC_j) \prod_{i=1}^{I} p(p_{yi} / NC_j) \prod_{i=1}^{I} p(d_i / NC_j) \quad for \quad all \quad j \neq k \qquad (3)$$

Where, *I* denotes the dimensions of the vectors.

Then, in order to assign a feature vector f_1, which represents a image, to its corresponding category based on (3), the following problem is to model the probability density functions $p(h / NC_k), p(p_y / NC_k), p(d / NC_k)$ for all k, $k \in [1, m]$.

Here, we prepare the following 6 categories in advance. These categories are patterns as fabrics & woods &papers & others (NC_1),landscape(NC_2), arranged flowers(NC_3), tree & wild flower (NC_4), sunset(NC_5), and building(NC_6). Of course, the categories can be re-defined, or the new categories can be added, if necessary. Except sunset and building, each category collected 200 images from the particular volume of the Sozaijiten Image Book 1, published in Japan, as the training data set to model the corresponding probability density functions. The category of sunset collected 15 images from the Four Seasons & Nature. The building collected 200 images from web.

Furthermore, let the probability that $\frac{t_5(1, 45^o)}{t_5(1, 0^o)} > 1.1 \& \frac{t_5(1, 45^o)}{t_5(1, 90^o)} > 1.1$ when a image belongs to the building be denoted by P_b, and the probability of it when a image belongs to the other categories be denoted by P_{nb}. In order to identify the category of building with other categories, $\frac{P_b}{P_{nb}}$ is used as the weight of decision criterion.

As the whole, the procedure of the semantic classification of images is as the following. The values of *I* in (3) is equal to 2. $I_{f_1'}$ indicates the image with the feature vector $f_1' = \{h_1, h_2, p_{y1}, p_{y2}, d_1, d_2, t_5(1, 0^o), t_5(1, 45^o), t_5(1, 90^o)\}$.

Let $\prod_{i=1}^{2} p(h_i / NC_k) \prod_{i=1}^{2} p(p_{yi} / NC_k) \prod_{i=1}^{2} p(d_i / NC_k) = p(f_1' / NC_k)$, , $k \in \{defined \quad categories\}$

a)

$$\begin{aligned} & if \quad \frac{t_5(1, 45^o)}{t_5(1, 0^o)} > 1.1 \& \frac{t_5(1, 45^o)}{t_5(1, 90^o)} > 1.1 \\ & then \quad p(f_1' / NC_6) = \frac{P_b}{P_{nb}} p(f_1' / NC_6), \\ & else \quad p(f_1' / NC_6) = \frac{P_{nb}}{P_b} p(f_1' / NC_6) \end{aligned} \qquad (4)$$

b) $if \quad \frac{\max_k p(f_1' / NC_k)}{p(f_1' / NC_j)_j} \geq T1$, then assign $I_{f_1'}$ to NC_k, (5)

else assign $I_{f_1'}$ to NC_k and NC_j.

4.2. Categorization of human theme

The images are divided into three categories by the concept of human vs. non-human. The three categories are portrait HC_1, small face HC_2, and non-face group HC_3. The images in the portrait category are what the occupied rate of human face in the image is larger than a threshold. The images without humans belong to the non-face group. The rest belong to the small face group.

By analyzing the components of skin color from the 100 collected images with the human, we got a result that the color components of human face almost range in a certain region of HSV color space. We define this color region as R_f.

For the R_f, the value of H components h is equal to 1, and the value of S components s is equal to 6 or 7. In formula,

$$R_f : \quad h = 1 \& (s = 6 \mid s = 7) \qquad (6)$$

However, we also observed that if a image has the color components in R_f, besides the face, there is a possibility that the image has the other objects which color components are also in R_f. So, we know that the portrait and small face group are all questionable face groups if we assign a image to the one of the three categories based on the R_f space. The rate of false alarm regarding these groups will be discussed in the next section. Here, we give a procedure of assigning a image to the one of the three categories. $I_m^H(i,j)$, $I_m^S(i,j)$, $I_m^V(i,j)$ indicates the intensities of pixel (I, j) of a image with a ID *m* regarding the HSV color space, respectively.

a) Extracting the pixels which belong to R_f ;

$$if \quad I_m^H(i,j)=1 \,\&\, (I_m^S(i,j)=6 \mid I_m^S(i,j)=7) \quad for \quad all \quad i,j \qquad (7)$$
$$then \quad I_m^H(i,j)=0$$

b) Noise cleaning ;

c) Calculating the $SGLD, \Phi(2,0^0)=[\hat{f}(1,1\mid 2,0^0)]$ of the above processed H components;

d) Assigning the image to the one of three. $T2', T2''$ are thresholds.

$$\begin{aligned} &if \quad \hat{f}(1,1/2,0^o)=T2', \quad then \quad assign \quad I_m \quad to \quad HC_3 \\ &if \quad \hat{f}(1,1/2,0^o)>T2'', \quad then \quad assign \quad I_m \quad to \quad HC_1 \\ &else \qquad assign \quad I_m \quad to \quad HC_2 \end{aligned} \qquad (8)$$

5. Experimental results and analysis

In this section, we discuss the performance of the categorization integrating the nature theme with the human theme. Such categories are denoted by IC_{mn}. IC_{11} indicates the images belonging to NC_1 and HC_1, that is, the images having humans with the background of patterns.

The test data set has 300 images selected from the personal album randomly, being appointed to belong to the one of six categories of nature theme, and the one of three categories of human theme. Then, these images were re-assigned by the decision procedure (4), (5) and (8). The overlapped portions organized the integrated categories. Table 2 shows the results of the precision and recall of the integrated categories when *T1=1* and *T1=3*. N denotes no images assigning to the current category.

Table 2
Precision and recall of integrated category

Category	Precision		Recall	
	T1=1	*T1=3*	*T1=1*	*T1=3*
IC_{11}	1.0	0.56	0.83	0.87
IC_{21}	N	N	N	N
IC_{31}	0.3	0.26	0.3	0.62
IC_{41}	1.0	0.83	0.9	0.9
IC_{51}	N	N	N	N
IC_{61}	1.0	1.0	1.0	1.0
IC_{12}	0.71	0.69	0.43	0.48
IC_{22}	0.75	0.67	0.88	0.92
IC_{32}	0.33	0.6	0.31	0.8
IC_{42}	0.45	0.41	0.82	0.86
IC_{52}	N	N	N	N
IC_{62}	0.58	0.5	0.54	0.59
IC_{13}	0.5	0.67	0.33	0.66
IC_{23}	0.89	0.78	0.73	0.81
IC_{33}	0.33	0.35	0.36	0.63
IC_{43}	0.47	0.43	0.75	0.81
IC_{53}	0.14	0.14	0.25	0.31
IC_{63}	0.92	0.87	0.4	0.47
average	0.63	0.58	0.61	0.72

From table 2, the overall average precisions of the integrated categories, when *T1=1* and *T1=3*, are 0.63 and 0.58, respectively. The overall average recalls of the integrated categories, when *T1=1* and *T1=3*, are 0.61 and 0.71, respectively. The experiment results showed the effectiveness that assigning the images to the categories of nature theme and human theme respectively, then taking the overlapped portions as the integrated categories with the both concepts.

Furthermore, we can also see that with the increasing of *T1,* the recall of integrated categories rises greatly and the precision drops slightly, which are accordance with the results of those regarding the nature theme. It illustrates that by adjusting *T1,* the dynamic association of the user's requirements with the integrated categories can gain while optimizing goals such as maximum recall, maximum precision or the tradeoff between them.

However, we also noticed that the most part of integrated categories have the high precision or recall, but the performance of the some categories is not so good. Especially, the category IC_{53} (sunset without human) has the low precision and recall. The reason is that the dominant color of sunset is often in the space in skin color that results in determining the sunset as the human face easily. Conducting the association of category sunset with the category human maybe a solution of improving the overall precision and recall.

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Component Based Face Recognition Against Occlusions: Gabor Wavelets vs. GFD

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Abstract— **The need to assure the safety of places, people and information is particularly compelling nowadays. A reliable and widely accepted solution is the use of biometric systems and of face recognition in particular, thanks to its high degree of acceptance and ease of use. Most techniques presented in literature work on the whole face and often omit to consider the occlusion problem. This work proposes two classifiers, suitably adjusted to be Component Based and robust to occlusions. The experiments that we carried out show how these approaches perform well even in presence of partial occlusions.**

I. INTRODUCTION

The more and more chasing technological progress and the induced globalization effects are deeply transforming human culture and habits. At the same time they both provide effective solutions to old problems and introduce new ones. On one hand they reduce cost and time required to connect places that were formerly difficult to reach and make it easier to retrieve and share information through a wide number of new services. On the other hand, they increase vulnerability of people and information, so that they are a further cause of the present pressing need for safety. For example, traditional badges, cards and passwords are now much easier to stole or forge, so that they cannot guarantee such safety anymore. One of the present research trends aims at exploiting biometric features tightly binding a person identity with his/her physical and behavioural characteristics. Among the most reliable biometrics nowadays we can certainly count iris and fingerprints. Nevertheless, their low degree of acceptance and their inapplicability in case of non consentient subjects are fostering the development of alternative biometrics such as the face or the ear. Though face does not reach the same recognition performances compared with fingerprints, it is more widely accepted and can be applied even in case of non consentient or unaware subjects. Many face recognition algorithms are available in literature [11]. Each of them aims at overcoming some limit which is intrinsic to the nature of the method (e.g. lighting, posture, expression …). However, definitely few of them deal with the recognition problem in presence of partial occlusions, as the scarce number of available references demonstrates. Moreover, most proposed methods tackle the problem considering the whole face. Actually few of them break the face down into components before feature extraction, for instance the one in the work by Heisele *et al.* [1]. In this paper we propose the study of two methodologies, the first one exploiting the *Generic Fourier Descriptor* (GFD) and the second one based on *Gabor wavelets*. GFD was originally presented by Zhang [9],[10] for the classification of binary images representing trademarks and was never applied in the biometric field. Gabor wavelets have already been used for face recognition (i.e. [5]) but not combined with a component based approach. We adjusted both approaches for elaboration on face components, and further studied them in case of partial occlusions. Experimental results highlight how the two methods differ as for efficiency and effectiveness, and allow a comparison with other face recognition techniques found in literature which address occlusion [7]. The rest of the paper is organized as follows: Section I offers a description of GFD and Gabor Wavelets methods, while system architecture is described in Section II. The Section with experimental results follows, where system performances are evaluated; finally, a Section with conclusions closes the paper.

II. GFD AND GABOR WAVELETS

A. The GFD

The Fourier Transform (FT) is largely used in image processing; because it often makes some limitations to be overcome by working in the frequency domain (e.g.: noise, shifts). In particular, we adopted a FT based descriptor defined by Zhang in [9],[10] for classifying binary trademarks, but we readapted it to our purposes.

Given an image *I* in the Cartesian space *xOy*, we convert it in a polar space *ρOθ*, by relating *I(x,y)* with *I(ρ,θ)*, defining $\rho = \sqrt{(x - x_c)^2 + (y - y_c)^2}$ and $\theta = a\tan 2((y - y_c)/(x - x_c))$, where $O(x_c, y_c)$ is the centre of the Cartesian space. The polar Fourier Descriptor is defined on this polar space as follows:

$$PF(\rho,\phi) = \sum_r \sum_i f(r,\theta_i) e^{[j2\pi(\frac{r}{R}\rho + \frac{2\pi i}{T}\phi)]} \quad (1)$$

where $0 \le r < R$ and $\theta_i = i(2\pi/T)$, $0 \le i < T$; $0 \le \rho < R$ and $0 \le \phi < T$. The ρ and ϕ represent the number of selected radial and angular frequencies. The *FD* descriptor is made rotation invariant by retaining only the magnitude of the coefficients, while robustness with respect to the scaling is achieved by dividing the first coefficient by the area containing the image and all the remaining coefficients by the first one, as follows:

$$V = \left\{ \frac{|FD(0,0)|}{area}, \frac{|FD(0,1)|}{|FD(0,0)|}, \ldots, \frac{|FD(m,n)|}{|FD(0,0)|} \right\} \qquad (2)$$

The most important factor affecting the result is the way to locate the point $O(x_c, y_c)$. Indeed, imposing some restrictions places this method on a par with all the approaches requiring a pre-alignment of the face. We solve this problem by choosing $O(x_c, y_c)$ as the Mass Centre of the face component:

$$x_c = \frac{1}{N}\sum_{x=0}^{N-1} x, \quad y_c = \frac{1}{M}\sum_{y=0}^{M-1} y \qquad (3)$$

Only a small number of GFD characteristics are required for an effective shape description. It was experimentally demonstrated that 36 coefficients, obtained from 4 radial and 9 angular frequencies, are sufficient to describe the shape. The selected coefficients form a feature vector which is used to index the shape itself. Given two shapes represented by their feature vectors obtained through the GFD, it is possible to measure their similarity using *city block distance*.

B. Gabor Wavelets

Gabor wavelets are widely used in image analysis as they present particular computational features, such as spatial localization, selectivity of orientation and spatial frequency. Moreover, they are particularly suited for image decomposition and representation when the aim is to derive local and discriminating features.

Gabor wavelets, also known as *kernels* or *filters*, are defined as follows, as in [1][4]:

$$\psi_{\mu,\upsilon}(z) = \frac{\|k_{\mu,\upsilon}\|^2}{\sigma^2} e^{-\left(\frac{\|k_{\mu,\upsilon}\|^2 \|z\|^2}{2\sigma^2}\right)} \left[e^{ik_{\mu,\upsilon} z} - e^{-\left(\frac{\sigma^2}{2}\right)} \right] \qquad (4)$$

where μ e υ define orientation and scale of the filters, $z = (x, y)$ is an image point, $\|\cdot\|$ is the norm operator, and $k_{\mu,\upsilon}$ vector is defined as follows:

$$k_{\mu,\upsilon} = k_\upsilon e^{i\phi_\mu} \qquad (5)$$

where $k_\upsilon = k_{\max} / f^\upsilon$ e $\phi_\mu = \pi\mu / 8$. f is the spacing factor between kernels in the frequency domain and $k_{\max}$ represents the highest frequency [4]. Gabor kernels show some self-similarities because they are produced by a filter, the mother wavelet, using scaling and rotation operations which are performed through the $k_{\mu,\upsilon}$ vector. Each kernel is the product of a Gaussian envelope and a complex plane, while the first term in square brackets in (4) determines the oscillatory part of the kernel and the second term compensates for the main component value. In most cases one uses Gabor wavelets with five different scale values, $\upsilon \in \{0,\ldots,4\}$, and eight orientations, $\mu = \{0,\ldots,7\}$ [3].

An image representation through Gabor wavelets is obtained by performing a convolution between the image itself and a family of Gabor kernels, as previously defined. Given an image grey level distribution $I(x, y)$ the output of the convolution of image *I* and of a Gabor kernel is defined as follows:

$$O_{\mu,\upsilon} = I(z) * \psi_{\mu,\upsilon}(z) \qquad (6)$$

where $z = (x, y)$ and $*$ is the convolution operator.

Convolution is a computationally very expensive operation, however. In fact, given two matrices A and B of dimensions respectively $n \times n$ and $k \times k$, $A * B$ has complexity $O(n^2 k^2)$. For this reason, convolution theorem is applied for performances optimization, so that we can derive convolution output using the *Fast Fourier Transform* (FFT). If

FilteredImage = OriginalImage $*$ *Filter*

applying the theorem we will have

$\Im$ (*FilteredImage*) = $\Im$ (*OriginalImage*) · $\Im$ (*Filter*)

and consequently

FilteredImage = $\Im^{-1}$($\Im$ (*OriginalImage*) · $\Im$ (*Filter*))

where $\Im$ and $\Im^{-1}$ respectively indicate Fourier transform and its inverse. Applying the convolution theorem complexity drops to $O(n \log n)$.

From (6) we then obtain

$$\Im\{O_{\mu,\upsilon}(z)\} = \Im\{I(z)\}\Im\{\psi_{\mu,\upsilon}(z)\} \qquad (7)$$

and consequently

$$O_{\mu,\upsilon}(z) = \Im^{-1}\{\Im\{I(z)\}\Im\{\psi_{\mu,\upsilon}(z)\}\} \qquad (8)$$

From now on we will indicate with $O_{\mu,\upsilon}(z)$ the magnitude of the convolution output. As such outputs are formed by different local scale and orientation features, they will be linked together to obtain a feature vector χ. As a result, the feature vector will be formed by both the real and the imaginary part of Gabor transform. Before linking, a downsampling of each $O_{\mu,\upsilon}(z)$ of a factor ρ is performed to reduce the dimensionality of the original vector. Given the downsampled output $O_{\mu,\upsilon}^{(\rho)}$, the feature vector χ^{ρ} is defined as follows:

$$\chi^{\rho} = \left(O_{0,0}^{(\rho)^t} O_{0,1}^{(\rho)^t} \ldots O_{4,7}^{(\rho)^t}\right)^t \qquad (9)$$

where t is the transposition operator. The vector so obtained will then include all the $O_{\mu,\upsilon}(z)$ outputs as discriminant information.

The downsampled χ^{ρ} vector is still too large to be managed; for this reason we apply the DCT transform to each $O^{(\rho)}{}_{\mu\upsilon}$ in (9) to further reduce their dimension. As DCT concentrates most information in the first elements of the output vector, compression is achieved taking only the first n elements of it to form a new vector of reduced dimension. We will indicate such vectors as $C^{(n)}{}_{\mu\upsilon}$. It has been experimentally proved that the best results are obtained with n=10. After this further step, all the obtained $C^{(n)}{}_{\mu\upsilon}$ must be linked together to form the final feature vector

$$\chi = \left(C^{(n)}{}_{0,0}C^{(n)}{}_{0,1}\ldots C^{(n)}{}_{4,7}\right) \qquad (10)$$

The final dimension will be of 400 elements as we take the first 10 elements of the 40 downsampled elements $O^{(\rho)}{}_{\mu\upsilon}$. The whole process is summarized in Figure 1.

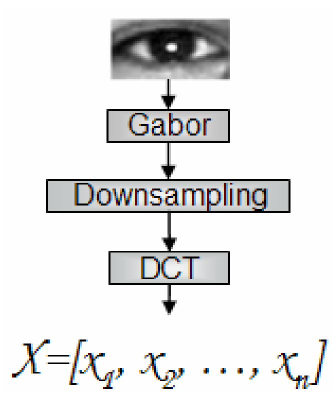


Figure 1 Feature vector extraction.

III. THE SYSTEM ARCHITECTURE

The system is formed by two modules: The feature extraction module and the enrolment/testing module. The core idea for the feature extraction phase is to locate and extract from the face image the main characteristics such as eyes, nose and mouth; for each of them a feature vector is computed and stored in the database

As for the enrolment/testing phase, only the non-occluded face characteristics will be extracted from the image; a vector is computed from each of them. Then, in order to search for the most similar face, we compute distances among such vectors and the ones extracted from the corresponding characteristics of each image in the database. The output image will be the one achieving the lower distance.

The schema in Figure 2 describes how the proposed algorithm works.

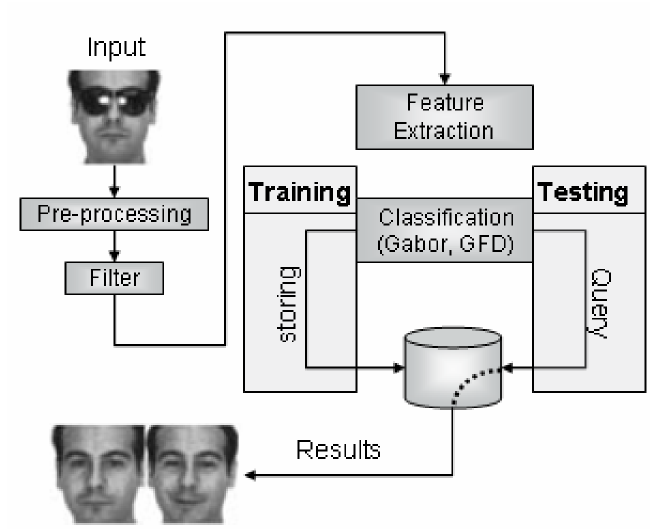


Figure 2 Algorithm schema.

We have four functional blocks:

Pre-processing module: takes the face image as input and normalizes it. In particular, a new 256 x 256 image is created, which only contains the face without hair, ears and chin. This is because the method focuses on locating and extracting eyes, nose and mouth so that it is better to remove any possibly disturbing element. Face location within the image is performed using a tool provided by the OpenSource OpenCV library [12].

Filter: the normalized image is filtered so that only face characteristics are highlighted, while uniform zones are removed. Moreover, a binarization is performed through a tresholding operation, in order to facilitate the localization phase. The 3 x 3 kernel of the exploited filter has values obtained from the function:

$$f(x,y) = \left\lfloor 2^n - (2^n - 1)\sqrt{x^2 + y^2} \right\rfloor \qquad (10)$$

with n=3, graphically shown in Figure 3 (a), while Figure 3 (b) shows the results of filtering on a test image.

However, it has been proved that a constant value in the central pixel of the filter is not suited for colour differences in subjects' skin. As a matter of fact, for those who show a dark complexion, the filter leaves too much information that worsens the performances in characteristics localization. On the contrary, information is reduced too much for subjects with fair complexion, so that it is impossible at times to locate some face parts. To overcome these problems, the value for the central pixel is adaptable and is computed according to the average colour of image pixels. It has been experimentally observed that the subjects' average colour ranges approximately from 90 and 180. Moreover the optimal values for the central pixel range from a minimum of 5.2 for dark complexion subjects to a maximum of 6.3 for fair complexion ones. For this reason, for each subject having pixel average $\overline{m}$, the corresponding value for the central pixel of the kernel will be:

$$p = 6.3 - 0.012 \cdot \left(\overline{m} - 90\right) \qquad (11)$$

As previously described, binarization through a tresholding operation is performed after filtering.

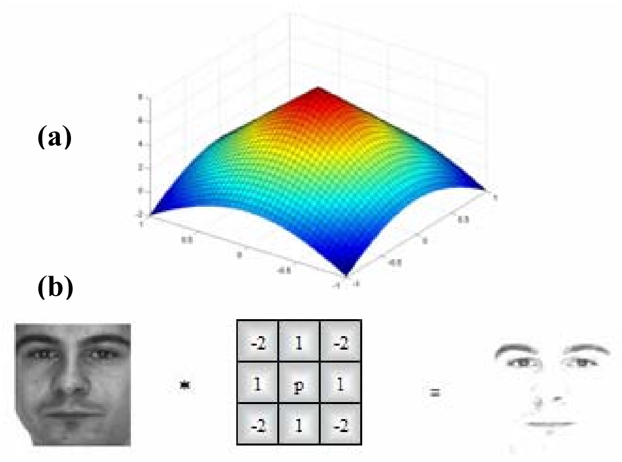
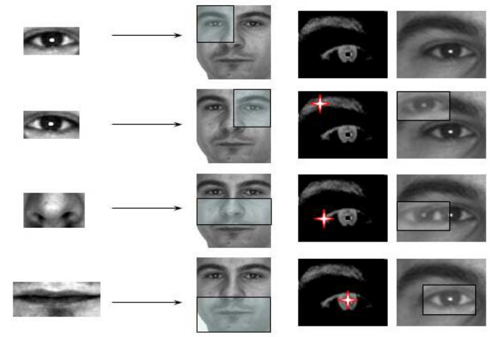


Figure 3 Filtering of the normalized image.

Location module: determines the position within the binarized image of eyes, nose and mouth. In order to perform such operation, the image is divided in four search areas, one for each characteristic. Figure 4 (a) shows where each of them is searched for. Localization occurs through a scanning of the interest zone within the binarized image, analyzing each white pixel inside it. Starting from the upper left corner of the search zone, for each white pixel of the binarized image, the central position of the reference component (eye, nose or mouth) is superimposed on the original image. Then the absolute value of the difference is computed pixel by pixel between the region in the original image and the one in the reference image so aligned. The area corresponding to the lower error will be the one containing the searched characteristic. The zone will be 64 x 32 pixels for eyes, 70 x 40 for nose and 100 x 40 for mouth. Figure 4 (b) shows an example of eye location.

The location module will return the position within the original image of the pixel indicating the centre of the characteristic. Due to the high variation of the mouth, more reference images have been used to have a more precise location.



(a) **(b)**

Figure 4 Location of face characteristics

Characterization module: given the extracted characteristics, two corresponding vectors are created that will be stored in the database during the training phase and exploited for comparisons in the recognition phase. Vectors are computed using GFD and Gabor wavelets.

As shown in Figure 2, during the enrolment phase the subject's face is extracted from the obtained image, and then it is filtered and divided in its four component regions. For each such region the corresponding facial characteristic is located. During the characterization phase, the two vectors associated to each extracted characteristic are computed and then written in the database. As described above, such vectors are computed respectively through GFD and Gabor wavelets. During the testing phase, characteristics to be used for the search are selected and extracted, while the characterization operation computes the two feature vectors. Euclidean distances between feature vectors (eyes, nose or mouth) and the corresponding vectors stored in the database are computed.

IV. EXPERIMENTAL RESULTS

System performances have been measured using the *Cumulative Match Score* (*CMS*), which represents the methodology most widely diffused in literature. Let's define *rank n* as the set of the first *n* images that are returned by the system; the searched image must be present in such set in order for the recognition to be considered as correct. CMS computes the rate of images in a test set that fall within rank *n*.

$$CMS = \frac{\text{Number of Test Images recognized among the first n results}}{\text{Total Number of Training Images}} \cdot 100 \qquad (11)$$

In order to test system efficiency we performed 3 kinds of test. *Test 1*and *3* are performed on AR Faces database [6], using the same protocol which has been exploited by the

author (Martinez) to obtain the experimental results for his method [7]. *Test 2* is performed on FERET database. It is to notice that FERET does not contain images of partially occluded faces. For this reason test sets have been suitably modified by superimposing the image of a pair of sunglasses on eyes and the image of a scarf on mouth.
Tests on FERET were performed to stress the system. First of all the database contains a higher number of images, 400 compared to the 50 images of Martinez; moreover, such images show even variations in expression, posture, brightness and contrast, that in addition to glasses and scarf superimposition make the recognition process very difficult.

Considering the results of *Test 1* in Figure 5, some interesting issues are highlighted. In general, the results obtained using Gabor wavelets are slightly better than the ones obtained using GFD, but we can notice how in many cases they are almost equivalent or, as it happens in Figure 6 GFD even overcomes wavelets.

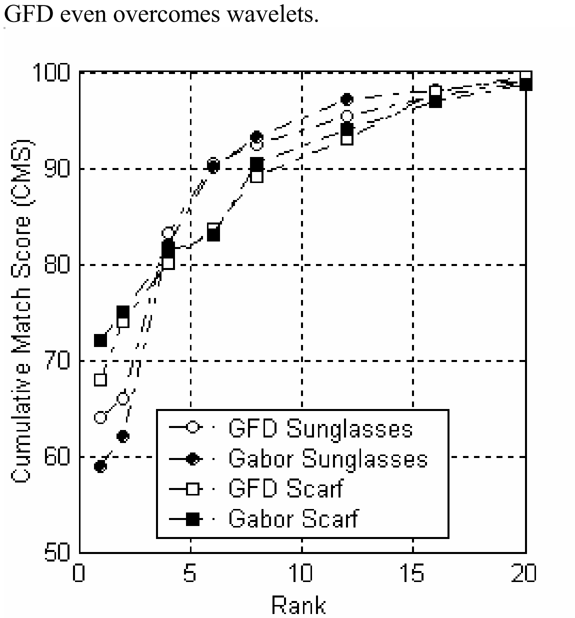


Figure 5 AR Faces database, 50 subjects with neutral expression, 50 training images and 50 probe images.

This can be considered a good result if we think that only 36 coefficients per characteristic are used compared to the 400 ones of Gabor.
The automatic location of characteristics improves system performances. This is due to the fact that the characterization appears to be more accurate when determining a more precise position for eyes, nose and mouth; it is to notice that the performances of the recognition of faces with sunglasses are lower than those achieved for faces with a scarf, as eyes have a higher discriminating power than mouth.
As regards *Test 2* in Figure 6, it is plain that, for sunglasses, performances are lower than tests performed on Martinez database. However, the obtained results can be considered as good if we consider the high number of images, used both for training and test, and the characteristics of FERET database discussed above.

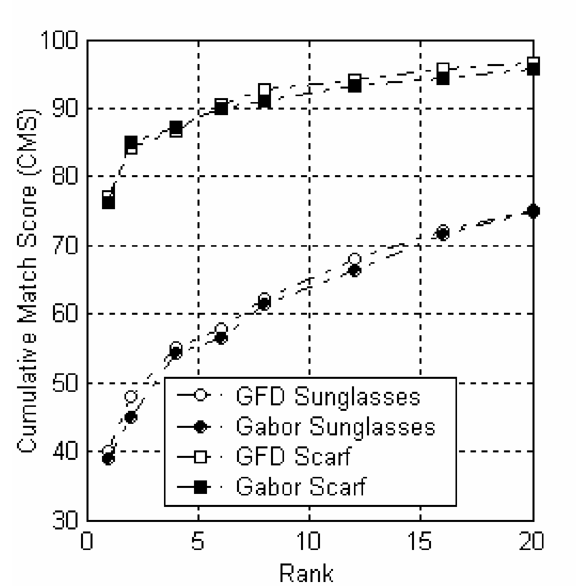


Figure 6 FERET database, 200 subjects, 400 training images and 200 probe images.

A. Comparison with the state of the art

In the last years a large number of biometric systems have been developed for face recognition. However, only few of them take into consideration the problem of occlusions. One of the most recent and effective methods is the one proposed by Martinez [7]. Its results have been used as a point of reference to evaluate our system performances. In order to perform such comparison, we used the same protocol, as discussed above for *Test 1* and *2*, exploiting a *gallery* with 50 images, one for each of 50 subjects chosen at random with neutral expression and two *probe* sets of 50 images each portraying as many subjects divided in categories with sunglasses and with scarf. Figure 7 shows the compared results.
As we can see from Figure 7, for a value of *n* greater than 5 and for eye occlusion, both proposed methodologies exceed the results obtained by Martinez. This can be considered a good result for our research and opens up positive prospects of further improvements for future work.

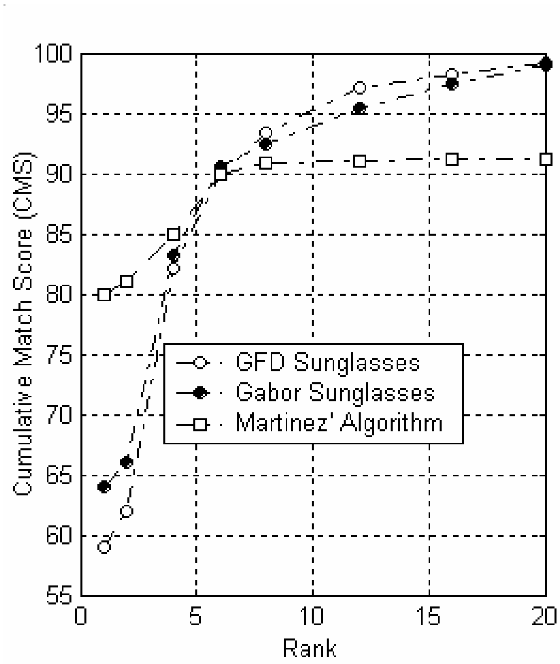


Figure 7 Comparison with the method of Martinez.

V. CONCLUSIONS AND REMARKS

In this work we proposed two new kinds of approach to the problem of face recognition in presence of partial occlusions. Both methods are based on extracting from the face image of characteristics such as eyes, nose and mouth using a location procedure. The first technique exploits the *Generic Fourier Descriptor* to represent such characteristics. It has been applied till now only as a shape descriptor for binary images and has never been introduced in the field of face recognition. The second technique is based on the use of *Gabor wavelets* applied locally on face parts extracted through location, differently from previous works where they were globally used on a face image.

The two proposed approaches have provided satisfying results in the recognition of partially occluded faces. From the tests that were performed it comes out that the GFD has good performances even for face recognition even if they do not reach those achieved through Gabor wavelets, in all cases. An important aspect to notice is that the GFD used a much reduced number of coefficients to describe each face characteristic. As a matter of fact the best results are obtained with only 36 coefficients while 400 are needed for Gabor. In particular, in the case of occluding eyes with sunglasses, both methods perform better than the method proposed by Martinez [7].

As for future work, we could design a more efficient procedure for the location of face characteristics, based for example on fractals, and a technique to automatically establish the position of occlusions on the image. Moreover, more methods could be introduced to reduce the dimensionality of feature vectors, such as the *Principal Component Analysis*, able to concentrate information in a lower number of coefficients.

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The DocSearch: Distributed Storage and Retrieval of Document Images

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Abstract

Ubiquitous computers have dramatically increased the volume of paper documents being printed. We often find ourselves burdened by piles of loosely organized papers eating up precious time and space. Large companies and government agencies retain enormous paper archives as records. Advances in technology, as well as economic and environmental advantages have brought about a shift from paper archives to digital document image repositories. Such repositories replace what would be warehouses full of paper documents and make them all fully searchable and highly available to any connected computing devices. Numerous document image analysis techniques are used to automatically build up metadata to be used as index values on which the documents can be retrieved. Thus a document can quickly be retrieved based on those metadata, or visual or content similarity to another document simply by being placed in the repository. We have developed the DocSearch system, which is a web-based distributed document image retrieval system. It allows both simple and sophisticated queries and returns the matching documents as a list of thumbnail images in descending order of relevance. By clicking a thumbnail, the user can view the full sized image as well as the thumbnails for the rest of the pages in that particular article.

1. Introduction

The information age has brought about drastic changes in the ways people use and store information. Ubiquitous computers have dramatically increased the volume of paper documents being printed. We often find ourselves burdened by piles of loosely organized papers taking up time and space. Large companies and government agencies retain enormous paper archives as records. Advances in technology, as well as economic and environmental advancements have brought about a shift from paper archives to digital document image repositories. Such repositories intend to replace warehouses full of paper documents and make them searchable and available to any connected computing devices. Numerous document image analysis techniques are used to automatically generate metadata to be used as index values on which the documents can be retrieved. Thus documents in the repository can quickly be retrieved based on those metadata, or visual or content similarity [5]. The goal is to put enormous amounts of information at people's fingertips while still allowing them to find what they want the same way they might flip through a pile of papers without the Herculean effort. In this paper, we discuss issues related to document image retrieval. We also describe the architecture, infrastructure, and technologies used to create our Internet-based distributed document image retrieval system - DocSearch.

1.1. Documents

One of the most fundamental uses of computers today is creating, manipulating, storing and transmitting documents. Even the most novice computer users see the documents they create on a computer as manipulable, searchable entities. This type of availability is something people have become accustomed to with documents endogenous to the computer, but the problem of efficient and accurate retrieval becomes significantly harder when dealing with digitized or scanned document images. Because these images are just an array of pixels, essentially a photograph of its paper counterpart, much work must be done by the system to recover the content and meaning of the document so it can be retrieved both accurately and efficiently. Often the textual content of the document cannot be accurately recovered due to poor image quality or the lack of domain specific knowledge. It is desirable that the system be capable of indexing on partially converted documents and make use of the copious structural information that can be extracted without domain knowledge.

1.2. Document Databases

Building, maintaining, and querying a database of documents is more complex than building, maintaining, and querying a traditional database. Queries on traditional databases are formulated based on the set fields, their relations, and calculations based on those fields [1]. The index information for these fields is extracted directly from the generally well-structured data. For example, one could query a traditional database for, “how many people bought a ford truck in 2005”, and would receive the response as a quantitative answer. For documents, the lack of knowledge on document structure makes it difficult to derive the index information. The attributes such as author, title, or publisher are easily indexed. Returning an appropriate answer to that query in a document database is difficult unless the database is highly domain dependent and the relevant data can be extracted or if the index only relies objective structured identifiers. Answering a question not only requires the computer to understand the query, but also to understand the documents in the database, a daunting task when considering the ambiguity of natural language. An unambiguous query language like SQL used for traditional database query is much simpler to interpret than the natural language that would be used to pose questions in a document database. A more realistic goal for document retrieval is to return a subset of its documents that are likely to contain that information in some sort of relevance ranking order. The user can then simply extract the answer they are looking for from the results.

1.3. Document Image Databases

One can see that while providing the exact answer to any question posed in natural language may not be a practical goal, there are still many benefits to building and maintaining a document database. More often than not, printed documents are digitized with a scanner and those images are to be indexed into the database. This is a popular way to archive information because of its recent economic feasibility and the fact that a digital image provides a precise representation of its paper counterpart without the real world storage costs and requirements. The problem, however, is that an electronic representation of the document text is not always available. Documents endogenous to the computer contain all of the information and text representing the content of the document, but with document images all we have to work with are a set of pixels with which to extract that information from the image. Unfortunately this information extraction is not always accurate or possible. Poor document image quality resulting from imperfect scanning can be problematic for extracting information from the image for indexing. Optical character recognition (OCR) is used to recover the actual text from the scanned image for indexing into the document image database, but the quality of the character recognition depends directly on the quality of the image. In document images that are not completely text, it is also difficult to decompose graphic and picture segments of the document into indexable units. Clearly this means that some sort of human supervision or manual entry must take place to have good clean data for the database. In certain domains, however, a simple document id may suffice for retrieval and this can be generated without human intervention. In other instances we are forced to make use of the wealth of information contained outside of the recognized text of the document.

2. The DocSearch

DocSearch is a web-based distributed document image retrieval system. We use the extracted data for indexing, but present the clean image to the user following the same approach as the SMART [4].

2.1. Design Choices

There are two common approaches to web application development, generally referred to as Model 1 and Model 2. In the Java world, Model 1 requests are handled completely by JSPs. Everything from page layout to database access code is intertwined within the JSP. For this reason, Model 1 designs suffer from maintainability issues. Model 2 adds a servlet to the Model 1 architecture, which acts as a controller that receives requests from clients and dispatches the request to a separate business layer for processing. After processing, the servlet redirects the request to a JSP page whose sole responsibility is to generate the view for the client. Model 2 creates a clear distinction between form and function clearing all business logic out of the JSP page. This separation makes Model 2 the preferred architecture for serious web application development. DocSearch is a Model 2 web application built atop the Jakarta Struts framework making heavy use of standards compliance and best practice design. It is built using J2SE 1.5 and makes use of the Java Advanced Imaging libraries. We chose to use the Struts Framework because it facilitates maintainable, scalable, cross platform Model 2 designs.

2.2. Indexing and Searching with Lucene

For our indexing and searching needs, we chose a high performance open source Java API called Lucene [7]. On the surface you are either indexing documents or searching for documents. Lucene only deals with documents, not files, so everything that needs to be indexed must be converted to a document. Documents are little more than a set of one of more fields (name/value pairs), analogous to a row in a relational database (fields are like columns). Lucene takes care of many of the underlying details of indexing and searching such as optimization of the index, sorting, encoding of term positions, frequency counting, optimizing queries, merging sub results, placement on disk, et cetera.

2.3. Text Normalization

Lucene allows analyzers to be defined that are essentially preprocessors for text input during indexing and searching. Analyzers are generally used for normalizing text in an attempt to improve the quality of search results. This can include removal of common words deemed useless for queries, removal of common inflexional endings from words, converting all text to lowercase, or even defining relationships between similar words such that a query for documents containing “water” in the title might also consider documents containing “H2O.” Our analyzer performs a number of these processing steps on our textual input. The first step is to convert everything to lowercase to eliminate case sensitivity. After that, the input is run through a stop list consisting of common words that have a negligible effect of the content of the document. These are often words like “by”, “and”, “is”, et cetera. They have no effect on the content of the document, so removing them will save time, space, and improve the accuracy of our searches. Finally, the analyzer attempts to stem English words to their roots by removing common morphological and inflexional endings using the Porter stemming algorithm. This allows us to query based on word roots so the user does not need to match the inflexions of the words in the text exactly.

2.4. Query Features and Scoring

A flexible query system is necessary for searching a large document image database. Our system supports both simple and complex queries using both a query language and an advanced search feature. The query language is capable of handling single terms, phrases, searches within a particular document field, single and multiple character wildcards, fuzzy searches based on Levenshtein distance, proximity searches, range searches, term boosting, Boolean operators including required and prohibited, and term grouping. Forming complex queries can be a difficult task for those who are unfamiliar with the syntax of the query language. For this reason, an advanced search is provided which clearly defines and separates the search options for the user. It allows users to easily search both functional and logical components of the document. Logical components are chosen from a dropdown menu, while functional components are chosen from either dropdown menus or radio button sets. The user simply fills in the sub-queries they would like to use, and the system combines them into a complex query. Results are returned in descending order of relevance. The relevance is calculated based on a variety of factors including, but not limited to, the number of documents in the index, the frequency of the term within the document, the size of the field in which the term was found, the number of other documents containing that term, the edit distance (for fuzzy queries), et cetera.

2.5. System Implementation

The DocSearch is implemented in Java, using Jakarta Struts, JSP, Jakarta Lucene, and other related technologies [7][8]. The system is built with extensibility and standards compliance in mind making use of the model-view-controller (MVC) design pattern. We have outlined the architecture, infrastructure, and technologies used to create this Internet-based document image retrieval system as well as potential for ongoing research on intuitive web-based retrieval. In our system, we used the ground truth data put together by the University of Washington as the extracted data. We used the 624 English journal articles in the UWII set as our data [6]. All of that data is extracted and placed in an index for subsequent retrieval through the web interface. It allows both simple and sophisticated queries and returns the matching documents as a list of thumbnail images in descending order of relevance. By clicking a thumbnail, the user can view the full sized image as well as the thumbnails for the rest of the pages in that particular article.

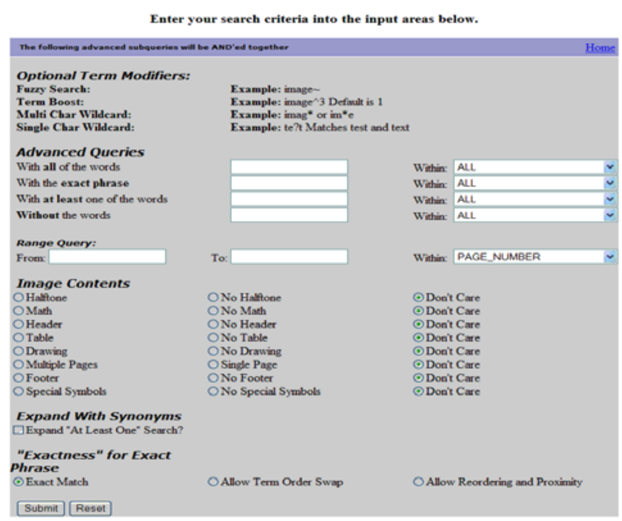

Figure 1: Advanced Query Interface of the DocSearch.

3. Evaluation

Our system makes a number of improvements over existing systems, but draws from many existing systems. For example, we draw our indexing and display concept from Cornell’s S.M.A.R.T. system [4] and draw our thumbnail and term highlighting from the DocBrowse interface [3]. Our query language is very flexible and allows for everything from simple keyword searches to multidimensional complex queries based on both functional and logical components. Our main improvement is a search expansion feature that uses a thesaurus to modify queries with synonyms. This can be very useful when a complex query does not return a sufficient number of results because the user is not using the same words in their queries as those used in the documents. This can be considered a "concept" query in which the system attempts to query a concept rather than a specific set of words. As shown in Figure 1, we also added a number of useful advanced sub-queries that can be combined including, "With all the words", "With the exact phrase", "With at least one of the words", and "Without the words." We include a range search, typically used for searching numerical fields, but can also be used lexicographically for arbitrary string fields. We also allow the user to define what it means to search "With the exact phrase." It can be a perfect match, a match in which the order of words can be swapped, or it can allow words to be completely reordered, essentially allowing a proximity search. Users can develop complex queries with little if any knowledge of the query language. Our system, through stemming, search expansion with synonyms, fuzzy search, and proximity search, allow users to easily find documents pertaining to what they want, without forcing them to define it precisely.

4. Conclusion and Future Work

The notion of a fully autonomous system capable of reading heterogeneous sets of images and accurately indexing them for retrieval is one that may be more of a hope than a reality. Despite decades of research in computer vision, nobody has been able to successfully bridge the semantic gap and replicate the human ability to visualize and classify. Document image retrieval systems have, however, been implemented and successfully replaced large paper archives. The systems often use the inaccurate, yet adequate, information from document image analysis to build the index for retrieval but return the error free image of the document as the result of a query. Such a system does not allow users to manipulate documents but can be practical replacement for paper archives. In this paper we described our implementation of such a system and the improvements it makes over existing systems. It has a richer query language and features such as search expansion, fuzzy search, term boosting, proximity search, facilitate searching by concept. It allows for searching based on both logical and functional components. Document image retrieval systems represent a paradigm shift in the way people will manage, share, and use documents. They allow us to make warehouses full of images searchable and instantaneously available to any computing device. These retrieval systems complement content only "keyword-based" retrieval systems commonly used by web search engines by providing richer ways to query a large heterogeneous document image repository the way a human would, through both visual characteristics and content similarity. Its economic, environmental, educational potential make research in this area a worthwhile endeavor.

Our system has been built with extensibility in mind so that features can be integrated into it easily in the future. One of our goals is to further allow the user to "query by concept" meaning they can query the corpus of data without being forced to precisely define what it is they want. One such feature that would facilitate this is to allow users to define queries based on a document example. This concept of query by example has become popular recently and been used in a number of ways for scene image databases. The problem with such a feature is that it is difficult to define what "similar" means in any particular domain. One user's notion of similarity may be completely different from another's. Nevertheless, we would like to implement the content and structure based similarity measure for query by example as described in [2].

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Frame Dropping Control by Video Content Characteristics under The Limited Bandwidth

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***Abstract*— Due to the limited bandwidth and the unpredictable network, the MPEG-4 video coding stream with Fine Granularity Scalability (FGS) can be flexibly dropped by very fine granularity to adapt to the available network bandwidth. However, this is a trade-off problem between to drop the partial frames to reduce frame rate and to drop the partial packets of frames to keep frame rate. We propose the weighted assignment scheme in order to dynamically control frame dropping by our scheduling algorithm when the bandwidth is not sufficient. Our proposed scheme not only can integrate with our optimal scheduling algorithm to maximize total important packets by the available bandwidth but can also control frame dropping by video content characteristics. In our experimental results, we analyze the frame rate preference for video content characteristics under the limited bandwidth. Based on the prior information for each test sequence, our frame dropping control scheme can be better than other fixed frame rate.**

I. Introduction

Decoding and re-encoding a stream at a different frame rate in real-time is not easy, particularly for MPEG and H.263 schemes which employ motion estimation techniques. Motion estimation is an extremely time-consuming process, particularly if a full motion search algorithm is employed. When the bandwidth is not sufficient, the sender cannot arbitrarily drop frames in the compressed domain because decoding of subsequent frames at the receiver depends on them. If the sender is to re-encode the video stream at a different frame rate, it would have to recompute the motion vectors.

One solution is the adaptation approaches which offer sub-optimal solutions to the problem of selecting the application settings that better fulfill the users expectations. These schemes encode and store the sequence at different frame rates (say 30, 24, 21, 18 fps and so on) to adapt the bandwidth requirement. This will take up a lot of space on the server. The second solution is the dropping approaches which sacrifice the unimportant data to save the bandwidth resource. The method stores only the largest frame rate (say 30 fps) to save a lot of space on the server, but it increases the complexity of scheduling to drop some frames under the insufficient bandwidth network.

In MPEG-4 Fine Granularity Scalability (FGS) framework, the basic video packets for the base layer are not allowed data dropping because the data may be needed during the decoding for the enhancement layer. The FGS framework with both the temporal and the SNR scalabilities requires three encoders: one for the base-layer and two for the enhancement layer. The base layer can ensure the basic acceptable QoS requirements of the user, while the enhancement layer can refine the result. Therefore, the important data to user must be satisfied the acceptable requirement. The FGS with hybrid temporal-SNR scalability has been added to the MPEG-4 video coding standard[1] in order to increase the flexibility of video streaming. The temporal scalability can be cut anywhere before transmission. The received part of the stream can be successfully decoded thus improving upon the basic video quality. The SNR scalability[2] can code a video sequence into two layers at the same frame rate and the same spatial resolution, but with different quantization accuracy. A higher accuracy discrete cosine transform (DCT) coefficient is obtained by adding the base layer reconstructed DCT coefficient and the enhancement layer DCT residue. The DCT coefficients with a higher accuracy are given to the inverse DCT unit to produce reconstructed image domain residues that are to be added to the motion-compensated block from the previous frame. When the amount of the data for the previous frame is considerably less than the predicted frame, the decoding will fail.

Our proposed method employs the dropping approach which discards the packets of the lower weight by a greedy scheduling algorithm. We survey some real-time scheduling research, most of them consider the measurement of miss ratio that computes the number of missing deadline tasks over the number of all tasks. The imprecise computation model in this field is similar to MPEG-4 FGS framework. The FAST algorithm proposed by Shih and Liu [3], [4] in the model has been proved with the optimization for the measurement of miss ratio. In our previous study [5], we found that the scheduling based on the earliest deadline first (EDF) policy does not work during the decoding in MPEG-4 FGS because it does not consider whether the dropping data will affect the decoding. Unfortunately, the FAST algorithm is based on the EDF. This results in the decoding failure. On the other hand, their algorithm does not consider the problem of adjusting the frame rate when the bandwidth is not sufficient for transmitting all the packets. Our scheduling algorithm will dynamically control frame dropping by our weighted assignment scheme for the MPEG-4 FGS framework.

The paper is organized as follows. Section 2 presents the related work. Section 3 states our system model and problems. We make use of the unit time tasks scheduling algorithm to solve the problem for maximizing total weights including the packets of the base layer in Section 4. Results of the experiment are shown in Section 5. The conclusions are drawn in Section 6.

II. Related Works

A network with limited bandwidth may not be able to deliver all the multimedia requests and fulfill all the QoS requirements. The dropping policy adopted by most research drops some data packets in order to satisfy the schedulability requirements. The dropping mechanism saves up the bandwidth utilization to satisfy the requests with the real-time constraints [6], [7], [8]. These researchers discover that discarding the frames of incurring peak rate can save the bandwidth.

Furini and Towsley[6] propose several frame dropping mechanisms to reduce bandwidth consumption subject to a QoS constraint. The proposed algorithms are evaluated by the JPEG and MPEG videos under the proposed bandwidth allocation mechanism.

Zhang et al.[7] propose an efficient selective frame discard algorithm for stored video delivery across resource constrained networks. They attempt to minimize the discarded frames to meet the constraints in JPEG videos.

Besides, reducing the frame rate can also save the bandwidth utilization. Pejhan et al.[9] propose a dynamic frame rate control mechanism. The scheme is to encode and store the sequence at different frame rates. It stores only the motion vectors for the lower frame rates, but this will take up a lot of space on the server. This way all motion estimation is done off-line. When re-encoding, motion vectors can be read from the motion files instead of being computed. The advantage of the scheme is that the motion files are much smaller than the corresponding compressed streams. The dynamic frame rate control, used in conjunction with dynamic bit-rate control, allows clients to solve the rate mismatch between the bandwidth available to them and the bit-rate of the pre-encoded bitstream.

Song and Chun[10] present a virtual frame rate control algorithm and a bit allocation algorithm at frame level for efficient MPEG-2 video encoding. The proposed frame rate control scheme is composed of three steps. At the first stage, the scan format of an input video sequence is converted into progressive scan format before video encoding. At the second stage, an average motion activity of the frames within a previous temporal window of a pre-defined size is examined, and a proper frame rate of a current temporal window is adaptively determined based on the computed average motion activity. At the final stage, the frames located at particular positions in a current temporal window are virtually skipped according to the determined frame rate. The scheme can skip the selected frames by deliberately fixing the coding types of all the macroblocks in those frames to skipped macroblocks.

Chan et al.[11] propose a structured Rate-Quantization base rate-control framework for low-delay video coding which contains three processing stages: the control of encoding frame-rate, bit-allocation for frame-level and the decision of quantization parameters for macroblock-level. At the first stage, the proposed framework decides the encoding frame-rate per group of pictures (GOPS) for better motion continuity. At the second stage, target-bit per frame is effectively estimated with the frame texture and buffer fullness. At the final stage, based on an adaptive Rate-Quantization model modified by the Kalman filter for each cluster of macroblocks, a suitable quantization parameter of each macroblock can be confirmed.

Song et al.[12] propose a new H.263+ rate control scheme which supports the variable bit rate (VBR) channel through the frame rate adjustment. In particular, a fast realization of encoding frame rate control based on motion information within a sliding window is developed to efficiently determine the tradeoff between spatial and temporal qualities.

Yang and Hemami[13] propose a frame rate-control scheme with a MINMAX distortion criterion in the framework of a rate-distortion (RD) optimized motion compensated embedded wavelet coder. The MINMAX criterion aims to minimize the maximum distortion in a group of pictures (GOP) for a given bit rate. The proposed frame level bit allocation scheme combined with RD optimized within frame allocation allows precise rate control up to the exact bit. A simplifying fast algorithm is developed using an initial prediction of the operating distortion and adaptive adjustment during GOP coding.

Lee and Kim[14] propose an adaptive video frame rate control method for the network of time-varying rate channel with explicit rate feedback. It consists of a prediction module of future channel rate and an adaptive frame discarding and skipping module. They derive an encoder buffer constraint which guarantees an end-to-end delay bound of video frames. Recursive Least-Squares(RLS) method is used as a tool to predict the low frequency component of channel rate. The adaptive frame discarding method prevents delay violation of frames due to the channel rate prediction error. Also, the frame skipping method adapt the encoder output rate to the channel rate while keeping the constant level of video quality.

III. System Model

A. System Model

Our system model based on MPEG-4 FGS framework is as Fig. 1. The hybrid temporal-SNR scalability with an all FGS structure supports both the temporal and the SNR scalabilities through a single enhancement layer[1]. Each multimedia streaming is made up of encoded frames such as Intra frame (I frame), Bidirectional frame (B frame) and Predicted frame (P frame). At the encoding time, the frame is coded using DCT for compressing the base layer and the enhancement layer.

The encoded data for the enhancement layer form a number of bitplanes. Every bitplane consists of 16×16 macroblocks, and each macroblock includes four 8×8 luminance blocks and two chroma blocks. In this stage, the frame rate is set to 30 fps. The sampling rate of the base layer is 3, i.e., one frame per three frames is encoded. The sampling rate of the enhancement layer is 1. The Group of Pictures (GoP) structure is set $IBBPBBPBBPBB$. The sampling rate of the enhancement for the SNR scalability must depend on the base layer, since the frames I and P are with SNR scalability enhancement. The frame B is with temporal scalability enhancement.

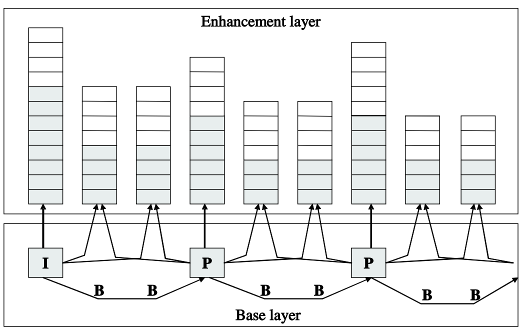

Fig. 1. The system model based on MPEG-4 FGS framework

At the transmission time, the compressed bitstream in MPEG-4 is divided the frames into some video packets with the same bit size in order to overcome the effect of a transmission error occurred in group of blocks. These packets are classified into three parts illustrated by Fig. 2. A packet of the base layer is regarded as a mandatory task, and a packet of the enhancement layer for both the the temporal and the SNR scalabilities is regarded as an optional task. In the model, performing a trade-off between the SNR and the temporal enhancement has to depend on an adaptive scheduling algorithm. We propose the weighted assignment scheme which employs the characteristics for the sequence content such as the motion and the texture. Fig. 2 illustrates the assignment example for keeping the original frame rate. The scheme can provide the priority of the packets for the scheduling algorithm to drop partial packets of the lower priority when the bandwidth is not sufficient.

At the decoding time, the packets of the base layer must be completely received. The packets of the enhancement layer for the temporal scalability can smooth the consecutive frames, while the packets for the SNR scalability can refine the image quality.

B. The problem of frame dropping control

We observe the relationship between the average bits for the motion characteristic in group of pictures and the frame rate. The higher motion characteristic the sequence suits with the larger frame rate. Fig. 3 illustrates the relationship. We also observe the relationship between the average bits for the

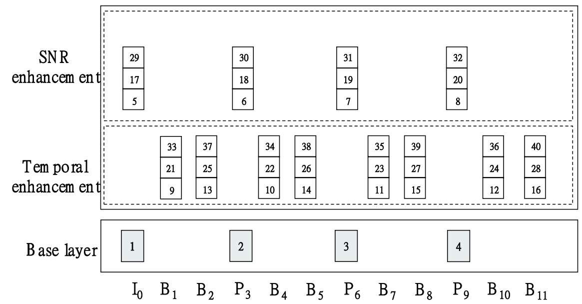

Fig. 2. The weighted assignment principle

texture characteristic in group of pictures and the bit rate. The higher texture characteristic the sequence suits with the larger bit rate. Fig. 4 illustrates the relationship. We aim at adjusting the adaptive frame rate according to our weighted assignment scheme when the motion and the texture characteristics have been known in advance. In our system model, the frame rate for each sequence is initially set to 30 fps. When the bandwidth is not sufficient, we drop the unimportant packets by our scheduling algorithm to adapt to the available bandwidth. We assign the weights to the packets for the video sequences of the different content characteristics by the mean opinion scores(MOS) of the subjective measurement in advance. The scheduling problem consider not only maximizing total weight, i.e, maximizing the number of important packets, but also controlling frame dropping under the constraint of satisfying the schedulability of the base layer.

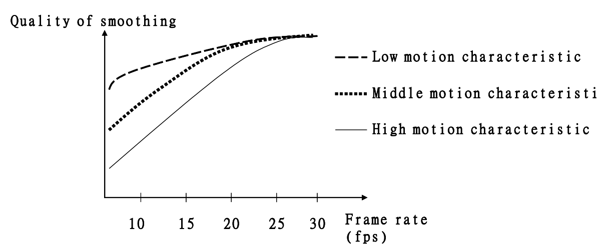

Fig. 3. The relationship between the motion characteristic and the frame rate

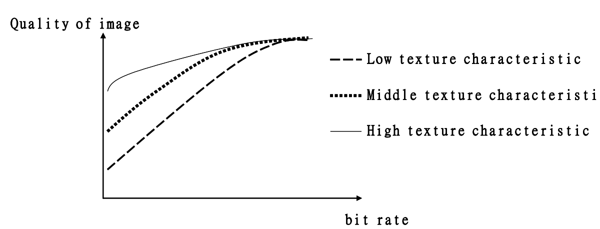

Fig. 4. The relationship between the texture characteristic and the bit rate

IV. Scheduling algorithm

A. The weighted assignment scheme

According to the prior information of the characteristics for the sequences, we can assign the weight to packets so as to control the frame dropping during the transmission. For example, we assign the weight to the packets of the frames shown in Fig. 5 when the sequence prefers 20 fps during some consecutive frames. The smaller number represents the higher priority. To illustrate the scheme, we consider 12 frames as a GOP and denote 6 frames as a half of GOP, called the HGOP. Then, 30 frames are divided into 5 HGOPs. Our original frame rate is set to 30 fps, so the number of the decoded frames is usually 20 fps if drops 2 frames per HGOP. When the bandwidth is not sufficient for transmitting most of data, the packets of the lower priority are always dropped. Therefore, the scheme can control the frame rate according to drop frames. Based on the weighted assignment scheme, the frame rate can be controlled by 30, 25, 20, 15, and 10 fps if drops 0, 1, 2, 3, and 4 frames per HGOP, respectively.

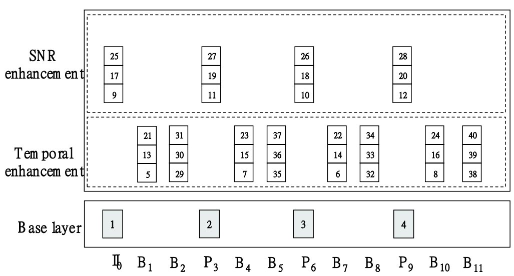

Fig. 5. The weighted assignment scheme for the preference of 20 fps

B. Satisfying the schedulability of the base layer

To solve the packets schedule problem, we employ a known scheduling algorithm, called the unit time tasks scheduling. The problem of scheduling unit time tasks with deadlines and weights has the following inputs: a set $T = T_1, T_2, \ldots, T_n$ of n unit-time tasks; A set of n integer deadlines such that each d_i satisfies $1 \leq d_i \leq n$; And a set of n nonnegative weights $w_1, w_2, \ldots, w_n$ such that w_i is offered for task T_i only if it is finished before the time d_i. This well-defined problem can find a schedule for T that maximizes the total weight and meets deadlines. This has been proved using the greedy algorithm of running time $O(n^2)$ to find the optimal schedule [15]. Table I shows an example of the unit time tasks scheduling. We use the unit time tasks scheduling algorithm to get the optimal schedule. Therefore, we can select tasks $1, 2, 3, 4$ and 6 according to the algorithm, and then reject task 5. This optimal schedule has a total weight of 275.

Table I. An example for the unit time tasks scheduling

task i	1	2	3	4	5	6
d_i	4	2	4	3	1	5
w_i	80	70	60	50	40	15

However, our problem is both to maximize the total weight and to satisfy the schedulability of the base layer. We define the problem as follows.

Problem 1. Follow the above definitions, we consider that the set of tasks is classified into the mandatory set of tasks and the optional set of tasks. This problem is to find a schedule including all the mandatory tasks for T that maximizes the total weight and meets deadlines.

We make use of the unit time tasks scheduling algorithm to solve Problem 1 by the theorems which have been proved in our previous study[5]. Therefore, the set of the optimal solution, S, found by the algorithm including the given set M if there exists at least a solution including the given set M and the weights of all the elements in M is added by a constant y. This problem is proved in Theorem 1. We define a new set T' based on the set T. The weights set T' is similar to the weights set T except that the weights of all the elements in a given set M, $M \subseteq T$, are added by a constant y where y is defined as $\sum_{t \in T} W(t)$. The weight of tasks in M can be expressed as $W'(t) = W(t) + y$, if $t \in M$, and $W'(t) = W(t)$, otherwise.

Secondly, Problem 1 for the set T is equivalent to Problem 1 for the set T' in Theorem 2. This means $OPT' = OPT + y * |M|$ where OPT' and OPT are an optimal solution for Problem 1 in the set T' and T, respectively.

Finally, Problem 1 for the set T' is equal to Problem 1 in Theorem 3. Therefore, according to Theorem 2 and 3 under the condition that there exists at least a solution including the given set M, this optimal solution of Problem 1 in the set T is equal to subtract a constant value, $y * |M|$, from the solution of Problem 1 in the set T'.

Theorem 1: A set of the optimal schedule solution, S, found by the algorithm for the set T' exist that the given set M is belong to S if there exists at least a solution including the given set M in the set T.

Theorem 2: Problem 1 for set T is equivalent to Problem 1 for set T', where $W'(t) = W(t) + y$ if $t \in M$ otherwise $W'(t) = W(t)$.

Theorem 3: The unit time scheduling problem for the set T' is equal to Problem 1 for the set T'.

Theorem 4: The unit time scheduling problem for the set T' is equivalent to Problem 1 for the set T.

V. Experiment results

In our experiments, we use the Microsoft MPEG-4 software encoder/decoder with FGS functionality[16]. We encode the videos using 30 frames per second with the CIF(352×288 pixels) format. Every sequence has 300 frames, then the encoded stream of a frame is divided into hundreds of tasks(packets). The data size of each task is set to 64 bytes. The videos are processed in the YUV format(Y is the luminance component, U and V are color components of a frame). The test sequence after encoding and scheduling under the limited bandwidth is made up of the truncated encoded file. We compute the PSNR of luminance for each test sequence. The sequences employed in our evaluation are well-known MPEG-4 test sequences.

The sequences adopted for the analysis contain various degrees with both the motion and the texture characteristics. In the "Akiyo" sequence, the motion characteristic is static background and talking head, and the texture characteristic is easy. In the "Foreman" sequence, the motion characteristic contains high motion in the first part of the sequence and low motion in the second part, and the texture characteristic contains also easy in the first part and detailed in the second part. In the "Stefan" sequence, the motion characteristic is very high and the texture characteristic is relatively detailed. In the "Mobile" sequence, the motion characteristic is slow and constant movement, and the texture characteristic is very detailed.

We compute the average bits of all frames for the motion characteristic shown in Fig 6 and the average bits of Intra frames for the texture characteristic shown in Fig 7, respectively. In our encoded data, the ratios of the base layer for the "Akiyo", the "Foreman", the "Stefan", and the "Mobile" sequences are 0.03, 0.03, 0.07, and 0.04, respectively. According to the information, our weighted assignment scheme can recognize the video content characteristics. In our previous study[17], we evaluated the perceived quality by the double stimulus continuous quality scale (DSCQS) method[18]to get the preference frame rate for each test sequence. The measurement is based on the mean opinion scores(MOS) of the respondents. Fig. 8 illustrates that the sequences "Akiyo" and "Mobile" prefer 10 fps and the sequences "Foreman" and "Stefan" prefer 30 fps under the insufficient bandwidth.

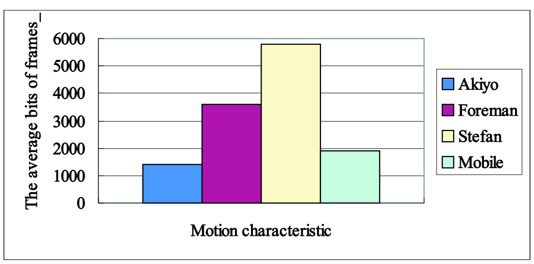

Fig. 6. The average bits of all frames for motion characteristic

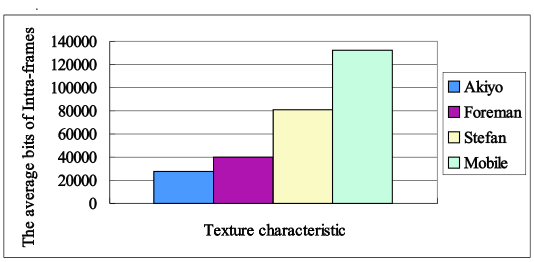

Fig. 7. The average bits of Intra frames for texture characteristic

We use the earliest deadline first (EDF) algorithm and the FAST algorithms as base lines to evaluate the performance of transmitted packets. We implement the FAST algorithm by [3], [4] and our scheduling algorithm to analyze the lost packets of the base layer. These algorithms can maximize the total number of packets. However, the EDF algorithm cannot deal with the problem for satisfying the schedulability of all the mandatory tasks. The FAST algorithm has been proved the optimal scheduling for CPU in the imprecise computation model, but it may fail to decode in MPEG-4 FGS by our previous study[5]. Our optimal scheduling algorithm, named OPT, has the optimal packets scheduling and guarantee successfully decoding in MPEG-4 FGS. Table II, III, IV, and V show the lost ratios and the lost packets of the base layer by various available bandwidth for each sequence.

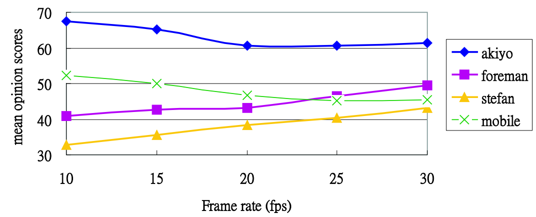

Fig. 8. The average mean opinion scores(MOS) by varying the frame rate for each sequence

Table II. The lost packets of the base layer for the "Akiyo" sequence

bandwidth(bps)	0.9M	1.0M	1.1M	1.2M	1.3M
lost ratio	0.75	0.72	0.70	0.67	0.64
EDF	0	0	0	0	0
FAST/OPT	0	0	0	0	0

Table III. The lost packets of the base layer for the "Foreman" sequence

bandwidth(bps)	1.2M	1.4M	1.6M	1.8M	2.0M
lost ratio	0.83	0.80	0.78	0.75	0.72
EDF	161	79	16	0	0
FAST/OPT	0	0	0	0	0

Table IV. The lost packets of the base layer for the "Stefan" sequence

bandwidth(bps)	2.4M	2.6M	2.8M	3.0M	3.2M
lost ratio	0.76	0.74	0.72	0.69	0.67
EDF	328	111	53	0	0
FAST/OPT	0	0	0	0	0

Table V. The lost packets of the base layer for the "Mobile" sequence

bandwidth(bps)	3.8M	4.0M	4.2M	4.4M	4.6M
lost ratio	0.72	0.71	0.70	0.68	0.67
EDF	218	3	0	0	0
FAST/OPT	0	0	0	0	0

To understand the effects of image quality for varying the frame rate, we show the relationship for each sequence in

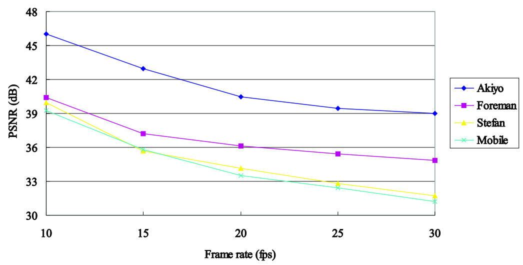

Fig. 9. The average PSNR by varying the frame rate for each sequence

Fig. 9. The figure illustrates that reducing the frame rate can increase the image quality when the bandwidth is not sufficient. However, the smoothing quality of consecutive frames cannot be measured by the PSNR.

We adopt the subjective video quality assessment to measure our performance. Table VI illustrates that the perceived quality based on the subjective measurement for our scheme can be better than other fixed frame rates when the bandwidth is not sufficient. This is because our scheme can control the frame dropping to adapt the preferred frame rate of video content.

Table VI. The analysis of effectiveness for our scheme

sequences	Akiyo	Foreman	Stefan	Mobile
MOS for our scheme	67.5	49.5	43.2	52.3
MOS for fixed 15 fps	65.2	42.7	35.6	49.9
MOS for fixed 20 fps	60.6	43.2	38.5	46.8
MOS for fixed 25 fps	60.6	46.6	40.5	45.2

VI. Conclusion

We have proposed the weighted assignment scheme to control frame dropping for MPEG-4 FGS framework when the bandwidth is not sufficient. Our scheduling algorithm not only can guarantee the schedulability of the base layer in MPEG-4 FGS framework but can also maximize total important packets when the available bandwidth is sufficient for all the packets of the base layer.

Our experimental result shows that our scheme can control the frame dropping to correspond to the preference for each test sequence. The mean opinion scores for our frame dropping scheduling algorithm can be better than other scheduling for the fixed frame rate.

Our weighted assignment scheme and the scheduling algorithm can drop the partial frames or keep all the frames as far as possible to adapt to various video content characteristics. The frame dropping scheduling mechanism contributes to MPEG-4 FGS framework under the limited bandwidth.

Acknowledgement

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Virtual Theater Network: Enabling Large-Scale Peer-to-Peer Streaming Service

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Abstract

This research paper addresses three technical challenges associated with the design of a large-scale, peer-to-peer, high-volume, streaming video distribution network: 1) contributions from peers with limited transmit bandwidth capacity, 2) advertisement and discovery of time-bounded video frame availability, and 3) design of P2P community structure that enables above functionalities.

To address above issues, we propose a video distribution model based on a hybrid architecture between client-server and peer-to-peer computing. In this model, a video is divided into a series of small segments. It employs a scheduling scheme through which users with excess bandwidth and buffer space may retrieve video segments from multiple sources at or below the nominal streaming rate. The model also employs an advertisement and discovery scheme through which users can share their complete sequence of time-varying video segment availability information in one advertisement and one query.

The simulation study shows that the proposed model greatly alleviates the bandwidth requirement of the video distribution server, especially when the number of participating users grows large. As much as 90% of load reduction was observed in some experiments when compared to a traditional client-server based video distribution model.

1 Introduction

With the advent of recent Internet technological advances, multimedia streaming service is gaining increasing importance. Video streaming applications, such as on-line DVD rentals, have a potential to enrich our lives and create new business opportunities.

As high performance end-user systems are becoming widely available and the number of subscribers to broadband Internet access is rapidly raising, a new computing paradigm known as *Peer-to-Peer* (P2P) has emerged. P2P enables direct exchange of contents among a group of end users without a need for a centralized management structure. In P2P, each user plays a dual role: a client role and a server role. Once a user nishes downloading a content through a client function, it takes on a server role to distribute the received content and services a small number of requests from other users while the resource is available. P2P offers a framework in which a large-scale, distributed, and self-organizing content distribution network can be constructed.

Although P2P has a potential to overcome the scalability problem associated with a traditional client-server based content distribution network, it introduces new set of challenges. First, a limited uplink capacity of a typical broadband access technology may only allow a transmission of a video stream at a fraction of the nominal streaming rate. Only a small percentage of the participating users may be able to become contributing sources when a bandwidth intensive content is being distributed. Second, streaming allows playback of video frames as they arrive. It also allows discarding of video frames once they are played back. Thus, the contents of user buffer is constantly changing during the life time of the video presentation. As such, the design of an advertisement and discovery scheme must capture the dynamic nature of video frame availability of participating users. Third, in order to support above functionalities, an ef cient and robust design of a P2P community structure is required.

To address these issues, we propose a new streaming video distribution network, called *Virtual Theater Network* and its accompanying video reception and discovery schemes. In this model, a video stream is divided into a sequence of segments. Users with excess receive bandwidth and buffer space are allow to prefetch future video segments at rates below the nominal streaming rate. The accompanying schedule algorithm determines the order, the timing, and the rate of each video segment download to ensure an orderly and timely segment reception for a smooth playback. The model also employs an advertisement and discovery scheme through which users can describe/capture their life-time of changing segment availability states in one advertisement/query. This is made possible by incorporating the parameters of scheduling algorithm in the advertisement and discovery scheme.

The remainder of this document is organized as follows. Section 2 surveys the related work. Section 3 presents the architecture and the components of Virtual Theater Network. Section 4 describes *Sliding Batch*, the video stream reception scheme used in Virtual Theater Network. Section 5 describes *Virtual Chaining*, the scheme for the advertisement and discovery of video segments among the users. Section 6 presents the analysis of a simulation study. Section 7 concludes the document.

2 Related Work

A number of attempts have been made to enable the deployment of P2P based streaming service over the Internet. Under the single-source distribution approach, a requesting peer receives the entire video stream from one of the peers in the network. Peers organize themselves to form chains [1], loops [2], or trees [3, 4] to provide video distribution paths that alleviate the load on the video server. Many of the schemes under this approach focus on the support of live-media applications, such as news tickers and real-time stock updates, which distribute low-bandwidth contents to many users. When stored-video streaming application support is intended, limited transmit bandwidth availability of typical broadband access technology is not considered and falls short in the support of high-bandwidth video distributions.

Under the multiple-source distribution approach, a requesting peer receives multiple video streams from multiple peers. The combinations or the concatenations of all streams allow the reconstruction of the entire video. Schemes such as [5, 6] split the video in multiple layers and each layer of decodable video stream is transmitted from different sources. While this approach avoids the total loss of service, it induces a large amount of overhead to support the functionality. Other schemes, such as [7, 8, 9], divide the video in time-axis and a sequence of segmented video is transmitted from different sources. Our scheme belongs to this category. The major difference between our scheme and others lies in the assumption of video segment availability at the distribution sources. Our scheme is based on an assumption that the availability of downloaded segments are time-bounded, as it is often the case in video streaming applications where received video frames are discarded after their playback. Other schemes assume, implicitly or explicitly, a long-term availability of downloaded contents at users' storage system. Our solution addresses the challenges associated with the advertisement and discovery of time-bounded content availability of P2P network and with the contributions from peers who are unable to send video stream at the nominal playback rate.

3 Architecture Design

This section presents the architectural overview of Virtual Theater Network, identifies its components, and describes their functionalities.

Virtual Theater Network is a network model designed to support a large-scale, on-demand, peer-to-peer, stored-video streaming service over the Internet. It is based on a hybrid architecture between a traditional client-server model and an emerging peer-to-peer computing paradigm.

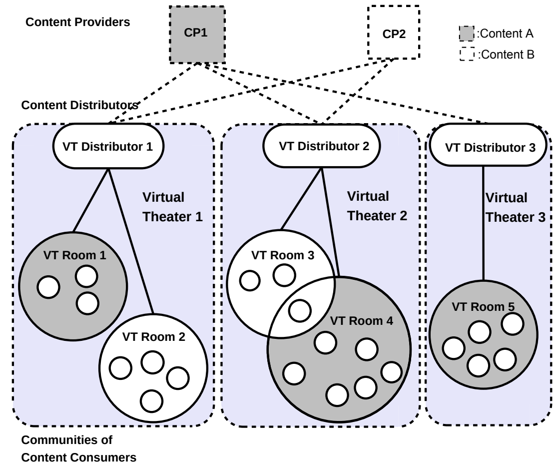


Figure 1. Virtual Theater Network

Central to this model is a set of *Virtual Theaters*. A Virtual Theater provides a means to mass distribute video streams to users in a certain geographical area, similar in function to that of movie theaters and video rental shops. Within each Virtual Theater, there exists a content distributor, known as *VT Distributor*, which receives video feeds from content providers (e.g. Dysney, MGM, Paramount). A VT Distributor organizes one or more *VT Rooms* to service local video distribution needs. A *VT Room* is a group of peers who form a P2P community to receive and distribute a video stream at a specific playback rate and in a specific encoding format. A cyber-cinema created by a VT Distributor and a set of VT Rooms constitute a Virtual Theater.

Fig. 1 illustrates the Virtual Theater Network model. In this example, two content providers, *CP1* and *CP2*, supply video feeds to a set of VT Distributors. CP1 provides a video feed to VT Distributors 1, 2, and 3. CP2 provides a video feed to VT Distributors 1 and 2. VT Distributors 1 and 2 manage two instances of VT Rooms (i.e. VT Rooms 1, 2, and 3, 4 respectively) while VT Distributor 3 only manage one VT Room (i.e. VT Room 5). Small circles within each VT Room represent peers. With the support from the respective VT Distributor, users of each VT Room work together to sustain the distribution of a streaming video.

The keystone of our proposed streaming service architecture is a dynamic and distributed storage space available at the members of a VT Room. To take advantage of this architecture, a video stream is divided into blocks of segments and dispersed at the caches of user systems at various locations in a VT Room. Users playback the video by locating and retrieving the segments in their playback sequence. As video segments are being downloaded, the user makes them available for others to access. Initially, when a VT Room is first organized, users receive streaming feeds from the VT Distributor. Once a sufficient number of cached and replicated video segments become available within the community, the distribution of streaming content becomes selfsustainable. Only those occasions where the needed video segments are unavailable within a VT Room, will the user request the missing segments from the VT Distributor.

4 Video Segment Reception Management

This section describes *Sliding Batch*, a video segment reception scheme used in a VT Room. It allows users of a VT Room to retrieve a video stream as a sequence of small video segments from multiple distribution sources. The scheduling algorithm de ned in Sliding Batch determines when and at what rate each video segment should be retrieved to assure an orderly and timely video playback. The algorithm is de ned in terms of *segments*, *epochs*, and *batches*. The following subsections provide their de nitions and describe how they relate to the management of the available receive bandwidth and buffer space to determine the scheduling of segment receptions.

4.1 Segments

A video stream is a continuous o w of a sequence of compressed video frames transmitted over a network so that the recipient may playback the video frames as they arrive. In Sliding Batch, a block of a sequence of video frames makes up a *Segment*, S_i. In turn, a sequence of segments constructs a video, V. S_i is a logical unit in V, similar to a chapter in a DVD, and may vary in size and length. It is also a unit of video frames being exchanged among the users of a VT Room. S_i is characterized by its sequence position, i, in V, a set of frames that belongs to S_i, its starting playback time, $\alpha(S_i)$, and a batch it belongs to, $\beta(e_j)$.

$$V = \{S_i, i = 1, 2, \cdots, N\}$$

$$S_i = \begin{cases} \{f_k, k = 1, 2, \cdots, n_i,\ \ n_i \leq F\} & \text{if } i = 1 \\ \{f_k, k = n_{i-1}+1, n_{i-1}+2, \cdots, n_i, \\ \qquad n_i \leq F\} & \text{if } 2 \leq i \leq N \end{cases}$$

$$S_i \cap S_j = \emptyset$$

$$\alpha(S_i) = \begin{cases} t_0 & \text{if } i = 1 \\ \alpha(S_{i-1}) + \delta(S_{i-1}) & \text{if } 2 \leq i \leq N \end{cases}$$

$$S_i \in \beta(e_j)$$

where N is the total number of segments in V, t_0 is the time the user joined the VT Room and began playing back the rst segment, S_1, and $\delta(S_i)$ is the playback duration of S_i.

Let $|V|$ and $|S_i|$ be the size of V and S_i respectively. Let $\delta(V)$ be the total duration of video playback time. Then, η, the nominal streaming rate of video is given by $\eta = |V| \,/\, \delta(V)$, where $|V| = \sum_{i=1}^{N} |S_i|$. Accordingly, the playback duration of S_i, $\delta(S_i)$, is de ned as $\delta(S_i) = |S_i| \,/\, \eta$.

The detail of $\beta(e_j)$ is given later.

4.2 Epochs

In Sliding Batch, a life-time of a video streaming is divided into a sequence of time intervals, known as *epochs*. An epoch, e_i, is characterized by its starting epoch time, $\alpha(e_i)$, its duration, $\delta(e_i)$, and its associated batch, $\beta(e_i)$. An e_i is closely related to the playback property of S_i as shown below:

$$\alpha(e_i) = \alpha(S_i)$$

$$\alpha(e_{i+1}) = \alpha(e_i) + \delta(e_i)$$

$$\delta(e_i) = \frac{\delta(e_i)}{\eta} = \delta(S_i)$$

Each epoch is associated with a batch, $\beta(e_i)$, and the details of their relationship are given next.

4.3 Batches

A *batch*, $\beta(e_i)$, is a set of segments whose downloading is initiated at the same time. There are N batches in a video as there are N epochs. Each batch consists of a set of segments that are unique to each batch, except for those batches that are of empty set. $\beta(e_i)$ is characterized by the following attributes: an associated epoch, e_i, a set of associated video segments, and a set of streaming sessions that are initiated at epoch e_i with rate r_j each.

$$V = \{\beta(e_i), \quad i = 1, 2, \cdots, N\}$$

$$\beta(e_i) = \begin{cases} \{S_j, j = 1, 2, \cdots, n_i, \\ \qquad n_i \leq N\} & \text{if } i = 1 \\ \{S_j, j = n_{i-1}+1, n_{i-1}+2, \cdots, n_i, \\ \qquad n_i \leq N\} & \text{if } 2 \leq i \leq N \text{ and } n_{i-1} < N \\ \emptyset & \text{otherwise} \end{cases}$$

$$\beta(e_i) \cap \beta(e_j) = \emptyset$$

Segments that belong to the same batch all start downloading at the same time at the beginning of the associated epoch.

$$A(S_j) = \alpha(e_i), \ \ \forall S_j \in \beta(e_i)$$

where $A(S_j)$ is the starting download time of S_j.

The ending download time of segment j, $\Omega(S_j)$, differs from segment to segment and it is the ending playback time of segment j.

$$\begin{aligned} \Omega(S_j) &= A(S_j) + \frac{\|S_j\|}{r_j} \\ &= \alpha(e_j) + \delta(e_j) \end{aligned}$$

where $\|S_j\|$ is the size of S_j in number of bits and r_j is the rate of S_j download. r_j is given by

$$r_j = \frac{\|S_j\|}{\Omega(S_j) - A(S_j)}, \ \ S_j \in \beta(e_i)$$

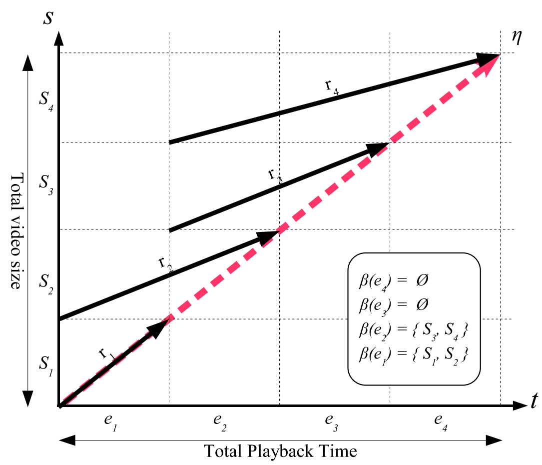


Figure 2. Relationship among segments, epochs, and batches

Fig. 2 illustrates the relationship among segments, epochs and batches in a simpli ed video reception scenario. In this example, a video is divided into $N = 4$ segments of equal length. Batch $\beta(e_1)$ consists of segments S_1 and S_2. Segment downloading for $\beta(e_1)$ was initiated at time $\alpha(e_1)$ for both S_1 and S_2 at rates r_1 and r_2 respectively. Batch $\beta(e_2)$ consists of segments S_3 and S_4. Segment downloading for $\beta(e_2)$ was initiated at time $\alpha(e_2)$ at rates r_3 and r_4 respectively. No segment is associated with $\beta(e_3)$ or $\beta(e_4)$.

4.4 Batch Sizes

One of the important parameters of Sliding Batch is the number of segments that belong to a batch, or the size of a batch, $|\beta(e_i)|$.

$$|\beta(e_i)| = min(\bar{N}(e_i),\ |\beta_R(e_i)|,\ |\beta_B(e_i)|)$$

where $\bar{N}(e_i)$ is the number of remaining segments yet to be downloaded at time $\alpha(e_i)$, $|\beta_R(e_i)|$ is the *rate-limited* batch size at time $\alpha(e_i)$, and $|\beta_B(e_i)|$ is the *buffer-limited* batch size at time $\alpha(e_i)$. The number of remaining segments, $\bar{N}(e_i)$, is de ned as:

$$\bar{N}(e_i) = \begin{cases} N & \text{if } i = 1 \\ N - \sum_{k=1}^{i-1} |\beta(e_k)| & \text{if } 2 \le i \le N \end{cases}$$

The rate-limited batch size, $|\beta_R(e_i)|$, refers to the size of a batch being computed based solely on the available receive bandwidth, R_A, and is determined by the maximum number of concurrent segment downloading sessions that can be sustained given the available receive bandwidth at time $\alpha(e_i)$.

$$|\beta_R(e_i)| = \begin{cases} m_i, & \text{if } i = 1 \\ \quad \exists max(m_i) | \sum_{k=1}^{m_i} r_k \le R_A(e_i), & \\ \quad m_i \le N & \\ m_i - m_{i-1}, & \text{if } 2 \le i \le N \\ \quad \exists max(m_i) | \sum_{k=m_{i-1}+1}^{m_i} r_k \le R_A(e_i), & \\ \quad m_i \le N & \end{cases}$$

Similarly, the buffer-limited batch size, $|\beta_B(e_i)|$, is computed based solely on available buffer size, B_A, at time $\alpha(e_i)$, as if there were in nite amount of receive bandwidth available. $|\beta_B(e_i)|$ is determined by the maximum number of concurrent segment downloading sessions that can be accommodated given B_A at $\alpha(e_i)$.

$$|\beta_B(e_i)| = \begin{cases} m_i, & \text{if } i = 1 \\ \quad \exists max(m_i) | \sum_{k=1}^{m_i} \|S_k\| \le B_A(e_i), & \\ \quad m_i \le N & \\ m_i - m_{i-1}, & \text{if } 2 \le i \le N \\ \quad \exists max(m_i) | \sum_{k=m_{i-1}+1}^{m_i} \|S_k\| \le B_A(e_i), & \\ \quad m_i \le N & \end{cases}$$

where $\|S_k\|$ is the size of batch in number of bits.

4.5 Receive Bandwidth Management

The receive bandwidth available at the beginning of the rst epoch, $R_A(e_1)$, is de ned as the total receive bandwidth, R_T, that can be set aside for the support of the streaming service. The available receive bandwidth for the beginning of the subsequent epoch is determined by how much bandwidth has been consumed in the previous epoch, $R_U(e_{i-1})$, and how much bandwidth has just been added due to the release of a segment reception session, r_{i-1}.

$$R_A(e_i) = \begin{cases} R_T & \text{if } i = 1 \\ R_T - R_U(e_{i-1}) + r_{i-1} & \text{if } 2 \le i \le N \end{cases}$$

The used received bandwidth, $R_U(e_i)$, during epoch e_i is given by

$$R_U(e_i) = \begin{cases} \sum_{k=1}^{m_i} r_k, & \text{if } i = 1 \\ \quad \exists max(m_i) | \sum_{k=1}^{m_i} r_k \le R_A(e_i), & \\ \quad m_i \le N & \\ R_T - R_A(e_i) + \sum_{k=m_{i-1}+1}^{m_i} r_k, & \text{if } 2 \le i \le N \\ \quad \exists max(m_i) | \sum_{k=m_{i-1}+1}^{m_i} r_k \le R_A(e_i), & \\ \quad m_i \le N & \end{cases}$$

4.6 Buffer Management

The total buffer space, B_T, consists of two buffer areas: the download buffer area, B_D, and the post-playback buffer area, B_H. B_D is used as a temporal storage space to buffer segments that are being downloaded. The size of downloading buffer, $|B_D|$, determines the maximum number of segments that can be downloaded at the same time (i.e. max. buffer-limited batch size). Based on $|B_D|$, the available buffer space, $B_A(e_i)$, and the used buffer space, $B_U(e_i)$, are computed by applying a similar logic and algorithm defined in the receive bandwidth management.

Let $\|B_D\|$ be the size of downloading buffer area in number of bits. The available buffer space, $B_A(e_i)$, at time $\alpha(e_i)$ is given by

$$B_A(e_i) = \begin{cases} \|B_D\| & \text{if } i = 1 \\ \|B_D\| - B_U(e_{i-1}) + \|S_{i-1}\| & \text{if } 2 \le i \le N \end{cases}$$

The used buffer space, $B_U(e_i)$, during epoch e_i is given by

$$B_U(e_i) = \begin{cases} \sum_{k=1}^{m_i} \|S_k\|, & \text{if } i = 1 \\ \quad \exists max(m_i) | \sum_{k=1}^{m_i} \|S_k\| \le B_A(e_i), \\ \quad m_i \le N \\ \|B_D\| - B_A(e_i) + \sum_{k=m_{i-1}+1}^{m_i} \|S_k\|, \\ \quad \text{if } 2 \le i \le N \\ \quad \exists max(m_i) | \sum_{k=m_{i-1}+1}^{m_i} \|S_k\| \le B_A(e_i), \\ \quad m_i \le N \end{cases}$$

The post-playback buffer area, B_H, is used to retain segments that have finished playing back. The size of post-playback buffer, $|B_H|$, determines the duration of time the segments will be held in a user system after their playback.

Fig. 3 illustrates an example of how a user may receive segments in a series of batches. In this example, a streamed video consists of 24 equal-size segments and segments are received in a total of 15 batches. The total receive bandwidth, R_T, of the user is twice as the nominal streaming rate of the video segment. The total download buffer space, B_D, can accommodate a maximum of 10 simultaneous segment downloads. Notice that the first two batches are bandwidth limited, the next eight batches, $\beta(e_3)$ through $\beta(e_{15})$, are buffer limited, and the final nine batch sizes are determined by the remaining number of segments, $\bar{N}(e_i)$, yet to be received.

4.7 User Profile and VT Room Profile

The parameters used in Sliding Batch for the computation of batch sizes are grouped into two types of profiles.

VT Room profile describes the attributes of a video distributed in a VT Room. They include parameters such as the size of a streaming video, $|V|$, its playback duration, $\delta(V)$, the total number of segments, N, and the size of each segment in number of bits $\{\|S_i\|, i = 1, 2, \cdots, N\}$. VT Room profile is given to all users in each VT Room at their join time by the VT Distributor.

User profile describes the attributes of an individual user, primarily its resource availability, and consists of the following parameters: the time a user joined a VT Room, t_0, the total receive bandwidth set aside for the streaming service, R_T, the downloading buffer size, $|B_D|$, which determines the maximum number of concurrent segment downloads, and the size of post-playback buffer space, $|B_H|$, which determines how long a segment will remain in buffer after its playback. Users in a VT Room advertise their user profile through the advertisement and discovery scheme described in the next section.

Sliding Batch significantly simplifies the advertisement of segment reception states of users. It enable users to express their complete segment reception order, timing, and rates from the first epoch to the last by advertising their user profile in one advertisement at the time of their VT Room join. Accordingly, one query is sufficient to know the entire video segment downloads and playback sequences of another user. In the following section, the details of how the user profile is shared among the users of a VT Room are given.

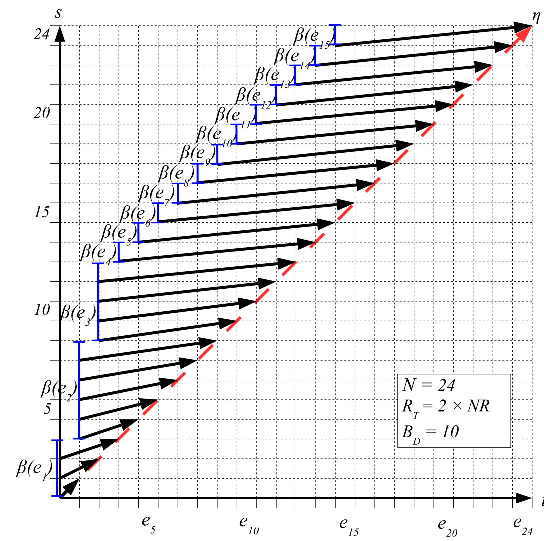


Figure 3. Sample segment receptions: bandwidth and buffer limited case

5 Segment Advertisement and Discovery

This section describes the video segment advertisement and discovery scheme used in a VT Room. *Virtual Chaining* allows users of a VT Room to cooperatively maintain a collection of user profiles, known as a *state table*, to share the segment reception state information of users. Through a selection process, users identify a set of prospective distribution sources from the state table. Virtual Chaining also defines a mechanism through which users communicate the changes in their transmit bandwidth availability. The details

IP	t_0	R_T	$\|B_B\|$	$\|B_H\|$	T_A	Time of Entry

Figure 4. Entry fields of a state table

of state table maintenance and distribution source identification procedures are described next.

5.1 State Table Sharing

A state table is a collection of user profiles maintained cooperatively among the members of a VT Room. It describes each user's segment reception state and the transmit bandwidth availability. An entry in the state table consists of the following fields: IP address of the user advertising its state, parameters of the user profile (t_0, R_T, $|B_B|$, $|B_H|$), available transmit bandwidth (T_A), and the time of its entry. This is depicted in Fig. 4.

The state table is shared among the users of a VT Room in the following manner. VT Distributor maintains the tail-end portion of the state table, which contains user profiles of the last M users who joined the VT Room. VT Distributor receives a user profile from each newly joining user and drops the oldest entry from the state table when its size becomes greater then M. A newly arrived user U_i receives the tail-end portion of the state table from the VT Distributor and examines the table to identify users who are capable of distributing needed segments. If the qualified distribution source is not found, U_i requests U_{i-M}, the oldest entry in the state table, to send its state table so that U_i may receive the user profiles of U_{i-M} through U_{i-2M}. This process is repeated until a qualified distribution source is located. If no qualified user is found after iterating through the chain of state tables, U_i requests VT Distributor to transmit the needed segment.

5.2 Distribution Source Identification

The selection of a distribution source from the state table is a two-step process. First, U_i identifies a set of *prospective* distribution sources. This is executed once at the time of VT Room join. Second, U_i identifies a *qualified* distribution source among the candidates. This process is executed for each segment download at the beginning of each epoch.

To be considered for a prospective distribution source, an entry in the state table must satisfy the following two requirements: playback distance requirement and segment availability requirement. The playback distance requirement states that U_i can receive a video segment from another user, U_j, only if U_i begins playing back the first video segment after U_j and before it is being dropped from U_j's post-playback buffer. The segment availability requirement states that U_i can receive a segment from U_j only if U_j began downloading the segment before U_i does.

To be qualified for and selected as an actual distribution source, the transmit bandwidth availability requirement must be satisfied. It states that U_i can receive S_k from U_j only if U_j has the sufficient transmit bandwidth to support a segment distribution session at rate r_k, as required by U_i. When multiple users qualify, the user who departs first from the VT Room will be selected. This is done to minimize the loss of unused resources in a VT Room.

In order for U_i to be able to identify a qualified distribution source, the time-varying transmit bandwidth availability of prospective distribution sources must be known. To achieve this, U_i subscribes to a transmit bandwidth change notification service at each prospective distribution source using a publish-subscribe method. Each time a change in transmit bandwidth occurs at a prospective distribution source, a notification message is sent to the subscribers through a point-to-multipoint link.

Due to its simple operation, Virtual Chaining is relatively easy to implement, deploy, and study its behavior. A distributed and redundant state table available at participating users offers resiliency such that a loss of a few users do not break the segment advertisement, discovery, or distribution operation. Virtual Chaining is fair, in terms of the carried workload among the users, that no single user is expected to perform more work than others. Virtual Chaining is also scalable in that the workload placed upon each user remains a constant regardless of the size of the membership in the P2P community.

6 Simulation Design and Analysis

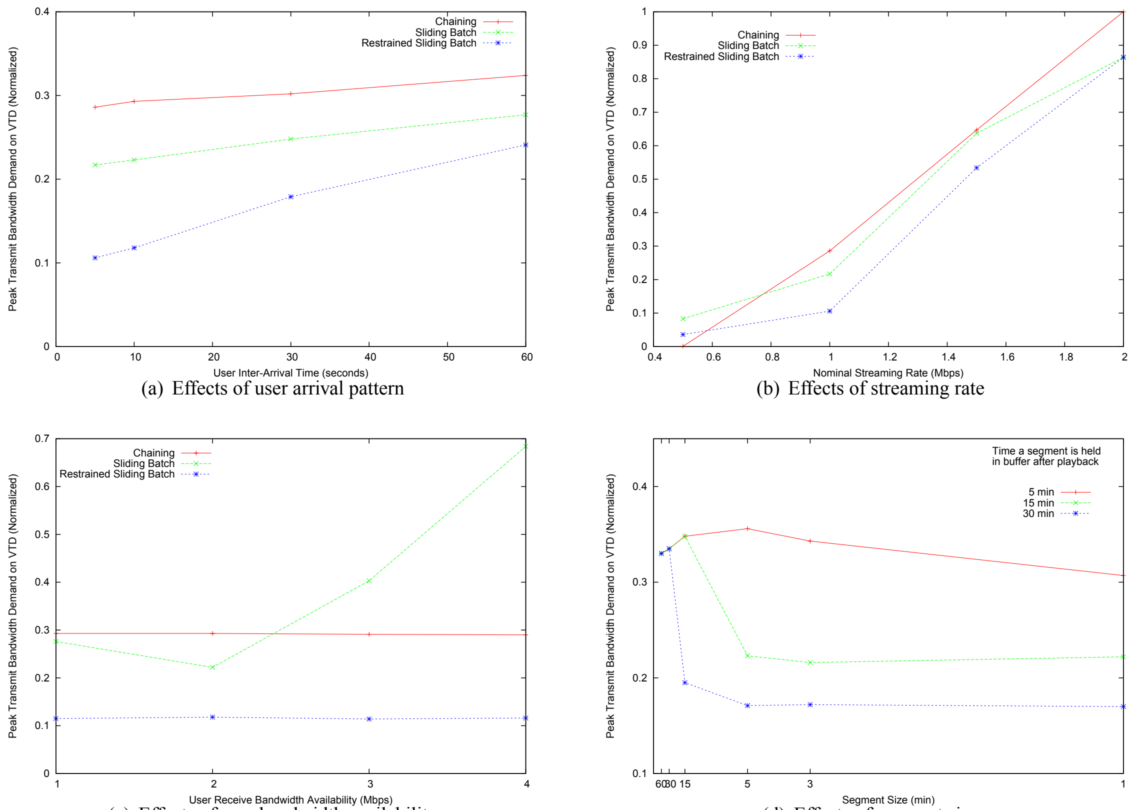
This section describes the design and analysis of experiments performed on Virtual Theater Network. A software model was created to simulate the behavior of a VT Room. The focus of the experiments was to study how well the proposed video distribution schemes would alleviate the load on the VT Distributor under different operating environment. Specifically , the peak transmit bandwidth usage of a VT Distributor is measured under different user inter-arrival times, nominal streaming rates, video segment sizes, and user receive bandwidth availability. The description of the model, the design of the experiments, and the analysis of simulation results are given below.

6.1 The Model Description

The simulated VT Room consists of a VT Distributor and a series of user processes that arrive to the VT Room. VT Distributor supplies the parameters defined in VT Room profile to the newly joining users, such as the total video playback time *(120 minutes)*[1], the nominal streaming rate *(1.0 Mbps)*, and the total number of segments *(24)* in the video. For simplicity, the video is divided into the equal length of segments and equal duration of playback time *(5 minutes)*.

The user processes simulate the behavior of peers joining the VT Room, discovering other users, identifying possible distribution sources, receiving video segments, distributing video segments as requests arrive, and departing from the

[1] The value in the parenthesis denotes the default value used in the experiments



(a) Effects of user arrival pattern
(b) Effects of streaming rate
(c) Effects of user bandwidth availability
(d) Effects of segment size

Figure 5. Measurement results on peak transmit bandwidth demand at VT Distributor

VT Room. The inter-arrival time of user processes is exponentially distributed *(mean 10 seconds)*. To re ect the asymmetrical nature of the transmit and receive bandwidth capacity of typical broadband access technologies, as well as the diversity in the amount of transmit bandwidth availability, each user is equipped with a xed receive bandwidth *(2.0 Mbps)* and varying transmit bandwidth *(30% to 100% of the receive bandwidth; uniformly distributed)*. Each user executes Virtual Chaining to identify possible distribution sources and implements Sliding Batch to receive video segments. All experiments simulate the bandwidth-limited network environment where suf cient amount of downloading buffer exists at each user ($|B_H| \geq N$). The default post-playback buffer size allows a segment to remain in buffer for a nate period of time *(15 minutes)* after its playback. The experiments are designed so that all users receive needed segments successfully and complete the viewing of the entire video.

6.2 Experimental Design and Analysis

Four sets of experiments are conducted, each measuring the effectiveness of proposed schemes in mitigating the bandwidth demand on the VT Distributor. They focus on the following areas: 1) the effects of user arrival patterns, 2) the effects of nominal streaming rates, and 3) the effects of user receive bandwidth availability, and 4) the effects of video segment sizes.

For each set of experiments, the measurements are taken on the peak transmit bandwidth usage of VT Distributor using the following schemes: a traditional client-server video distribution scheme, Sliding Batch, Restrained Sliding Batch, and Chaining [1]. A traditional client-server video distribution refers to a scheme where all users receive video feeds from a central server. The measurements taken from this scheme are used as the base-line and the measurements from other schemes are normalized to the base-line values when graphed. *Restrained Sliding Batch* is a variant of Sliding Batch and it limits the use of receive bandwidth at or below their initial available transmit bandwidth. In other words, a user is allowed to prefetch segments if the total segment downloading rate does not exceed the initial available transmit bandwidth. It tames the greedy nature of the Sliding Batch and further reduces the bandwidth demand on the VT Distributor. The simulation results from Chaining are used as a reference point. Chaining is a peer-to-peer based streaming video distribution scheme. A major difference between Chaining and Sliding Batch is that Chaining distributes video stream in its entirety from one user to another at the nominal playback rate while Sliding Batch distributes video stream in multiple segments at or below the nominal playback rate.

The rst set of experiments studies the effects of user inter-arrival times on the load at VT Distributor. The mean inter-arrival times of user processes are varied from 5.0 to 60.0 seconds while other parameters were kept constant. The simulation results are shown in Fig. 5(a). Restrained Sliding Batch offers as much as 90% of bandwidth reduction at the VT Distributor. Sliding Batch and Chaining achieved roughly 80% and 70% of bandwidth reductions respectively at their peaks. A common and assuraning trend observed among the three schemes was that the greater the rate of user arrivals, the greater the bandwidth reductions at VT Distributor. This is most appearent in Restrained Sliding Batch and is a sign of scalability.

The second set of experiments studies the effects of playback rates on the load at VT Distributor. The nominal playback rate of a video stream was varied from 0.5 to 2.0 Mbps. Under Chaining, the load on the video server increased linearly as the playback rate increased. Sliding Batch and Restrained Sliding Batch both have a milder incline when the playback rates are below the mean available transmit bandwidth of users. Chaining performed the best among the three schemes when the playback rate is very low. Sliding Batch and Restrained Sliding Batch both achieved a greater load reduction in all other regions of playback rates. This is depicted in Fig. 5(b).

The third set of experiments focuses on the effects of the amount of available receive bandwidth at users. As expected, a sharp increase in the bandwidth demand at VT Distributor is observed on Sliding Batch when users have a large amount of excess receive bandwidth. This is due to the greedy nature of Sliding Batch that it will prefetch a series of segments until all available receive bandwidth is consumed. In contrast, both Chaining and Restrained Sliding Batch maintain a constant level of transmit bandwidth demand at VT Distributor regardless of how much receive bandwidth is available at each user. Fig. 5(c) shows that Restrained Sliding Batch requires roughly one-third of bandwidth at VT Distributor than Chaining.

The nal set of experiments evaluates the impact of segment sizes to the load on VT Distributor. It also tries to build a relationship between the segment sizes (i.e. segment playback duration) and the post-playback buffer size (i.e. duration of time a segment is held in post-playback buffer). Segment playback duration is varied from *1* minute to *60* minute and each experiment is conducted with the post-playback buffer size of *5* minutes, *15* minutes, and *30* minutes. Fig. 5(d) shows that, generally speaking, lower bandwidth demand is placed on VT Distributor when segments are held in buffer for a longer duration of time after their playback. When the segment size is larger than the post-playback buffer size, the same amount of load is placed on the VT Distributor regardless of how long the segments are kept in post-playback buffer. A decrease in the bandwidth demand at VT Distributor is observed once the segment size becomes smaller than the post-playback buffer size. With 15-minute and 30-minute post-playback buffer experiments, a substantial amount of bandwidth decrease is observed for segment sizes down to 5 minutes; however, very little load change is observed beyond that point.

The above four sets of experiments have con rmed that peer-to-peer based streaming service can alleviate load on the video server in signi cant amount. They also gave an assurance that splitting a video stream into multiple segments and distributing them concurrently at rates below the nominal playback rate allow further reductions in the transmit bandwidth demand on the video server. Additional load reduction was achieved by taming the greedy nature of Sliding Batch by restraining the amount of segment prefetching.

7 Conclusion

We proposed *Virtual Theater Network*, a new video streaming distribution network model based on a hybrid architecture between client-server and P2P computing paradigms. In this model, streaming contents are divided into small pieces of segments and placed at the caches of participating users. Through *Virtual Chaining* and *Sliding Batch*, as well as its variant *Restrained Sliding Batch*, users advertise, discover, and distribute available segments in their caches among the users of the VT Room. A simulation study indicated a sign of scalability and a dramatic reduction in the transmit bandwidth requirement on the video server. Future work will focus on the support of QoS among the peers to provide a level of assurance in video segment receptions.

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Packet and Frame Rate Control Methods for Continuous Media over Heterogeneous Environment by Wired and Wireless Networks

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Abstract

In this paper, packet loss rate and frame rate control function for multimedia communication systems under heterogeneous environment by the wired and the wireless networks is proposed. In our suggested system, as channel coding, FEC (Forward Error Correction) method with Reed-Solomon coding is introduced to reduce the packet error rate on the wireless network. On the other hand, a frame rate control function is introduced on the source host receive host and the BS (Base Station). When it becomes larger for the rate of packet loss or delay, frame rate is changed, a frame can be chosen and be transmitted. Thereby, It can maintain the throughput of End-to-End while the packet error rate is reduced to the accepted value.

Keywords: QOS control, multimedia communication, FEC, Frame rate control, wireless network.

1. Introduction

In recent years, various multimedia services like multimedia conference system, streaming video, and VoD services have been realized by the development of the high speed and broadband of networks. Not only the present wired networks, such as Cupper-based LANs, optical fiber networks, or CATV-based networks but also wireless and mobile networks, have been used to heterogeneous network environments where the bidirectional multimedia communication is realized beyond the limits of time and space. Then, the usage of the heterogeneous network by the wired and wireless networks makes us to expect the realization of new applications like the advanced traffic system[1], the disaster prevention system, and the adhoc network system. However, the wireless network has essential problems as follows: 1) network bandwidth is not sufficient.2) packet delay is large.3) the bit error, namely packet error is high, compared with wired networks. Those problems cause difficulties for seamless communication through the wired and wireless networks. As example, current popular wireless network such as IEEE 802.11b with 2.4GHz and 11Mbps provides the packet loss by the bit error over wireless and causes service quality degradation when the communication distance is larger than a couple of Km or obstacles are existed between communicating stations. On the realtime bidirectional communication by the audio/video, the delay and jitter on packet arrival at the receiver make the realtime communication very difficult, eventually conducts the service quality degradation. To avoid these problems, it is necessary to introduce end-to-end QoS (Quality of Services) guarantee mechanism into the heterogeneous network environment. Moreover, if the reliable protocol like TCP is applied, the delay time due to retransmission for the lost packets would be increased, eventually the realtime communication would become difficult.

In order to solve those problems, we introduce, a new dynamic QoS control method based on the combination of channel coding and transcoding. As channel coding, FEC (Forward Error Correction) with Reed-Solomon coding [2,3,4] is used while various transcoding methods are used.

First, our suggested system can dynamically control the FEC redundancy to enable bidirectional realtime video communication and to reduce the packet error rate under the heterogeneous environment where the wired and wireless networks are interconnected. The packet error rate is periodically observed at the receiver side and feed backed to the sender side when the error rate varied. The number of redundant packets for error correction in the unit time is determined by observing packet error rate and the desired packet error rate. The FEC with Reed-Solomon coding is applied to both data packets and redundant packets at the sender side and the calculated packets are sent to the receiver side. The receiver side recalculates whether the packet error happened or not. If packet error happened, then error correction process is executed. Thus, the length of FEC redundancy is dynamically controlled to maintain the actual packet error rate at a constant on the end-to-end communication.

Next, transcoding method[5,6] as source coding is introduced to provide stable end-to-end multimedia service quality between the wired and wireless networks[1,7].

Transcoding can control the required network throughput even the FEC method generates additional redundant packet transmission and increases the required communication bandwidth. The transcoding is executed by the system functions by frame rate at the sender side and Receiver side and BS. Here, the controls of frame rate are dynamically fitted by the corresponding to change the network bandwidth and the user resources.

The reminder of this paper is organized as follows. The next section provides system configuration of interconnected wire and wireless networks. Section 3 introduces our suggested system architecture for QOS control of realtime multimedia communication system. The functional modules are shown in Section 4 . Section 5 explains the error recovery method by FEC and it dynamic control. Section 6 introduces the frame rate control system. Section 7 introduces prototyped network system and experiment. Finally section 8 presents the conclusions.

2. System Configuration

The multimedia communication services network currently assumed in this paper is organized by integration of wireless network such as IEEE 802.11b (2.4GHz, 11Mbps) and the wired network based on an optical fiber, as shown in Fig. 1. This interconnected network is constructed by fixed hosts (FH) like desktop typed personal computers, and mobile hosts (MH) like notebook typed personal computers.

FH and MH have video cameras and video capturing functions to facilitate realtime TV conference system or net meetings. The wired and wireless networks are interconnected by base stations (BS) which performs as gateway functions. Therefore, FH and MH can communicate with each other in both directions by end-to-end manner.

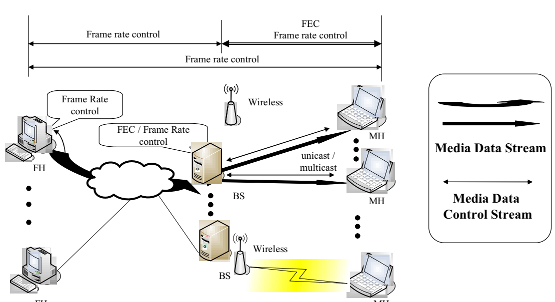

Fig1. The Heterogeneous Network by the Wired and Wireless Networks

However, since the interconnected network is consisted of the wired network which is based on sufficient resource environment and the wireless network which is not, especially because of the higher packet error rate due to the bit error rate on wireless environment, the end-to-end audio/video communication services cause service quality degradation. Therefore, when real time bidirectional communication by the audio/video is implemented using the interconnected network, the quality deterioration over audio/video streams due to the delay and jitter on packet arrivals at the receiver make the realtime communication very difficult. In order to solve these problems, it is necessary to introduce novel functions to guarantee end-to-end QoS in audio/video communication system through the wired and the wireless networks, as introduced in the next section.

3. System Architecture

In this paper, the system architecture of MidField System [8] is introduced. Fig.2. shows the system architecture to realize constructing dynamic intercommunication environment.

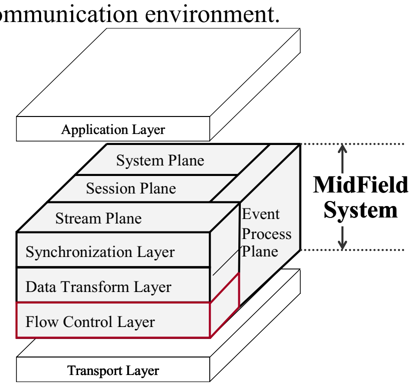

Fig2. System Architecture

This system architecture is between the application and the transport layer. The system is constructed by 3 layers and 4 vertical planes and offers multimedia communication functions to the application layer. Steam Plane is constructed by synchronization, data transform and media flow control layer, and performs multimedia stream processing. Session Plane performs management of communication sessions. System Plane monitors network traffic and CPU rate in the local host, and performs admission tests for QoS requirements from system user. Event Process Plane processes various events that are created in the system.

4. Functional Modules

The functional modules are realized in the MidField system. It is shown in Fig.3. The transcoding is executed by the system functions by frame rate at the sender side and Receiver side and BS. The FECCM

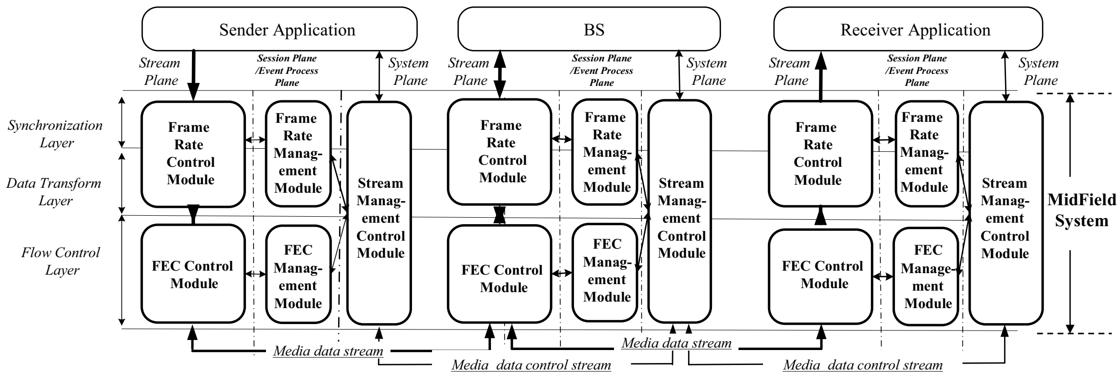

Fig3. Functional Modules

(FEC Control Module) and FECMM (FEC Management Module) function module are included in flow control layer. The FRCM (Frame Rate Control Module) and FRMM (Frame Rate Management Module) function module are included between synchronization layer and data transform layer. The FECMM measures and determines a packet loss . The FECCM performs processing packet that determined packet loss at FECMM. The FRMM measures and determines frame rate value. The FRCM performs processing frame rate that determined a frame rate value at FRCM. The SMCM (Stream Management Control Module) function is stream transmission processing.

5. Error Recovery by FEC

In the environment where a certain amount of packet error is allowed like this research, FEC is considered to be the very effective method when focusing on the importance of a time-critical characteristic. Compared with ARQ (the Automatic Repeat reQuest) which is a method to repeat transmitting the error or lost packets, FEC which carries the additional redundant data by the error correction code has the smaller calculation time during the recovery than the packet delay time by ARQ. Reed-Solomon (RS) coding as the FEC code was introduced to the media flow control layer in our system architecture as indicated in Fig 4.

When the number of the RS coding packets is set as n and the data packets set as k in a unit time, RS coding has the capability to correct n-k error packets when the position of the bit error in a packet is known. When many packet errors occur more than n-k pieces among n packets, the error probability after RS coding and recovering processes can expressed as,

$$E = \sum_{i=n-k+1}^{n} {}_nC_i e^i (1-e)^{n-i} \qquad (1)$$

Here, e presents the rate of the packet error between

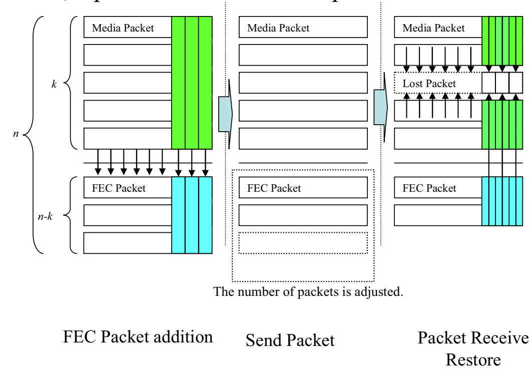

Fig 4. Reed Solomon Coding

the transmitted and receipt hosts. Since k is known value, E is determined by the value of n. If E is calculated for various cases of n in advance, target error rate can be calculated. Thus the error recovery power of RS coding is determined by n. Therefore, the packet error rate can be kept within the admissible value below by measuring e periodically, then calculating the E using formula (1) for the measured e and various n, and by feeding back the value of n which is equivalent to the admissible error rate E.

Even though the unexpected packet error may randomly cause beyond the predefined packet error rate, those packet error rate is periodically measured at the receiver side and suitable length n of RS coding packets can be calculated and dynamically feed back to the sender side. Therefore, the dynamic redundancy control for to maintain the packet error rate at constant can be attained.

6. Frame Rate control

The increase of the number of the transmitted packet per unit time between the data transform layers in both hosts by FEC redundancy when the burst error in bit transmission occurred can be kept constant by the same way during video communication service. The assumed end-to-end communication was realized by the introduction of transcoding. As typical network environment, wireless side doesn't have sufficient resources like the available bandwidth although the wired side does. Here, in order to realize the seamless end-to-end communication, Frame rate control were introduced for our transcoding between wired and wireless side.

The video frame rate is controlled according to the user's requirement and resource conditions. In case of Motion JPEG, any frames are simply sub-sampled to adjust to the desired rate. In the case of MPEG video which is consisted of a number of group of pictures (GOP). Furthermore, one GOP is consisted of I, B, P-pictures for inter-frame prediction and has mutual relation to each video frame. It is obvious the priority of I-picture is the highest and the priority of P-picture is higher than the B-picture, because I-picture is required to predict the P- and B-pictures and P-picture is required to predict B-pictures. Therefore, when sub-sampling of the MPEG frames is required, some of B-pictures are sub-sampling first, then P-picture and finally I-picture depending on the host and network load conditions. Besides, the transform of video coding was adopted among one coding to another such as Motion JPEG, MPEG-1, 2 4, H-261, -323 or Quicktime, etc.

7. Prototype and Experiment

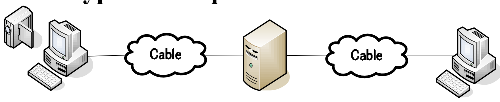

Fig5. Experimental Prototype

Table1. Experimental Parameters

Video Format Coding	**MPEG4**
Frame Size	**320x240**
Color Depth	**3byte(Full Color)**
Packet Size	**1200byte**
Frame Rate	**6fps**
Packet number/Frame	**20 Packet/Frame**

In order to evaluate the suggested method, an experimental prototype system was constructed as shown in Fig.5. where the sender host with video camera and receiver host are connected to middle host through the Ethernet. This middle host performs as a packet loss generator like a noisy wireless network. The transmitted video packets from sender are randomly lost on the middle host. Then the lost packets are arrived at the receiver side and decoded by FEC process. The packet loss rate was calculated on the receiver side and feedback to the sender side. The number of the redundant packets was controlled to maintain the target packet loss rate was 0.005. The Table 2 shows the number of the redundant packets for the observed actual packet loss rate.

Table2. The number of redundant packets

Packet loss rate	The number of redundant packets
0.00 - 0.01	2
0.01 - 0.02	4
0.02 - 0.03	6
0.03 - 0.05	8
0.05 - 0.08	10
0.08 - 0.12	16
0.12 - 0.15	22
0.15 - 0.20	34
0.20 - 0.30	62

In the experiment, the packet loss rate was changed for every 30 sec, namely 0 % for the first 30 sec, 2 % between 30-60 sec and again 0 % between 60-90 sec. and observed after FEC processing. As result, by controlling the number of the redundant packet due to feedback of the largest packet loss rate among the contiguous 10 times observation, the packet loss rate could be maintained to 0 % although more than 0 % for the first several seconds as shown in Fig. 6. The number of the redundant packets controlled based on the feedback information with packet loss from the receiver is shown in Fig. 7.

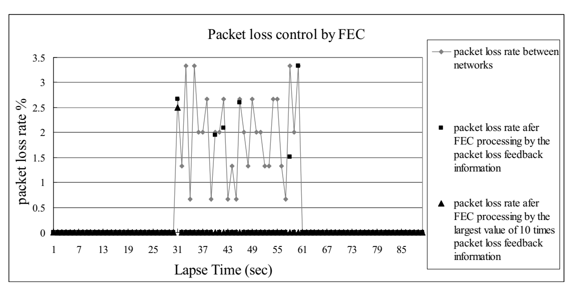

Fig6. Packet Loss Control by FEC

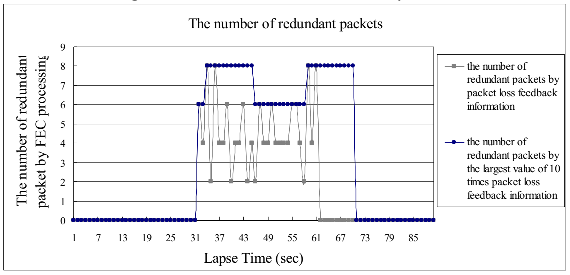

Fig7. The No. of Redundant Packets

Next fame rate control was carried out to reduce the increase of the required bandwidth due to the redundant packets. By sub-sampling the original fame rate at sender, the frame rate was reduced and maintained at constant as shown in Fig. 8. The original required bandwidth was about 1.2 Mbps and increased without frame rate control. By introducing the frame rate control as shown in Fig. 9, the required bandwidth could be maintained to the original value with 1.2 Mbps.

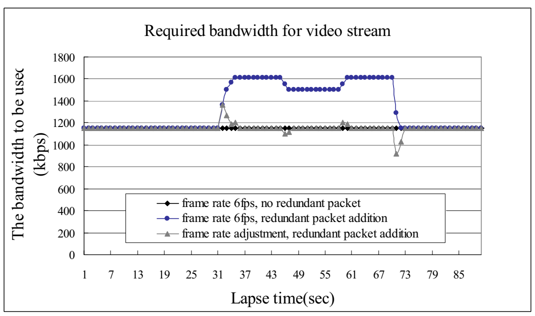

Fig8. Required Bandwidth for Video Stream

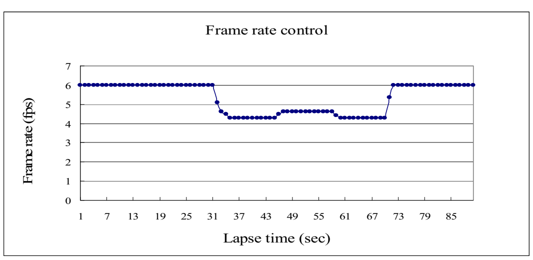

Fig9. Frame Rate Control

8. Conclusion and Future works

In this paper, packet loss rate and frame rate control function for multimedia communication systems under heterogeneous environment by the wired and the wireless networks was proposed. In our suggested system, as channel coding, FEC (Forward Error Correction) method with Reed-Solomon coding was introduced to reduce the packet error rate on the wireless network. On the other hand, a frame rate control function was introduced to maintain the required bandwidth. The experimental prototype system was constructed and carried out to evaluate our suggested method. Though this experiment, we could verify the usefulness and the effects of our suggested methods.

In a future work, the optimization of FEC process and experiment of multi-user and bi-directional video transmission over wired and wireless network environment will be carried out.

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A Recognition Framework based on LR Parsing for Hand-drawn Diagram

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Abstract

Sketching provides a natural way to express ideas during the early phases of design. The existing sketching systems provide good user interfaces but have only limited recognition capability for the graphical input. In this paper we present a framework for the recognition of hand-drawn diagrams that exploits LR parsing techniques to perform a context-based resolution of ambiguities in sketch drawing. The recognizer is automatically generated from a grammar specification, which allows diagram symbols to be defined hierarchically, and to specify the syntax of the language by composing the defined symbols.

1. Introduction

In recent years, there has been an increasing interest in the creation of computer software that works exclusively from freehand drawings, especially for the disciplines of engineering, software design, and architecture [4],[5],[6],[10],[11],[12],[17],[18],[21]. Underlying a sketch-based user interface several processes can be activated. These include the processing of pen strokes, recognition of symbols, stroke beautification [14], reasoning about shapes, and high-level interpretation.

The construction of sketch recognizers for new domain-specific languages is a non trivial and time-consuming task. Indeed, the recognition details of the new language are hand coded into the system and/or a considerable amount of training data are required to customize the system [2],[3].

The difficulties in the recognition process are increased by the lack of precision and the presence of ambiguities in messy hand-drawn sketches. Indeed, semantically different objects might be graphically represented by identical or apparently similar symbols. Sketch recognition systems should also not place constraints on how the users can draw a symbol [15]. They should be able to draw without having to worry about where to start a stroke, how many strokes to use, in what order to draw the strokes, etc. As a consequence, sketch understanding should include an ink parsing task that establishes which strokes are part of which shapes by grouping and segmenting the user's strokes into clusters of intended symbols [16].

In this paper we present a framework for the on-line recognition of hand-drawn diagrams [22]. The approach is based on the grammar formalism of Sketch Grammars for modeling diagrammatic sketch notations and for the automatic generation of the corresponding recognizers [9]. In particular, the formalism allows designers to hierarchically describe both the symbols' shapes and the syntax of diagrammatic notations and to obtain efficient recognizers whose parsing technique is based on LR parsing techniques [1]. These recognizers form the high layer of the sketch recognition system for a diagrammatic notation, while the low layer consists of a domain-independent primitive shape recognizer. Once integrated into a sketch editor, the proposed recognition system incrementally and unobtrusively interprets the sketches as they are created.

The proposed framework does not constrain users to a specific drawing style since the symbols of the diagrams can be drawn with a varying number of strokes and without a particular direction or order. Moreover, the approach exploits contextual information provided by grammars during the recognition of sketched ink. For example, when a recognized symbol is unique to a context then the recognizer uses this symbol to determine the context and thereby resolve pending recognition ambiguities.

The paper is organized as follows. In Section 2 we describe the grammar formalism for describing sketch languages. The recognition framework is presented in Section 3. Finally, the conclusion and further research are discussed in Section 4.

2. A grammar formalism for modeling sketch languages

In this section we describe *Sketch Grammars* (*SkGs*, for short) [9], a formalism used in the proposed recognition framework for modeling both the shape of the domain symbols and the abstract syntax of the sketch languages. SkGs are an extension of eXtended Positional Grammars (XPGs) [6], a formalism that overcomes the inefficiency of the visual languages syntactic analysis through efficient parsing algorithms based on suitable extensions of the well-known LR techniques [1].

The idea underlying the proposed formalism is to use the grammar productions for clustering the pen strokes of the input sketches into shapes of the domain language, and consequently for selecting the most appropriate interpretations for the input strokes provided by the primitive shape recognizer. The productions have also associated actions that allow designers to specify the display of the recognized shapes, to specify editing gestures [20], to define routines for verifying properties on the sketches.

The SkG formalism conceives the primitive[1] and domain symbol shapes as formed by a graphical representation and a *type*. The latter has associated a set of attributes, which are used to relate a shape to others, and their values depend on the "position" of the shape in the sentence.

*A*n SkG *G* can be seen as a particular type of context-free string attributed grammar (N, $T \cup POS$, S, P) where:

- N is a finite non-empty set of *non-terminal* shape types;
- T is a finite non-empty set of *terminal* shape types, with $N \cap T = \varnothing$;
- POS is a finite set of *binary spatial and temporal relation* identifiers, with $POS \cap N = \varnothing$ and $POS \cap T = \varnothing$;
- $S \in N$ denotes the starting non-terminal shape type;
- P is a finite non-empty set of *productions* of the following format:

$$A_{\Gamma} \rightarrow x_1(p_1)\, \mathbf{R_1}\, x_2(p_2)\, \mathbf{R_2} \ldots x_{m-1}(p_{m-1})\, \mathbf{R_{m-1}}\, x_m(p_m),\ Act$$

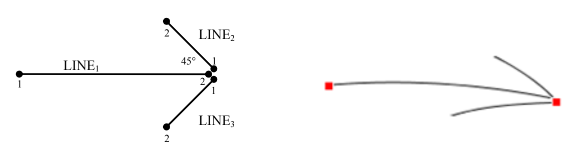
where

- A is a non-terminal shape type,
- Γ is a set of triples $\{(T_j, Cond_j, \Delta_j)\}_{j=1\ldots t}$, $t \geq 0$, used to dynamically insert new terminal shapes T_j in the input during the parsing process, enhancing the expressive power of the formalism [6].
- each x_i is a terminal or nonterminal shape type,
- each p_i is an optional value between 0 and 100 indicating the importance of the shape x_i in the modeled symbol, and
- each $\mathbf{R_j}$ is a sequence $(\langle REL_{j_1}^{h_1}(t_1),\ldots,REL_{j_n}^{h_n}(t_n)\rangle)$ with $1 \leq k \leq n$. Each $REL_{j_i}^{h_i}(t_i)$ relates attributes of x_{j+1} with attributes of x_{j-h_i}, with $0 \leq h_i < j$, by means of a threshold t_i. Notice that we denote $REL_1^0(0)$ simply as REL_1. Each $REL_{j_i}^{h_i}(t_i)$ may also be a temporal relation, in this case t_i represent the time value that relates the two shape types.
- *Act* specifies the actions that have to be executed when the production is reduced during the parsing process. These may include a set of rules used to synthesize the values of the attributes of A from those of x_1, x_2,…, x_m, a set of display instructions used to display properties of the sketches (such as their attributes) after the strokes are recognized, semantic routines, etc. The actions are enclosed into the brackets { }.

Thus, SkGs specifies a sentence by combining symbols with spatial and temporal relations. The idea of associating *importance values* to the shapes of the productions comes from noting that the symbols of a particular domain have different structural complexity. As an example, use case diagrams include actor symbols, which are obtained through the composition of several strokes, and communication symbols, which are simple lines. Thus, importance values can be associated to the complex domain symbols in order to allow the generated recognizers to associate to the partially recognized symbols a value that, as we will show in the following section, aids the recognition of messy or incomplete symbols. Indeed, the shapes that allow us to distinguish a symbol from the others with a high degree of certainty will have associated a high importance value.

The following production specifies the *Arrow* symbol.

Arrow → $LINE_1(60)$ **<*$joint_{2\_1}(t_1)$*, *rotate*(45,t_2)>** $LINE_2(20)$
<*$joint_{2\_1}^{1}(t_3)$*, *$rotate^{1}$*(-45,t_4)> $LINE_3(20)$,
{ Arrow.attach(1) = $LINE_1$.attach(1);
Arrow.attach(2) = $LINE_1$.attach(2) $\cup$ $LINE_2$.attach(1) $\cup$ $LINE_3$.attach(1);
Arrow.attach(1).Show("red");
Arrow.attach(2).Show("red");}



(a) **(b)**

Figure 1. The Arrow symbol (a) and the layout of a sketched arrow after the recognition (b).

[1] The primitive shapes are patterns that must be recognized directly, such as line segments and elliptical arcs.

The *Arrow* symbol is composed by three lines, as shown in Fig. 1(a) (the attributes are represented with bullets). The attribute 2 of $LINE_1$ is jointed to the attributes 1 of $LINE_2$ and $LINE_3$, and the latter are rotated with respect to the former of 45 and -45 degrees, respectively. The values $t_1,\dots,t_4$ specify the error margin in the satisfaction of the relations. The attributes 1 and 2 of *Arrow* are calculated from the values of the attributes of the three lines. Moreover, the *Show* method invoked on such attributes visualizes the start and end points of the arrow in red color when a sketched arrow is recognized by using the previous production, as shown in Fig. 1(b). Finally, the importance values indicate that the shaft of the *Arrow* symbol has a greater weight with respect to the other segments for discriminating an incomplete arrow symbol.

Temporal relations are particularly useful for defining multi-stroke editing gestures such as deleting, moving, copying, because they constrain users to draw the sequence of strokes forming such gestures within a fixed time. As an example, the following production defines an editing gesture formed by a circle with a line inside it, which logically groups the set of strokes inside the circle. Notice that the line must be drawn within t_4 milliseconds after the circle has been drawn.

$$\text{Group} \rightarrow \text{CIRCLE} \langle contain(t_1), joint_{1\_1}(t_2), joint_{1\_2}(t_3), \mathbf{before(t_4)} \rangle$$
$$\text{LINE},$$
$$\{ \text{SET selection = CIRCLE.contain; selection.group = true;} \}$$

SkG grammars are used to define both the *symbol grammars*, which specify the shapes of the language as geometric compositions of primitive shape, and the *language grammars*, which specify the sentences of the language as composition of the shapes defined by symbol grammars through spatial relations. For example, the following symbol grammar production specifies an *Actor* symbol of a use case diagram.

$$\text{Actor} \rightarrow \text{Ellipse}(45) \langle joint_{1\_1}(t_1) \rangle$$
$$\text{Line}_1(25) \langle near(t_2), near^1(t_3) \rangle$$
$$\text{Line}_2(12) \langle joint_{2\_1}(t_4), near^1(t_5), near^2(t_6) \rangle$$
$$\text{Line}_3(3) \langle {joint_{2\_1}}^2(t_7), rotate^2(135,t_8) \rangle$$
$$\text{Line}_4(12) \langle {joint_{2\_1}}^3(t_9), rotate^3(135,t_8) \rangle \ \text{Line}_5(3),$$
$$\{ \text{Actor.attach}(1) = \text{Ellipse.attach}(1) \cup \text{Line}_1\text{.attach}(1); \}$$

The non-terminals *Ellipse* and *Line* cluster the single stroke arcs that form an ellipse and the parallel single stroke lines, respectively.

The following language grammar production defines a sub-sentence of a use case diagram as the non-terminal *Sub* formed by an *Actor* connected through a *Line* to a *UseCase* non-terminal.

$$\text{Sub} \rightarrow \text{Actor} \langle joint_{1\_1}(t_1) \rangle \ \text{Line} \langle joint_{2\_1}(t_2) \rangle \ \text{UseCase},$$
$$\{ \text{Sub.attach}(1) = \text{Actor.attach}(1) \cup \text{UseCase.attach}(1); \}$$

3. The recognition framework

The recognition approach proposed in this paper exploits the context provided by grammars during the recognition of sketched ink. For example, when a recognized symbol is unique to a context then the recognizer uses this symbol to determine the context and thereby resolve pending recognition ambiguities. Moreover, the recognition process focuses on the shape of the strokes as opposed to other features, such as drawing speed and size. In this way, the system will not place single stroke requirements on the users, allowing users to draw the shapes as they would naturally.

As shown in Fig. 2, the process of definition of a sketch recognition system starts by specifying a grammar for each symbol of the domain language. As an example, for state transition diagrams the designer must specify a grammar for each one of the following symbols: state, initial state, final state, initial and final state, and transition. Next, a grammar is specified that models the abstract syntax of the language, i.e., the possible relations between the symbols. For each one of these grammar specifications the *Parser Generator* constructs the corresponding recognizer.

The recognition process consists in three phases. First the strokes are interpreted as primitive objects, such as lines, arcs, ellipses, etc., by using a domain independent recognizer. Then, symbol recognizers cluster the primitive objects in order to identify possible domain symbols. Finally, the language recognizer analyzes these candidate symbols produced by the symbol recognizers, prunes some of the symbol interpretations according to the recognition context, interacts with symbol recognizers to force the recognition of incomplete symbols, and selects the more suitable interpretation.

In the following we describe the three recognizers that constitute the three layers of the sketch recognition system shown in Fig. 2. The recognizer at the lower layer is activated each time a new stroke is entered into the edited diagram and the result of the recognition process is provided on demand to the sketch editor by the recognizer at the higher level.

3.1. The primitive shape recognizer

As shown in Fig. 2, the first task of the sketch recognition process is the classification of the pixels composing the strokes into primitive geometric

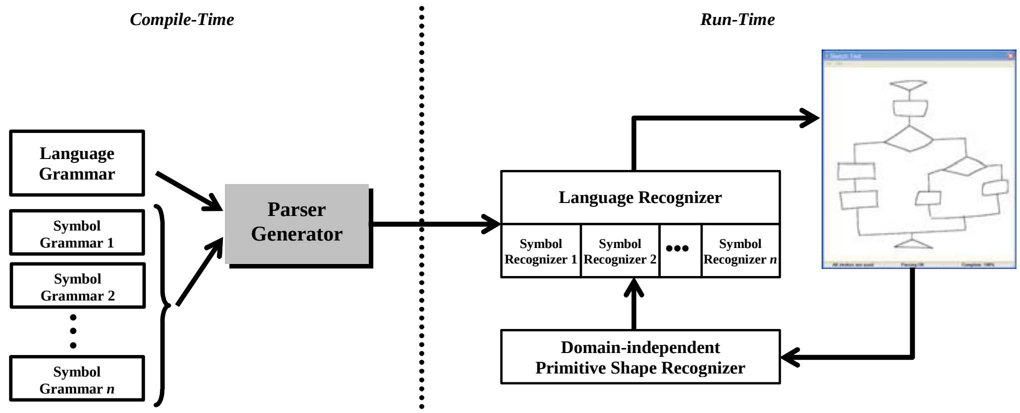


Figure 2. The process of generation of the sketch recognition system.

objects. This task is performed by the primitive shape recognizer whose architecture is shown in Fig. 3.

In order to support the recognition of multi-stroke symbols the stroke to be classified should be suitably split into single-stroke segments by exploiting stroke information such as curvature, speed and direction. This is accomplished by the segmentation algorithm of the *SATIN* toolkit [13]. Such segments are classified by using *Quill* [19], a domain-independent gesture recognition system, which has been properly trained on the primitive shapes used for the classification. Finally, a post-process is applied to the identified segments in order to eliminate possible redundancies. In particular, primitive shapes satisfying particular conditions are merged into single strokes. As an example, two connected line segments with nearly the same angle (two connected arcs with nearly the same center and radius, resp.) are represented with only one line (arc, resp.) stroke. Thus, for each input stroke the primitive shape recognizer outputs a sequence of substrokes with associated a classification of their most similar primitive shapes.

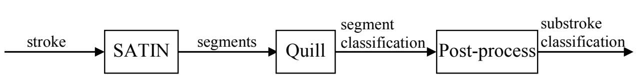


Figure 3. The architecture of the primitive shape recognizer.

3.2. The symbol recognizer

Symbol recognizers try to cluster into symbols of the domain language the classified segments produced by the primitive recognizer. The parsing technique underlying such recognizers is an extension of the approaches proposed in [7] and [8]. In particular, the parsers scan the input in an incremental and non-sequential way, driven by the spatial relations specified in the grammar productions.

The input to the incremental parser is formed by the new shapes produced by the primitive shape recognizer and stored in a dictionary, a parse tree and a graph stack built on the strokes analyzed so far. The parser restructures the parse tree, which represents the recognized strokes, on the base of the new strokes and updates the graph stack. Each node of the tree might have associated a value representing the importance rate of the strokes associated to the leaves of its subtree. In particular, such value is computed during the reduction of the applied productions by using the importance values associated to the symbols of the grammar. The output of the symbol recognizer is obtained by analyzing the parse tree and the graph stack. In particular, the interpretation is composed by the triple: *name* of the symbol, *sequence* of the strokes analyzed by the parser, which corresponds to the leaves of the parse tree, and eventually the *importance rate* obtained by the sum of the importance values associated to the grammar symbols in the graph stack.

Fig. 4 shows the recognition process of an actor symbol. In particular, from the bottom to the top it shows the incremental editing of the symbol, the primitive shapes (more similar to the last edited stroke) identified by the primitive shape recognizer, and how the symbol recognizer incrementally constructs the parse tree. Note that the third edited stroke is segmented in two substrokes.

3.3. The language recognizer

The language recognizer analyzes the interpretations produced by the symbol recognizers and applies its knowledge of the domain context to select the best interpretation, to force the recognition of incomplete or inaccurate symbols, and to prune the execution of unnecessary active symbol recognizers, thus improving the efficiency of the overall recognition approach.

Each time the user draws a new stroke the output of the primitive recognizer is given in input to all active symbol recognizers. The ones that are not able to compound the new interpreted strokes with those previously parsed reject the new strokes and wait for the next ones. The other recognizers give their new interpretations as input to the language recognizer. In any case new symbol recognizers are launched on the new strokes since they can be part of a new symbol. The language recognizer includes a non-deterministic parser [8], generated from the language grammar, which analyses the symbol interpretations produced by symbol recognizers and eventually uses the importance rates associated to them for selecting the most suitable. In some cases the language recognizer is also able to prune active symbol recognizers. In particular, when a symbol interpretation *S* reaches a predefined high importance rate it discards the active recognizers whose analyzed strokes are also in *S*. Moreover, when two different symbol interpretations are such that the strokes of one are a subset of the other the symbol recognizer analyzing the strokes of the first interpretation is pruned.

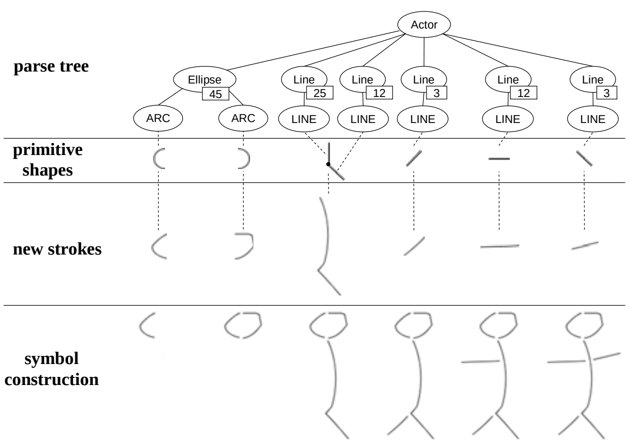


Figure 4. Incremental recognition of an actor symbol.

Fig. 5 shows the incremental editing and recognition of a use case diagram portion. At each editing step the figure shows the symbol interpretations provided by the active symbol recognizers and highlights the choices made by the language recognizer. In particular, the selected interpretations are indicated with a check-mark, whereas those pruned with a cross-mark. The user starts by sketching the head of the actor symbol with a single stroke, as shown in Fig. 5(a). The symbol recognizers able to parse such stroke are the *actor* recognizer with an importance rate of 45 and the *use case* recognizer. Obviously, the candidate symbol to be selected by the language recognizer is the *use case* interpretation since it is a complete symbol.

Successively, the user draws with a single stroke the body and a leg of the actor symbol as shown in Fig. 5(b). In this case, the new stroke is segmented into two line segments and only the *actor* recognizer is able to compound the lines to the previously recognized strokes with an importance rate of 82. Moreover, other recognizers are lunched on the new strokes. In particular, those that recognize symbols containing a line segment are active on the two new strokes.

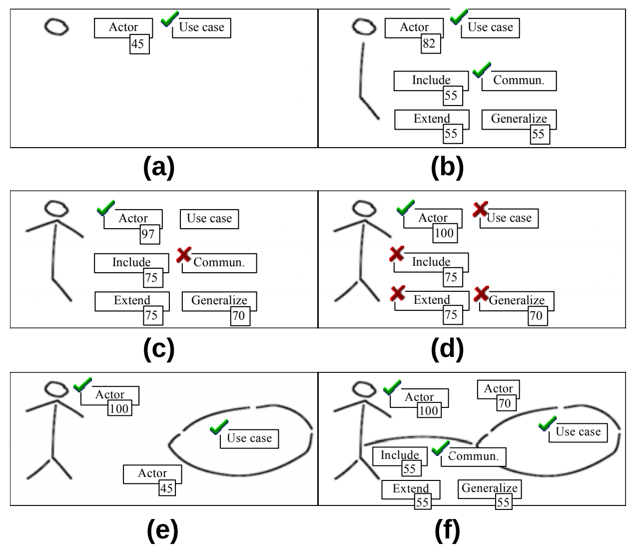


Figure 5. The incremental recognition of a use case diagram.

In this case, the language recognizer selects the complete interpretations provided by the *use case* and *communication* recognizers. When the user draws the arms of the actor (see Fig. 5(c)) the interpretation of the active actor recognizer reaches an importance rate of 97 that is enough for the language recognizer to disambiguate the actor symbol from the others. Moreover, it prunes the *communication* recognizer since it interprets a stroke that is included into the *include* interpretation. In Fig. 5(d) the actor symbol is completely drawn and the language recognizer discards the remaining active recognizers. After the sketching of a use case symbol with three strokes (see Fig. 5(e)), which is interpreted by *use case* and *actor* recognizers, the user draws a communication symbol connecting them as shown in Fig. 5(f).

4. Conclusions and future works

We have presented a framework for the recognition of hand-drawn diagrams based on LR parsing techniques. Symbol and language recognizers are automatically generated from grammar specifications modeling the symbol shapes and the abstract syntax of diagrammatic notations [9]. The obtained recognition system consists of three hierarchically arranged layers that include context-based disambiguation and ink parsing. In particular, the user' strokes are first segmented and interpreted as primitive shapes, then clustered into symbols of the domain by using the grammar-based symbol recognizers, and finally the best sentence interpretation is selected by exploiting the domain context of the recognizer of the diagrammatic notation.

In the future we intend to perform user studies in order to understand the limitations of the proposed parsing strategy. Moreover, we plan to integrate error correction techniques for improving the recognition effectiveness and symbol prompting strategies for assisting users during the drawing process [8].

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Enhancing the Expressiveness of Spider Diagram Systems

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Abstract

Many visual languages based on Euler diagrams have emerged for expressing relationships between sets. The expressive power of these languages varies, but the majority are monadic and some include equality. Spider diagrams are one such language, being equivalent in expressive power to monadic first order logic with equality. Spiders are used to represent the existence of elements or specific individuals and distinct spiders represent distinct elements. Logical connectives are used to join diagrams, increasing the expressiveness of the language. Spider diagrams that do not incorporate logical connectives are called unitary diagrams. In this paper we explore generalizations of the spider diagram system. We consider the effects of these generalizations on the expressiveness of unitary spider diagrams and on conciseness.

1 Introduction

Recent times have seen various formal diagrammatic logics and reasoning systems emerging [6, 13, 17, 25, 26, 31, 33]. Many of these logics are based on the popular and intuitive Euler diagrams augmented with shading. The diagrams in figure 1 are all based on Euler diagrams.

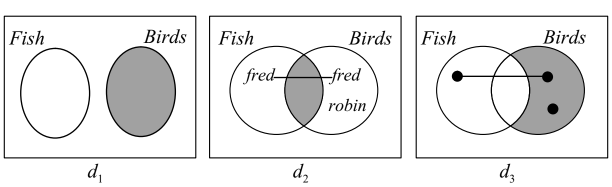

Figure 1. Various extended Euler diagrams.

The diagram d_1 expresses that there are no birds (by the use of shading) and that nothing is both a fish and a bird (since the two circles have disjoint interiors). The diagram d_2 is an Euler/Venn diagram [31] and expresses that nothing is both a fish and a bird (by the use of shading) and there is something called $fred$ that is either a fish or a bird, but not both. Furthermore, $robin$ is a bird but not a fish. Note that $fred$ and $robin$ could represent the same individual. Euler/Venn diagrams use shading to express the emptiness of a set and *constant sequences* to make statements about specific individuals. Finally, d_3 is a spider diagram [16] and expresses that something is either a fish or a bird but not both and there is at least one but at most two elements in the set $Birds - Fish$ (by the use of *existential spiders* and shading). So, by contrast to Euler/Venn, spider diagrams use shading to place upper bounds on set cardinality and spiders place lower bounds on set cardinality. Whilst the spiders in d_3 represent the existence of elements, spider diagrams use *constant spiders* to make statements about specific individuals.

Others have introduced diagrammatic logics based on Venn diagrams which form, essentially, a fragment of the Euler diagram language. Peirce used $\otimes$-sequences to assert non-emptiness and, instead of shading, o-sequences to assert emptiness [23]. The diagram d_1 in figure 2 is a Venn-Peirce diagram and expresses that $Fish - Birds = \emptyset$ or $Birds - Fish \neq \emptyset$. This example illustrates a key difference between the use of shading and the use of o-sequences because the statement made is disjunctive. The diagram d_2 is a Venn-II diagram [25] and uses an $\otimes$-sequence to express that $Fish \neq \emptyset$ and shading to express $Birds - Fish = \emptyset$. Venn-II does not incorporate o-sequences.

The expressiveness of various diagrammatic logics has been established. The Venn-II system has been shown to be equivalent in expressive power to monadic first order logic (without equality) [25]. In monadic first order logic, all of the predicate symbols are unary and they correspond to contour labels. So, for example, Venn-II cannot express that a property holds for a unique individual. Spider diagrams properly increase expressiveness over Venn-II. In [30] it is

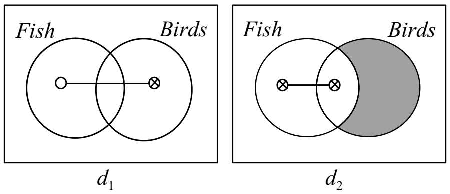

Figure 2. Venn-Peirce and Venn-II diagrams.

shown that the language of spider diagrams (without constant spiders) is equivalent in expressive power to monadic first order logic with equality and, hence, can express that a property holds for a unique individual. Furthermore, it has been shown that the inclusion of constant spiders does not increase the expressiveness of spider diagrams [28].

Spider diagrams have been used for specifying safety critical systems [3], visualizing clusters which contain concepts from multiple ontologies [14] and for allowing files to be viewed in multiple directories [4] as well as having many other applications. Furthermore, they form the basis of constraint diagrams, introduced by Kent [18], which are designed for object oriented specification [15, 20]. Kent's aim, when he introduced constraint diagrams, was to provide a user friendly, formal notation that is well suited to those who like to use diagrams for modelling but shy away from the textual languages that are currently on offer for formal specification. The hope is that, by providing sufficiently expressive formal diagrammatic notations, the use of formal methods will be encouraged leading to improved software design and, as a result, more reliable software will be built.

In order for Kent's vision to be realized, the syntax and semantics of constraint diagrams must be formalized (done in [6]). Furthermore, to enable software engineers to reason about their models, it is essential that sound and, where possible, complete sets of reasoning rules are specified. Two sound and complete systems have been developed for fragments of the langauge [26, 27] and sound rules have been defined for the full notation [5]. It is desirable to develop automated theorem provers for the constraint diagram language, thus providing practical support for software engineers to reason about their models. For example, it may be necessary to prove that two specifications are equivalent or that the post-condition of one operation implies the precondition of another.

The diagrams we have seen so far are all instances of *unitary diagrams*. Unitary diagrams can be joined using logical connectives such as $\wedge$ and $\vee$. Many diagrammatic systems have incorporated logical connectives, for example [5, 16, 25, 26], most of which are sound and complete. Unitary diagrams represent information more concisely than compound diagrams. The ability to express statements concisely could enhance the usability of a language as well as be important for theoretical reasons (discussed in section 2). An interesting question arises: is the unitary spider diagram system as expressive as the full system? The answer is, perhaps unfortunately, no. There are numerous examples of simple statements, as well as complex statements, that cannot be made by any unitary spider diagram that can be made by a compound diagram.

In this paper, we explore deficiencies in the expressive power of unitary spider diagrams. We generalize the syntax of spider diagrams, increasing the expressiveness of the unitary system, overcoming some of these deficiencies. These generalizations give rise to a more flexible system because there are more ways of expressing a given piece of information. As a consequence, it may be that there is a more natural mapping from a statement a user wishes to make to a diagram expressing that statement. We give our motivation for increasing the expressiveness of unitary spider diagrams in section 2. In section 3 we give a brief overview of the syntax and semantics of existing spider diagram systems. In sections 4 to 6 we present our generalizations. We give expressiveness results for the non-generalized and generalized unitary fragments in section 7, where expressiveness limitations of the generalized system are discussed and further generalizations are proposed.

2 Motivational Discussion

There are theoretical reasons for increasing the expressiveness of the unitary system. Firstly, there is interest in automatically generating proofs in spider diagram systems [11, 22]. Approaches have been developed that produce shortest proofs [8, 9]. These approaches use a heuristic function to guide the theorem prover towards good reasoning steps, reducing the amount of backtracking required and, hence, smaller search trees are produced. The heuristic function gives a numerical score that provides a lower bound on the length of a shortest proof from the premise diagram to the conclusion diagram.

Defining an accurate heuristic function for the compound system is challenging, partly due to the tree structure of the diagrams. Even if an accurate heuristic function can be defined, the size of the search tree can still explode due to an abundance of highly applicable reasoning rules causing the nodes of the search trees to have large out-degrees. One problematic rule is idempotency which can be applied to any diagram: from d_1 we can deduce $d_1 \vee d_1$, for example. Given the potentially large number of sub-diagrams in a compound diagram, it is easy to see that the idempotency rule can, sometimes, be applied in many ways. This high applicability makes it hard for the size of the search tree to be controlled. Furthermore, some other highly applicable rules are non-deterministic, such as the information weakening rule 'from d_1 we can deduce $d_1 \vee d_2$' and the

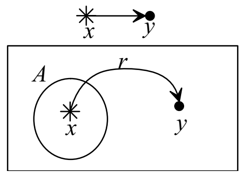

Figure 3. A constraint diagram.

information preserving absorption rule 'from d_1 we can deduce $d_1 \wedge (d_1 \vee d_2)$' (in both cases d_2 is any diagram). This non-determinism makes implementing theorem provers that operate with a complete set of rules for the compound system a challenging task. By contrast, the rules that exist for unitary diagrams are all deterministic.

The effectiveness of the heuristic function can be analyzed by comparing the sizes of the search trees generated by the theorem prover to those generated by conducting a breadth first search. Analysis has shown that restricting the theorem prover to the unitary fragment (without the generalizations presented in this paper) results in a much larger percentage reduction in the size of the search tree when compared with the compound case [8, 9]. We conjecture that similar results can be observed when comparing the more expressive unitary system suggested in this paper with the compound system; if this is the case then increasing the expressiveness of the unitary system will result in more theorems being provable in a reasonable amount of time. Given the inherent difficulty of developing efficient automated theorem provers, any generalizations that may result in more effective theorem proving techniques being developed should be thoroughly investigated.

We note that some people may prefer to use spider diagrams that do not include our generalizations. However, it is simple to translate proofs involving generalized spider diagrams into proofs that involve (non-generalized) spider diagrams. Thus, if we can develop more efficient theorem proving techniques for the generalized system then we can pass on these efficiency savings to the non-generalized system.

Secondly, we wish to be able to automate the drawing of diagrams (this is essential if we are to present automatically generated proofs to users in a diagrammatic form). Considerable research has been conducted into the generation of Euler diagrams [1, 2, 7, 19, 24, 32] and spider diagrams [21]. It can be time consuming to automatically draw visually pleasing Euler diagrams; see [10] for related work. It is preferable to automatically draw unitary diagrams instead of compound diagrams.

Finally, the constraint diagram language [6] extends the spider diagram language. The diagram in figure 3 is a constraint diagram and expresses

$$\forall x \in A\, \exists y \in U - A\big(\, r(x,y) \wedge \forall z\, (r(x,z) \Rightarrow y = z)\big).$$

In the constraint diagram language it can be difficult, maybe impossible, to make some first order statements involving disjunction inside the scope of a universal quantifier; see [29] for a discussion of this issue. It may well be that if the generalizations we propose are incorporated into the constraint diagram language then the expressiveness of the whole system is increased, not just that of the unitary fragment. Indeed, the task of finding efficient theorem proving algorithms for constraint diagrams is daunting because these diagrams are highly expressive. The better we understand how to control the search for proofs in spider diagram systems, the more tractable this task becomes for constraint diagrams. The work presented in this paper is an essential basis for the thorough exploration of theorem proving techniques for spider diagram systems, which will allow us to find highly efficient theorem proving algorithms.

3 Informal Syntax and Semantics

Various systems of spider diagrams have been developed, for example [16, 28], and in this section we give an informal overview of their syntax and semantics.

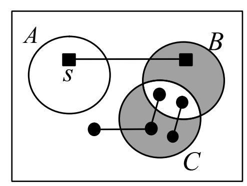

Figure 4. A unitary spider diagram.

A **contour** is a simple closed plane curve. Each contour is labelled. A **boundary rectangle** properly contains all contours. The boundary rectangle is not a contour and is not labelled. A **basic region** is a maximal, bounded set of points in the plane enclosed by a contour or the boundary rectangle. A **region** is defined recursively as follows: any basic region is a region; if r_1 and r_2 are regions then the union, intersection and difference of r_1 and r_2 are regions provided these are non-empty. A **zone** is a region having no other region contained within it. A region is **shaded** if each of its component zones is shaded. The diagram in figure 4 contains three contours, labelled A, B and C. There is one zone inside A and two zones inside B. In total there are five zones (including the zone which is outside all three contours) of which two are shaded.

A **spider** is a tree with nodes (called **feet**) placed in zones. The connecting edges (called **legs**) are straight lines. The feet of a spider are either all square (a **constant spider**) or all round (an **existential spider**). Each constant spider is labelled. A spider **touches** a zone if one of its feet is placed in that zone. A spider can touch a zone at most once. In figure 4 there are three spiders. The constant spider labelled s has a two zone habitat and, therefore, touches two zones.

A **unitary spider diagram** is a single boundary rectangle together with a finite collection of contours, shading and spiders. No two contours (constant spiders) in the same unitary diagram can have the same contour label (constant spider label). Unitary spider diagrams can be joined together using the logical connectives $\wedge$ and $\vee$ to form **compound diagrams**.

We now describe, informally, the semantics of spider diagrams, see [28, 30] for formal semantics. Contours represent sets. In our discussion, we will identify contour labels with the sets they represent. The diagram in figure 4 asserts that A and B are disjoint, for example, because the contours labelled A and B do not overlap. Zones and regions in a unitary diagram d also represent sets. The zone inside B but outside A and C in figure 4 represents the set $B \cap \big(U - (A \cup C)\big)$ where U is the universal set. A region represents the union of the sets represented by its constituent zones.

Spiders denote elements in the sets represented by their habitats and the spider type affects the precise meaning. Constant spiders denote specific individuals. As with contour labels, in our informal discussion we will identify constant spider labels with the individuals that they represent. The diagram in figure 4 expresses that $s \in A$ or $s \in B - C$. Existential spiders denote the existence of elements. The two existential spiders in figure 4 denote the existence of two distinct elements, one in the set C, the other in $C \cup \big(U - (A \cup B \cup C)\big)$. Since distinct spiders in a unitary diagram denote distinct elements it follows that spiders allow us to place lower bounds on set cardinality.

Shading allows us to place upper bounds on set cardinality. In the set represented by a shaded region, all of the elements are denoted by spiders. For example, the shaded zone inside C in figure 4 represents a set with at most two elements because it is touched by two existential spiders.

If $D = D_1 \vee D_2$ ($D = D_1 \wedge D_2$) is a compound diagram then the semantics of D are the disjunction (conjunction) of the semantics of D_1 and D_2. Unlike unitary diagrams, not all compound diagrams are satisfiable.

Spider diagrams are equivalent in expressive power to monadic first order logic with equality [28, 30]. The unitary fragment is less expressive than the full system. Suppose a statement, S, is made by compound diagram D. If there is no unitary diagram semantically equivalent to D then we say that S **cannot be expressed** by a unitary diagram.

4 Generalizing Constant Spider Labelling

An example of a statement that cannot be expressed by any unitary diagram is s is in A or t is outside A where s and t are specific individuals. This can be expressed by the compound diagram formed by taking the disjunction of d_1 and d_2 in figure 5. If, instead of labelling each constant

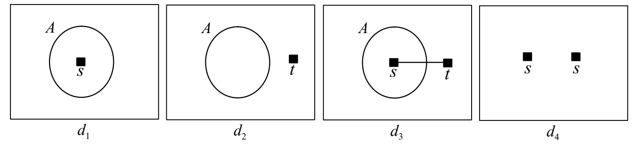

Figure 5. Labelling constant spider feet.

spider, we label each constant spider foot (the labels on distinct feet may be the same or different and each label may be used on multiple spiders), then the unitary diagram d_3 in figure 5 expresses s is in A or t is outside A, because spider legs represent disjunction, and is more concise than $d_1 \vee d_2$.

An interesting point is that, with these generalizations, contradictions can be made by unitary diagrams. For example, d_4 in figure 5 asserts that $s \neq s$ and is, therefore, unsatisfiable. The semantics of unitary diagrams containing these generalized constant spiders are more subtle when many constant spiders are present. Since distinct spiders denote distinct objects, the diagram d_1 in figure 6 asserts that there are two distinct individuals, one is either s in A or t outside A and the other is u. Note that d_1 does not imply that $s \neq u$, $s \neq t$ nor $t \neq u$. Without these generalizations, any unitary diagram that makes an explicit statement about s, t and u would assert that s, t and u are pairwise distinct. The diagrams d_1 and non-generalized $d_2 \vee d_3$ are semantically equivalent but d_1 is more concise.

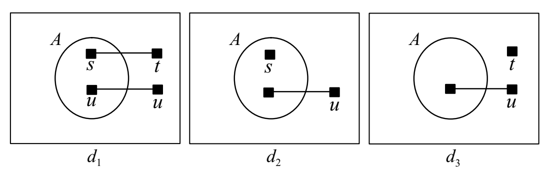

Figure 6. Interacting spiders.

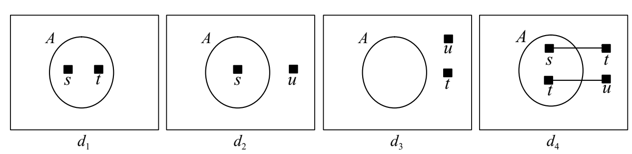

Figure 7. Multiple label use.

Suppose that we wish to assert that there are two distinct individuals, one is either s in A or t outside A and the other is either t in A or u outside A. Without our generalizations, this can only be expressed (implicitly) by a compound diagram, such as $d_1 \vee d_2 \vee d_3$ in figure 7. There is not a direct mapping from the statement to the diagram since $d_1 \vee d_2 \vee d_3$ explicitly expresses

1. there are two distinct individuals, s and t, both in A or
2. there are two distinct individuals, one of which, s, is in A, the other, u, is outside A or
3. there are two distinct individuals, t and u, both outside A.

This example shows that in order to make our required statement using the non-generalized syntax, we must first perform some reasoning to convert our statement into an explicitly representable form and then draw a diagram(s). Relaxing the constraint that each constant spider label occurs at most once in any unitary diagram allows us to express our required statement naturally and concisely, using d_4.

5 Multiple Typed Spiders

A restriction that, up until now, has been placed on spiders is that legs can only join feet of the same type. We generalize spiders so that feet of different types can be connected by legs. In figure 8, the spider in d_1 asserts that either

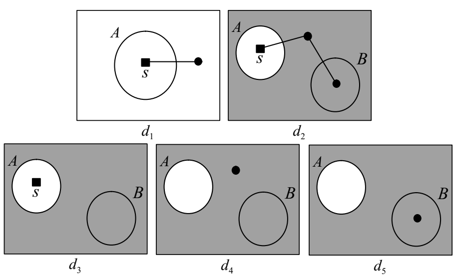

Figure 8. Multiple typed spiders.

s is in A or there is an element outside A. The diagram d_2 expresses that A and B are disjoint and either s is in A or there is an element outside A and, in addition, there are no other elements are outside A and d_2 is semantically equivalent to non-generalized $d_3 \vee d_4 \vee d_5$. This generalization has an analogy in Peirce's system where he allows $\otimes$-sequences to be joined to o-sequences [23].

6 Generalizing the Placing of Spider's Feet

In all previous spider diagram systems, spiders are permitted to touch any given zone at most once. Indeed, allowing spiders to touch a zone, z, more than once does not necessarily provide any more information than a single foot placed in z. For example, the diagram d_1 in figure 9 expresses that there is an element in A or in A, which is semantically equivalent to d_2. The semantics of generalized constant spiders with multiple feet placed in a zone are more interesting. The diagram d_3 asserts that A contains a single

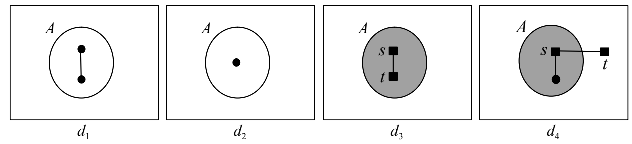

Figure 9. Touching zones many times.

element which is the individual s or the individual t; more formally $A = \{s\} \vee A = \{t\}$. It is not the case that d_3 expresses $s \neq t$. The diagram d_4 expresses t is outside A or s is in A or there is an unspecified element in A and, in addition, nothing else is in A.

7 Expressiveness

All of the generalizations that we have suggested do not change the basic building blocks of the spider diagram language, provided we only use round spider feet (there is no theoretical reason why constant spider feet must be square). The basic building blocks of spiders are feet, constant spider labels and legs. We have removed restrictions placed on how these building blocks can be joined together to make statements. It is easy to prove that the generalizations we have proposed increase the expressiveness of the unitary fragment. It is more interesting to consider how much we have increased expressiveness with our generalizations. Identifying the expressive power of both the non-generalized and the generalized unitary fragments will establish this. We identify fragments of Monadic First Order Logic with equality (MFOLe) equivalent to each of the unitary fragments. We use contour labels as monadic predicate symbols and constant spider labels as constant symbols in MFOLe.

In unitary diagrams, we say which set an element belongs to by placing a spider in the appropriate region of a diagram. In MFOLe, we describe the set that an element belong to using a formula. For example, the statement $\exists x A(x)$ expresses that there is an element in the set A, which is also expressed by d_2 in figure 9 because there is an existential spider placed inside A.

Definition 7.1 *Let x be a variable. A* ***placement formula*** *in x is defined inductively. For all monadic predicate symbols, A, the atomic formula $A(x)$ is a placement formula in x. If P and Q are placement formulas in x then so are $(P \wedge Q)$, $(P \vee Q)$ and $\neg P$. For all constant symbols c, $(x = c \wedge P)$ is an* ***extended placement formula*** *in x given c.*

In figure 7, non-generalized d_1 is equivalent to

$$\exists x_1 \exists x_2 \left(x_1 = s \wedge A(x_1) \wedge x_2 = t \wedge A(x_2) \wedge x_1 \neq x_2\right).$$

The structure of the MFOLe sentence above gives a clear indication of the type of MFOLe sentences that can be expressed by non-generalized unitary diagrams. However, in the particular example above, d_1 does not have any shaded zones. Shading brings with it implicit universal quantification and any fragment of MFOLe that corresponds to the non-generalized unitary system must include the syntax required to place upper bounds on set cardinality. For example, in figure 8, non-generalized d_4 is equivalent to

$$\exists x_1\big(\neg A(x_1) \wedge \neg B(x_1) \wedge \\ \forall x_2\big((A(x_2) \wedge \neg B(x_2)) \vee x_2 = x_1\big)\big).$$

The shading in d_4 corresponds to the universally quantified sub-formula in the equivalent MFOLe sentence above. In general, any element is either in a set represented by a non-shaded zone or is represented by a spider.

Definition 7.2 *Let V be a finite set of variables and let x be a variable not in V. Let P be a placement formula in x. A **bounding formula** in x given V is a formula of the form*

$$\forall x\big(P \vee \bigvee_{y \in V} x = y\big)$$

where an empty disjunction is taken as $\bot$.

We are now in a position to define MFOLe sentences that are expressible by our non-generalized unitary system using placement formulas and bounding formulas as our basis. We recall that non-generalized unitary diagrams are all satisfiable but *expressible sentences*, defined below, can be unsatisfiable. However, all satisfiable expressible sentences are equivalent to some non-generalized unitary diagram.

Definition 7.3 *An **expressible sentence** is defined as follows.*

1. *The true symbol $\top$, is an expressible sentence.*
2. *Any bounding formula with no free variables (that is, the disjunction over V is empty) is an expressible sentence.*
3. *Any sentence of the form*

$$\exists x_1 ... \exists x_n\Big(\bigwedge_{1 \leq i \leq n} P_i \wedge \bigwedge_{1 \leq i \leq n-1} x_i \neq x_{i+1} \wedge Q\Big)$$

is an expressible sentence provided

(a) *each P_i is either a placement formula in x_i or an extended placement formula in x_i given some constant c,*

(b) *for each P_i and P_j if P_i and P_j are extended placement formulas given constants c_i and c_j respectively then $c_i = c_j$ implies $P_i = P_j$ and*

(c) *Q is either $\top$ or a bounding formula given $V = \{x_1, ..., x_n\}$ in some variable, x, not in V.*

For example, the MFOLe sentence below is expressible, being equivalent to non-generalized d_1 in figure 10:

$$\exists x_1 \exists x_2\big(x_1 = s \wedge A(x_1) \wedge B(x_2) \wedge x_1 \neq x_2 \wedge \\ \forall x_3(\neg B(x_3) \vee x_3 = x_1 \vee x_3 = x_2)\big).$$

Theorem 7.1 *The non-generalized unitary fragment is equivalent in expressive power to the class of satisfiable expressible sentences.*

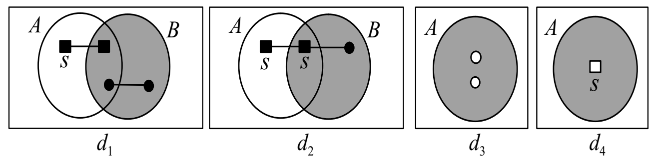

Figure 10. Expressing sentences.

Our attention now turns to the generalized case. All sentences that are expressible by non-generalized unitary diagrams are obviously expressible by generalized unitary diagrams. The generalizations we have proposed allow more disjunctive statements to be made by unitary diagrams. For example, in figure 10, generalized d_2 is equivalent to the *generalized expressible sentence*

$$\exists x_1\big(((x_1 = s \wedge A(x_1)) \vee (B(x_1) \wedge \neg A(x_1))) \wedge \\ \forall x_2\big(\neg B(x_2) \vee x_2 = x_1\big)\big).$$

Definition 7.4 *A **generalized expressible sentence** is defined as follows.*

1. *Any expressible sentence is a generalized expressible sentence.*
2. *Any sentence of the form*

$$\exists x_1 ... \exists x_n\Big(\bigwedge_{1 \leq i \leq n} R_i \wedge \bigwedge_{1 \leq i \leq n-1} x_i \neq x_{i+1} \wedge Q\Big)$$

is a generalized expressible sentence provided

(a) *R_i is any finite disjunction of placement formulas in x_i or extended placement formulas in x_i given some constant c,*

(b) *Q is either $\top$ or a bounding formula given $V = \{x_1, ..., x_n\}$ in some variable, x, not in V.*

Theorem 7.2 *The generalized unitary fragment is equivalent in expressive power to the class of generalized expressible sentences.*

Theorem 7.3 *The generalized unitary fragment is more expressive than the non-generalized unitary fragment.*

Theorems 7.1 and 7.2 show how our generalizations have increased the expressiveness of the unitary system. Furthermore, they show the type of statements that each unitary system is capable of expressing, thus highlighting expressive limitations. For example, no generalized unitary diagram can express either of the two statements $\forall x \neg A(x) \vee \forall x \neg B(x)$ and $\forall x \neg A(x) \vee \exists x_1 \exists x_2\ x_1 \neq x_2$. Peirce's o-sequences can be imported into spider diagrams to make the first statement but there is no obvious generalization that allows us to make the latter.

A further limitation is that no generalized unitary diagram can express arbitrary finite lower and upper bounds on any given set *without* also specifying further information, exemplified by the example $0 \leq |A| \leq 2$. *Schrödinger spiders*, introduced in [12], have round unfilled feet and express that an element might be present. Including such spiders in the language allows us to express $0 \leq |A| \leq 2$, shown by d_3 in figure 10. We can also introduce a new type of spider, called a **Schrödinger constant spider**, in order to express that an individual might be in a particular set, see d_4 in figure 10 which expresses $A \subseteq \{s\}$. Schrödinger spider feet, of either type, can also be joined to other spiders following all of the generalizations presented in the previous sections.

8 Conclusions and Open Problems

In this paper we have explored generalizations of spider diagrams that increase the expressiveness of the unitary fragment. By allowing constant spiders' feet to be labelled, for example, we have provided a natural way of making some simple statements using unitary diagrams. Indeed, all of the extensions we have proposed enhance the spider diagram system by making it more flexible and notationally efficient. We believe that our generalizations will make it easier for people to make certain statements. This is suggested by the fact that some statements can be explicitly made by generalized unitary diagrams which can only be implicitly made by the non-generalized (compound) system. However, the increased complexity of the generalized notation may mean that some people find certain generalized unitary diagrams harder to interpret than semantically equivalent non-generalized compound diagrams. It is straightforward to convert generalized diagrams into non-generalized diagrams. With appropriate tool support, such a conversion can be easily automated. It will be interesting to establish whether generalized spider diagrams are more effective, in terms of promoting human task efficiency, than non-generalized spider diagrams.

A particular challenge faced when attempting to increase the expressiveness of the unitary fragment further is how best to express disjunctive information that involves shading. Incorporating Peirce's o-sequences, as discussed above, will yield some increase in expressiveness but will not entirely solve the problem. Shading brings with it (implicit) universal quantification. To maximize expressiveness we need to interpret shading and spiders (which have existential import) in arbitrary orders which can make defining semantics difficult. It is likely that a dependence analysis would be required, as in the constraint diagram language [6]. We conjecture that such an extension of the unitary fragment will be as expressive as the full system.

The development of reasoning rules is necessary before we can investigate the effect of our generalizations on the ability of our theorem prover to find proofs. It will be interesting, and difficult, to provide a complete classification of the proof tasks where our generalizations are beneficial in terms of time taken to find a proof.

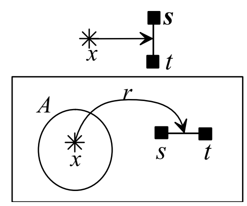

Figure 11. A generalized constraint diagram.

The constraint diagram language can be extended by incorporating our generalizations. The generalized constraint diagram in figure 11 expresses the same as the first order logic sentence

$$\forall x \in A(r(x,s) \vee r(x,t)) \wedge \forall y \big(r(x,y) \Rightarrow (y = s \vee y = t)\big).$$

The *reading tree* above the diagram informs us that we are to read the asterisk (a universal spider) before the constant spider. It is not obvious whether *any* non-generalized constraint diagram can make such a statement. Whilst the exact expressive of constraint diagrams is unknown, we believe that our generalizations will lead to an increase in expressiveness of the compound constraint diagram system as well as the unitary fragment.

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Designing Non-Ambiguous and Viable Visual Interactive Systems

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Abstract

This paper analyzes some characteristics of Visual Interactive Systems to guarantee non ambiguous and safe interaction to end users. To this aim, a formal model of Visual Interactive Systems is provided, based on the concept of virtual entity that is here refined and linked to the program that generates a virtual entity. We also discuss virtual entities that satisfy some given properties and study the relationships between such virtual entities and their generating programs. Such relationships are useful to establish when a Visual Interactive System proves to be non ambiguous, visible and viable with the aim to adequately support end users during the interaction.

1. Introduction

In the last twenty years the importance of end users and of their activities has been recognized in the development of computer systems. Cypher defines end users as persons who use computer applications as part of daily life or daily work, but who are not interested in computers per se [6]. Schön highlights that they are professionals performing their activities as *competent practitioners*, in that "they exhibit a kind of knowing in practice, most of which is tacit" and they "reveal a capacity for reflection on their intuitive knowing in the midst of action and sometimes use this capacity to cope with the unique, uncertain, and conflicted situations of practice" [7]. In this perspective, our work aims at developing Visual Interactive Systems (VIS) that adequately support end users. Formally, a VIS can be specified by an Interaction Visual Language (IVL) enriched by a description of the admissible user activities. An IVL is a set of *visual sentences*, each visual sentence being a formal system associating an image on the screen, its computational meaning (described in a suitable form for the user) and the relations between the image and its meaning [4].

We clarify in this paper that each visual sentence represents a state of the VIS, being the VIS modeled as a finite state machine. The interaction process is described by specifying the IVL and the actions which determine the transitions from one VIS state to another VIS state.

To this aim, the concept of *virtual entity*, is used to model both the whole VIS and its components [4][5]. In fact, in the computer age, workplaces are augmented by the use of computer-based systems that integrate and often substitute the real tools, documents, and sometimes also the real entities, on which end users were used to operate. The new tools, documents and entities become virtual entities (ves), in that they only exist as the result of the interpretation of a program P by a computer. Virtual entities are dynamic systems, able to capture the user inputs, compute the reaction to them and materialize their own state - the results of the computation – in a form perceivable by the user. To this aim, the program P must generate the images on the screen, capture the user activities, and manage their interpretation as well as the materialization (as new images on the screen) of the reactions to the user activities.

In this paper, we refine the notion of virtual entity and describe how to specify its dynamics by linking it to the design of the program P. Modeling a VIS through the notion of ve is useful to support designers to develop VISs that satisfy some formal requirements, thus allowing end users a non ambiguous and safe interaction. To this end, we restate in the global ve framework the following three necessary conditions, previously discussed in [4]:

- R1 (non-ambiguity request): for each screen pixel there is, at any state of the interaction, one and only one computational construct in the system, which is referred to when a user activity involves that pixel;
- R2 (structure visibility request): any computational construct in the system should be able to react to some user activities, and its reaction should be materialized by a set of pixels sufficient to make it recognizable;
- R3 (system viability request): no user activity should be allowed that would result in a non-meaningful situation or a system crash.

Some constraints are derived on ve and program behavior and structure for the satisfaction of the above conditions.

2. Modeling visual interaction in a syndetic frame

According to Barnard et al. [2], HCI is modeled as a syndetic process, i.e., a system composed by binding sub-systems of different nature, namely a cognitive sub-system (the user) and a computing sub-system (the machine). The word "syndetic" comes from the Greek term *syndesis* that means to bind together. To properly model the HCI process, the problems arising on the machine side, i.e., capturing and interpreting the human activities, must also be taken into account. Several models are proposed to reach this goal, including the one proposed in [1]. The model at the basis of our approach [3][4] considers HCI as a cyclic process, in which the user and the interactive system communicate by materializing and interpreting a sequence of messages at successive points in time. In WIMP interaction, these messages are the whole images represented on the screen display, formed by texts, pictures, icons, etc. They are seen as the pictorial part of *visual sentence* and are subject to two interpretations: one performed by the user, depending on his/her role in the task, as well as on his/her culture, experience, and skills, and the second internal to the system, associating the image with a computational meaning, as determined by the program P implemented in the system. Such program synthesizes how the designers understand the activities to be performed. Users are able to understand the meaning of the messages by recognizing some subsets of pixels on the screen as functional or perceptual units, called *characteristic structures* (**cs**s). Examples of **cs**s are letters in an alphabet, symbols or icons. Users associate to each **cs** a meaning which also depends on their tacit knowledge: the association of a **cs** with a meaning is called *characteristic pattern* (**cp**). Users recognize complex **cs**s formed by more simple ones (words formed by letters, plant maps formed by icons etc.) and attribute them a meaning stemming from the meaning of the components **cs**s. The interactive system itself is interpreted as a meaningful entity, a complex **cp**.

From the machine point of view, a cs is a set of pixels generated and managed by a computational process that is the result of the computer interpretation of the program P. (Note that words in **bold** denote entities perceived and interpreted by the human user, while those in arial denote processes and events perceived, computed and materialized by the computer). The computer execution of P creates and maintains active an entity, that we call *virtual entity* (ve). A virtual entity is a virtual dynamic open system. It is *virtual* in that it exists only as the result of the execution of the program P by a computer; *dynamic* in that its behaviour evolves in time; *open* in that its evolution depends on its interaction with the environment. During an interaction, the user operates on some input device to manifest his/her requirements or commands to the ve. The ve captures input events generated by user activities and reacts to them generating output events toward users. Output events are characteristic structures materialized on the output devices of a computer to become perceptible by the users. The user perceives the cs generated in reaction to his previous operation, decides what to do next, and performs a new operation. The program P generating a ve is a system of programs, some of which - called In (Input) programs - acquire the input events generated by the user activity, some - called Ap (Application) programs - compute the reactions to these events, and some - called Out (Output) programs - output the results of this computation. Hence $P = \langle In, Ap, Out \rangle$.

In order to formally specify how these programs operate we adopt the following notations. Let OP be the set of operations a user can perform on the images on the screen using the available input devices (e.g., mouse, keyboard) and CS be the set of characteristic structures visible on the screen. A user activity is then a pair $\langle op, cs \rangle \in A = OP \times CS$. In other words, it is defined as the operation a user can performs on a given characteristic structure in CS. Additionally, let Actions be the name of the actions managed by the application programs Ap and U be the set of the admissible states of Ap. The programs In, Ap and Out can be therefore described as functions defined as follows. The input programs $In: A \rightarrow Actions$ take as input a user activity $\langle op,cs \rangle \in A$ and give as result the name of an action $\underline{a} = In(op,cs)$ that will be executed by the application programs as reaction to the user activity. The application programs $Ap: U \times Actions \rightarrow U$ execute an action whose name belongs to Actions and change their current state $u \in U$ into a new state $u' = Ap(u, \underline{a})$ belonging to the set U of admissible states of Ap. Finally, the output programs $Out: U \rightarrow CS$ associate every computational state $u \in U$ of the application programs with a suitable physical manifestation $cs \in CS$.

3. Relating virtual entities and programs

Virtual entities are specified so that their behavior maps in the users' view of the tasks to be accomplished, in order to capture their needs and satisfy them. On the other hand, the specification of programs maps in the software engineers' view of the tasks to be performed by the users. The two specifications are built on two common subsets: the set of all characteristic structures used in the interaction and the set of activities performed by the user.

More formally, given a program $P = \langle In, Ap, Out \rangle$ as defined in the previous section, a ve generated by P is defined as a virtual dynamic open system by a 5-tuple $ve = \langle S, O, f, \eta, s_0 \rangle$ on a finite set of inputs, namely a set of user activities, $A = OP \times CS_{ve}$, where CS_{ve} is the set of possible characteristic structures the ve may manifest and

1. S is the set of admissible ve states, each state specified as a *characteristic pattern* cp=<cs, d, <int, mat>> where $cs \in CS_{ve}$ is the set of pixels managed by the In and Out programs, d∈D is a suitable description of the state u∈U of the programs Ap, int (interpretation) is a function, mapping cs onto d and mat (materialization) a function mapping d onto cs;
2. $O=CS_{ve}$ is a finite set of outputs;
3. f: A × S → S is the next state function;
4. η: A × S → O is the output function;
5. $s_0 = cp_0$ is the initial state of the ve.

Given a user activity performed on a cs of a ve, that is a=<op,cs>, and a characteristic pattern cp = <cs, d, <int,mat>>, where d is the description of the state u of Ap, the next state function operates as follows: f(a, cp) = cp' = <cs', d', <int, mat>>, where d' is the description of the state u' of Ap and cs'∈CS s.t. Out(u') = cs', and Ap(u, In(op,cs)) = u'. Note that, given a program P, a characteristic structure cs on the screen is the physical manifestation of a state u of Ap, that is Out(u) = cs, if and only if mat(d) = cs, where d is the description of the state u. In other words, the physical manifestation of a state of the application programs Ap is the materialization of the description of the given state of the ve generated by P, and vice versa. Moreover, if the application programs Ap change their state from u to u' through the execution of an action a caused by a user activity <op,cs> - that is, u' = Ap (u, In(op,cs)) -, then the description d of u provides the interpretation of the characteristic structure cs materializing the correspondent ve on the screen, that is int(cs) = d.

The whole Visual Interactive System can be seen as a special virtual entity, called ve_{VIS}, that is a composed virtual entity, whose css are whole images on the screen at each step of the HCI process. ve_{VIS} is generated and maintained active by a program $P_{VIS}=<In_{VIS},Ap_{VIS},Out_{VIS}>$ whose computational states u_{VIS} are materialized at each instant as an image i on the screen belonging to 2^i, and thus constituted by a finite set of css. Each computational state u_{VIS} belongs to U_{VIS} being constituted by a finite set of states u_i. Two functions int and mat, define the relations of elements in 2^i with elements in D_{VIS} which are the descriptions of states in U_{VIS}. Each state of ve_{VIS} is summarized by a *visual sentence* (vs), i.e. a triple $vs=<i, d_{VIS}, <int, mat>>$. The set of admissible states of a visual interactive system is a set of vss which constitutes a Visual Language [4].

As a dynamic open system, a Visual Interactive System could also be defined as a 5-tuple $ve_{VIS} = <\mathbb{S}, O, F, \Gamma, s_0>$ on $\mathbb{A} = OP \times CS_{VIS}$, where $CS_{VIS}= 2^i$ is the set of images i on the screen that the ve_{VIS} may manifest and

1. $\mathbb{S}$ is the set of admissible ve_{VIS} states, i.e. $\mathbb{S} = \{vs \mid vs = <i, d_{VIS}, <int, mat>>, i \in 2^i, d_{VIS} \in D_{VIS}$, where D_{VIS} is the set of the descriptions of admissible states of the programs Ap calculating the reactions of ve_{VIS} to the user activities, $int(i) = d_{VIS}$, $mat(d_{VIS}) = i\}$;
2. $O = CS_{VIS}$;
3. F: $\mathbb{A} \times \mathbb{S} \rightarrow \mathbb{S}$ is the next state function;
4. Γ: $\mathbb{A} \times \mathbb{S} \rightarrow CS_{VIS}$ is the output function;
5. $s_0 = vs_0$ is the initial state of the ve_{VIS}.

The next state function and the output function can be specified by means of *transformations*. In each state of the interaction a finite number of user activities can be performed. As a consequence of a user activity, a visual sentence vs_1 is transformed into a visual sentence vs_2. The interaction process is specified as a sequence of such transformations. In a transformation, vs_1 and vs_2 share a common part, while the variable part of vs_1 is transformed into the variable part of vs_2 through the application of a *transformation rule*. We define a transformation rule as a pair tr = <a, r>, where a is the user activity and r is a rewriting rule. A rewriting rule is a triple <ant, cond, cons> where ant and cons are states (cps) of a ve and cond is a condition on ant. More precisely, let a be an activity performed at time t, then ant is the cp of a ve at time t and cons is the cp of the considered ve at time t+1. The relationships between a and r in a transformation rule is given by the fact that a = <op,cs> where cs belongs to ant. An Interaction Visual Language (IVL) can thus be specified by the pair $<vs_0,TR>$, where TR is the set of the transformation rules.

4. Some notable sets of virtual entities and related programs

In this section we describe virtual entities and programs satisfying some interesting properties and we show the relationships between them. We start by refining the properties of *fullness* and *faithfulness* that were introduced in [3]. In that work, fullness was defined as a property ensuring that the computer is able to associate all computational constructs with some structure visible to the user. On the other hand, faithfulness ensures that everything visible on the screen is associated with a known computational construct. In this paper we extend these properties to virtual entities and we introduce two properties for programs, i.e. *transitivity* and *visibility*.

Properties of virtual entities characterize the way in which the user perceives the states of the ve and can act on them, i.e. characterize the interaction aspects of the ve.

They can be expressed as follows.

Definition 1: A ve is *full* iff ∀d∈D ∃cs∈CS s.t. mat(d) = cs and int(cs) = d, that is ∃cp∈S s.t. cp = <cs, d, <int, mat>>.

Definition 2: A ve is *faithful* iff ∀cs∈CS ∃d∈D int(cs) = d and mat(d) = cs, that is, ∃cp∈S s.t. cp = <cs, d, <int, mat>>.

The properties of a program P characterize the interactive computation performed executing P. A program P is transitive if every state of Ap is materialized as a characteristic structure and from every state of Ap it is possible to reach at least a new state through a computation executed by Ap, which is the controlled reaction to a user activity. Program visibility states that each user activity is captured and interpreted by P that determines a state transition and a physical manifestation correspondent to the reached state of P. In other words, P correctly visualizes the reactions to all the user activities. The transitivity and visibility properties for programs are defined in the following way.

Definition 3: P is *transitive* iff $\forall u \in U$, $\exists cs$ s.t. Out(u) = cs and $\exists op \in Op$, and $\exists u' \in U$ such that Ap(u, In(op,cs)) = u'.

Definition 4: P is *visible* iff $\forall cs \in CS$ and $\forall op \in Op$, $\exists cs' \in CS$, and $\exists u$, $u' \in U$ such that Ap(u, In(op,cs)) = u' and Out(u') = cs'.

The relationships existing between fullness and faithfulness of virtual entities and transitivity and visibility of programs can be formalized by means of the following theorems, whose proofs are trivial and not reported here for sake of brevity. Fullness of a virtual entity implies that its generating program must be transitive. By contrast faithfulness property of a ve requires for its generating program the satisfaction of the visibility property.

Theorem 1: ve full $\Rightarrow$ P transitive.

Theorem 2: ve faithful $\Rightarrow$ P visible.

Vice versa is not true, only if a program is both transitive and visible the ve fullness and faithfulness are satisfied.

Theorem 3: P transitive and P visible $\Rightarrow$ ve full.

Theorem 4: P transitive and P visible $\Rightarrow$ ve faithful.

Proving the relationships between properties of virtual entities and properties of programs is a necessary step to guarantee: 1) that each active program generates a ve having a cs visible on the screen; and 2) that each operation performed on each pixel of a cs on the screen is captured by the programs managing and generating the corresponding ve.

5. Non ambiguous, visible and viable VISs

This section discusses some of the characteristics that a VIS must enjoy to adequately support its human users. First, a VIS must not disorient its users. This means that for each user activity there exists one and only one system reaction, and for each system reaction there exists one and only one physical manifestation to be perceived by the user. Another important point is to drive users to not steer the HCI process into an absorbing or crash state. To meet these requirements, a first step is to provide some constraints on ve_{VIS} behavior in order to satisfy the three conditions R1, R2 and R3 illustrated in the Introduction.

Proposition 1: ve_{VIS} full $\Rightarrow$ R1 is satisfied.

Being ve_{VIS} a particular case of composed ve, we can assert that, from Theorem 1, if it is full then the program generating it is transitive and, as a consequence R1 (nonambiguity request) is satisfied.

Proposition 2: ve_{VIS} faithful $\Rightarrow$ R2 satisfied.

From Theorem 2, if ve_{VIS} is faithful, then the program generating it is visible and, as a consequence R2 (structure visibility request) is satisfied.

Proposition 3: R3 satisfied $\Rightarrow$ ve_{VIS} faithful.

This proposition defines a necessary but not sufficient condition for R3 to be satisfied. In fact, system viability request (R3) means that no user activity should be allowed resulting in a non-meaningful situation or a system crash. Hence, this implies that $\forall op \in Op$ on each $cs \in 2^i$, the system is able to capture and manage it. In other words, this means that ve_{VIS} must be at least faithful. Such conditions, however, are not sufficient, because other external causes may determine non meaningful situations or system crash, such as for example hardware malfunctioning, interference with other software systems, instability of the operating system, and so on.

6. Conclusions

The paper studies some properties of VISs, such as non ambiguity, visibility, viability, which drives the implementation of programs generating VISs that adequately support the interaction process, while avoiding user disorientation and impeding users to steer the HCI process into non meaningful situations or system crash.

7. References

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VIEW-GIS − An Environment Supporting Web GIS Developers

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ABSTRACT

In the last years, the increasing popularity of the Internet has greatly affected the activity of GIS researchers and laboratories, leading to the development of Web sites for the dissemination and the manipulation of spatial knowledge in specific domains. However, most of the available software development kits do not adequately support professionals like botanists, archaeologists and vets, who use GIS for spatial data management, analysis, and visualization but have no experience with web development techniques. As a solution to this issue, we propose a visual programming tool, named VIEW-GIS (**VI**sual **E**nvironment for **W**eb **GIS** generation), which supports unskilled users in the construction of customized Web GIS applications, following a Rapid Application Development approach. Based on their requirements, users may choose the functionality of the expected Web GIS application and customize its interface by visually manipulating graphical objects.

Keywords

Geographical Information Systems, Web User Interfaces, GUI Customization.

1. INTRODUCTION

In the last years, the development of web sites involving spatial maps has been a diffuse activity of research and commercial laboratories. As a matter of fact, several laboratories have acquired and processed a huge number of spatial data and they have published the obtained results in order to provide some innovative GIS services [3, 4, 6].

However, professionals like botanists, archeologists, and meteorologists, who use geographical information systems for spatial data management, analysis, and visualization but are not computer science experts, traditionally rely on specialized companies for the development and the maintenance of their GIS web sites.

For a long period, software applications supporting the development of GIS web sites have been very hard to use by non-experts users, who represent most of data producers. Recently, efforts along this direction have led companies and research laboratories to develop assisting tools that in most cases are simple wizards which produce Web GIS interfaces according to predefined layouts and specific widgets. They provide no ability to customize, locate and adapt interfaces to personal demands. Accordingly, the development of complex sites still forces to manipulate lines of code, which can be done only by computer science experts. In this context, the development of advanced, customizable visual interfaces for GIS construction and manipulation is still a challenging issue.

The basic idea for this research work is to follow a Rapid Application Development (RAD) approach to support development of customized Web GIS applications, both client and server side, within a highly flexible graphical environment. The environment, named *VIEW-GIS* (**VI**sual **E**nvironment for **W**eb **GIS** generation), allows developers to choose the functionalities that the GIS should provide, and design the positioning of the corresponding controls inside the interface layout. Each of the chosen functionalities is indeed associated with a set of graphical objects, carrying a set of default properties, which can be modified for customization purposes. Thus, common GIS functions (e.g., zooming and panning) and common working areas (like the map viewer and the legend manager), can be added to the interface possibly personalizing their behavior or their graphical aspect. Their correct positioning inside the web interface is also ensured by the environment thanks to an automatic procedure for acquiring absolute coordinates.

The remainder of this paper is organized as follows. Section 2 describes the *VIEW-GIS* environment by illustrating the widgets, which can be used when constructing Web GIS interface, and classifying them in agreement with the kind of GIS interaction they support. Also the algorithm useful to translate the visual positioning of objects to the corresponding web code is described. In Section 3, we report on the experience of a group of botanists who used *VIEW-GIS* for developing a Web GIS satisfying their specific requirements and we describe the client-server architecture which underlies a generated Web GIS and explain how a query is solved based on such architecture. Finally, Section 4 describes some related work and provides final remarks on the present research.

2. THE VIEW-GIS ENVIRONMENT

Starting from a deep analysis of what is expected by users, who are experts in spatial data management and/or of GIS application domains, we have identified a set of objects which typically appear in a GIS interface/application, classified in terms of their behavior and appearance.

Exploiting such classification, in *VIEW-GIS* each object has been associated with a widget, which embeds its properties and resembles the expected behavior with its graphical appearance. The widgets are made available in the environment and organized in a visual interface in a way consistent with the most common RAD tools (e.g., JBuilder, and Dreamweaver), so as to exploit users' familiarity with such tools. This approach also supports the *learnability* principle [1, 5], ensuring certain features in the interactive environment which allow novice users to understand how to use it initially and how to attain a maximum level of performance afterwards.

In Subsection 2.1 we describe the working areas composing the *VIEW-GIS* environment, whereas the widget classification and behavior are illustrated in Subsection 2.2.

2.1 The Interface

One of the most important aspects concerning Web GIS is certainly the design of the corresponding graphical user interfaces (GUI), by means of which, users may interact with the system in order to formulate complex operations on geographical data. Users' support to GIS development has been indeed the main focus of the present research. *VIEW-GIS* benefits from the use of common, advanced, up-to-date visual paradigms (i.e., WYSIWYG and direct manipulation), and visual objects (e.g., icons, dialog forms, pop-up menus, etc.). This ensures high-level graphical access to the underlying geographical database and provides efficient communication facilities for querying and analysis.

Basically, in order to exploit the familiarity that users may have with other RAD systems, we have organized the *VIEW-GIS* interface following the approach used in the popular JBuilder application, as shown in Figure 1.

The interface of *VIEW-GIS* contains a tabbed pane from which widgets corresponding to common GUI and GIS functionalities may be selected and arranged on the central *Composition_Panel*, which will contain the generated Web GIS interface. When one of the tabs is selected, the widget bar associated to the corresponding category of functions is displayed, from which the developer may choose the widgets he/she wishes in the GIS interface being constructed. In particular, in Figure 1, the mapping tab has been selected hence displaying the widget bar which provides all the widgets, that can be used to provide a Web GIS with common mapping functions. We call those widgets *geographical widgets*, to distinguish their specific role in human-GIS interaction.

On the right-hand side of the environment a *Property_Panel* can be used to customize the widget which is currently focused. This task will be described in detail in Section 3. The *Property_Panel* may also be activated by selecting the corresponding item from the left-hand side frame. Such frame lists all the widgets so far positioned inside the *Composition_Panel*, and provides an overview of the Web GIS project constructed so far.

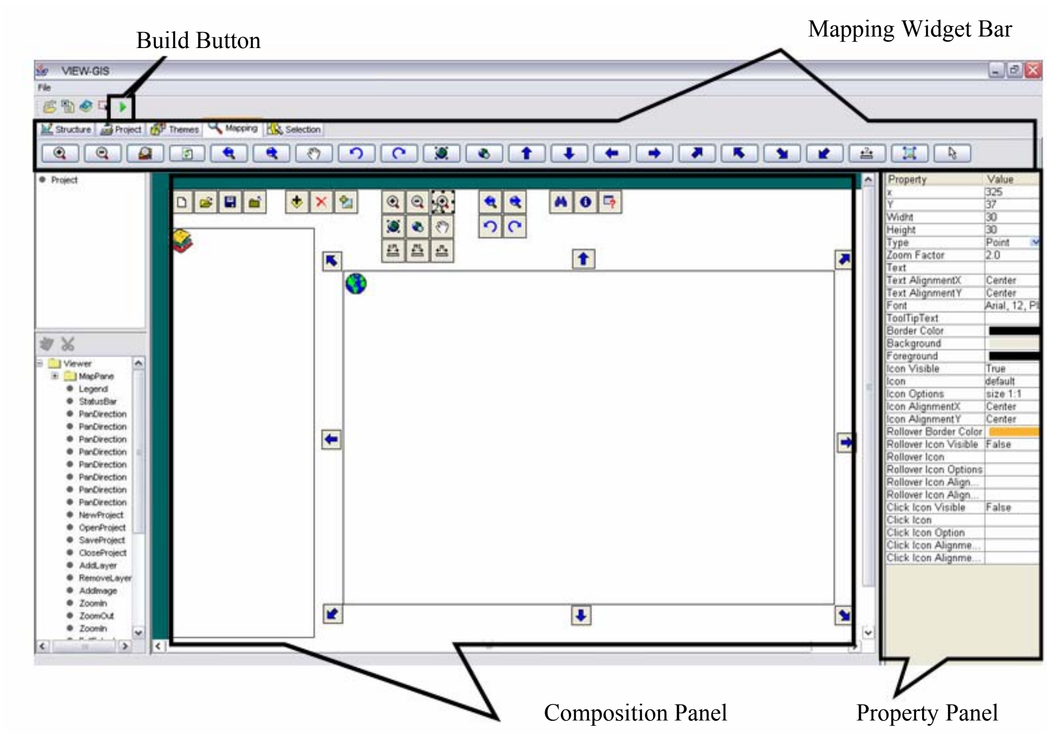
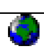


Figure 1. *VIEW-GIS* – an overview of the visual environment.

2.2 Geographical Widgets

Besides traditional widgets, such as buttons, check boxes, combo boxes, etc., *VIEW-GIS* provides domain specific controls which correspond to common functionalities of GIS and Web GIS applications. These can be selected from the widget bar associated to the Mapping tab. Table 1 depicts the minimal set of geographical widgets, whose representation and behavior are standard, and characterize every GIS interface.

Table 1. Widget description

Default Symbol	Name	Description
	Static	
	North Arrow	It indicates the North direction on the map.
	Dynamic	
	Map Legend	It lists layers currently present in the map, which may be shown or hidden. Moreover, it gives visualization details for each layer.
	Layer	It adds a new layer within the Map, MapLegend and MapKey.
	Zoom In	This operation performs an enlargement of a map portion either starting from a point or selecting an area of interest. It also reduces the scale.
	Zoom Out	This operation increases the visible area, hence making the ratio scale grows.
	Pan	This operation allows users to move the map focus.
	Full Extend	The Full Extend operation makes the whole map visible.
	Measure	It computes the Euclidean distance between two selected points on the map.
	Info	It provides the descriptive component of a geographical data.
	Find	It highlights all the features on the map which satisfy a given condition.
	Visualization	
	Map	It defines the area where vector and raster data are visualized.
	Map Key	It visualizes a small representation of the whole map where the current map focus is highlighted.
	Scale	It graphically indicates the ratio between the map and the real world part indicated by the map.

Depending on their behavior inside the generated Web GIS, we have classified them according to three different categories, namely s*tatic*, *dynamic* and v*isualization*.

Static widgets are widgets which are not subject to user's interaction. An example of static widget is the *North Arrow*, which can be positioned on the GIS interface during its construction, but is statically used to indicate the north orientation of the map and no action can be performed on it.

On the contrary, d*ynamic* widgets may respond to user's interaction, by changing their aspect and/or the internal state of the system. A particular subset of *dynamic* widgets correspond to *Measure* and *Find* which need to obtain some information by the user at runtime.

Dynamic widgets may also influence the behavior of visualization widgets, which are indeed widgets that change their appearance because of user's indirect interaction. *Map* is an example of visualization widget, which represents the area where vector and raster data are visualized, and where users see results of their operations. The map portion visualized in *Map*, may change depending on the action performed on some dynamic widget, e.g., the *Zoom In* button, which is pressed to query the GIS server. By taking into account the widget subdivision, let us now show how widgets may be configured by setting up their parameters.

One of the first customization users can perform deals with the icon associated with a widget, namely the first widget representation the user sees when he/she accesses *VIEW-GIS*. Generally, only *Static* and *Dynamic* widgets have an initial representation which can be easily set up by changing the source image file.

Each *Dynamic* and *Static* widget may be related to a label which describes it. Then, besides the text, some parameters should be provided in order to indicate the font used and the alignment with respect to the widget. Another parameter which may be set up for *Static* and *Dynamic* widgets is the *tooltip*, namely a text string explaining the widget behavior and appearing when the user moves the mouse over the widget and keeps it still for a short time slice. *Dynamic* widgets may be further enhanced by customizing the icons describing events which are usually caused by the mouse. Because of that, we have decided to allow users to decide the visual representation the widget should have in response to each kind of mouse action. A familiar example comes from the desktop metaphor, where a double click on a folder causes the folder icon to change into an open folder icon. Seven kinds of mouse actions exist, that is *Click, Double Click, Mouse Up, Mouse Down, Mouse Over, Mouse Out, Mouse Move.*

Other parameters that the Web GIS developer may set are *Layer* parameters, which indicate settings concerning with layer representations, such as the rendering colors, the layer name, etc. As for the *visualization* widgets, namely *map*, *mapkey*, and *scale*, parameters mainly concern with the size and the location. The size and position are parameters which can be set up also for *Dynamic* and *Static* widgets. We use the JBuilder approach where elements can be resized and relocated either by a mouse down action or by setting textual attributes on the size attributes.

Another important feature which distinguishes *VIEW-GIS* from other Web RAD tools refers to its capability to easily calculate the absolute position of widgets inside the interface. Basically, usual applications based on the HTML language can only determine a sequential positioning of graphical objects, unless users locate widgets by using tables which allow to divide the web page in cells where widgets can be positioned. However, common RAD tools are not able to manage this kind of information and charge the user with the task to find out which table is the best for inserting their widgets. This means that users need to know in advance the widget dimensions in order to calculate the right number of rows and columns, and the size of cells.

The approach followed with *VIEW-GIS* is different. It recalls the layout management technique on which *JBuilder* is based, which also allows a *null* layout to arrange widgets on the interface with no constraints. Similarly, in *VIEW-GIS* users are only supposed to position widgets inside the *Composition_Panel*, while their absolute positioning (i.e., the right table) is automatically determined by the underlying algorithm. In the following, an example shows how the algorithm works. Let us suppose to spatially arrange five widgets (1,2,3,4,5) within a web page as shown in Figure 2.

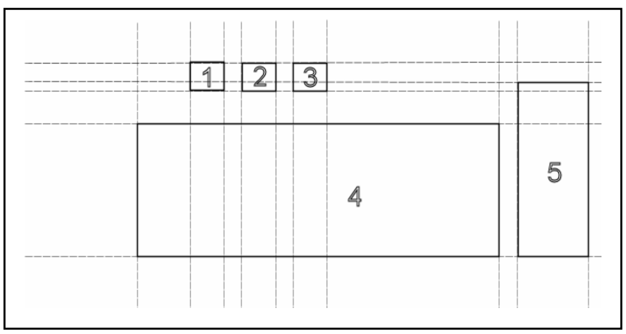


Figure 2. A spatial arrangement of five objects and their projections

The upper-left corner of the rectangle containing the widget is located at (x_i,y_i), and w_i and h_i are its width and height, respectively, for each i from 1 to 5. By projecting the bottom-left and the bottom-right corners of a widget *i* along the x and y axes, the algorithm computes the total number of rows and columns, as well as its width and height. The projection values are stored in two different sorted arrays. This phase of the algorithm requires twice the application of a sorting procedure, which both in the best and in the worst case yields a *O(n log n*) complexity, where *n* is the number of widgets. Figure 2 shows the projections resulting from the first phase of the algorithm. Once the initial table is calculated, if a widget occupies two or more cells, such cells are joined. The operation of aggregating the rows and columns crossing some widget is performed in *O(n)*, provided that a constant time is needed for each widget. Consequently, the overall running time for the positioning algorithm is *O(n log n)*.

3. THE CREATION OF A WEB GIS INTERFACE

The development of *VIEW-GIS* was first conceived as a way to satisfy the requirements of a group professionals, expert users coming from the botany domain. Such users frequently need to promote knowledge and publish maps concerning the spatial data they acquire during their survey activity, with the goal of monitoring the *status* of our environment and the human effects on it.

The group of botanists we interacted with, explained that, both to manage spatial data and to visualize their analysis results, they typically use basic GIS tools, which provide them only with equipment for browsing a map, querying the underlying data description and looking for specific patterns. On the contrary, they reported that when advanced applications and Web GIS services were required, they were forced to rely on specialized companies for the development of tools able to visualize data and perform querying on the Web. Moreover, the development of every new application required a strong interaction between users and developers to determine the expected functionalities, with increasing costs in terms of time and efforts.

VIEW-GIS has represented an effective solution to botanists' issue. By using this visual programming tool, a Web GIS has been built, which provides a set of mapping tools as well as functionality for querying the underlying database via Web, through a customized interface, totally developed by its users, namely the botanists themselves.

In the following, we describe the basic steps performed to build the Web GIS interface and show the customization tasks performed on some of its widgets.

The first phase of development consisted in the selection and arrangement of the widgets that were expected to provide the required functionalities. As an example, in order to perform the *map* selection task, the botanist-developers pressed the map button on the widget toolbar and used the mouse to drag the area where the map should be visualized. During the dragging phase a dashed rectangle is depicted in order to highlight the area where the widget will be located. A similar task was performed to properly place all the widgets on the *Composition_Panel*.

Subsequently, based on specific requirements, for some widgets the botanists needed to provide a customized behaviour, and a customized appearance. The customization task can be performed by simply recalling and modifying property values of the involved widgets. Let us focus on two specific customizations that botanists performed. The former was applied to the *zoom-in* button, which was expected to be associated with a predefined zoom factor. The latter was referred to the construction of a *find supervised areas* button, which was meant to enable users to highlight the areas where specimens of protected plants were detected. In order to perform the first customization task, the default icon was replaced by a new one, by simply setting up the value of the *icon* property located on the right of the interface. Figure 3 shows some details of the *Property_Panel* associated to the *Zoom In* button, as it appears in *VIEW*-GIS. As shown in the figure, the appearance is not the only aspect that users can adapt to their requirements. In the example, the behavior of the *Zoom In* widget was also customized by modifying the default values of the two properties named *Type* and *Zoom Factor*. The *Type* property indicates the zoom type, which determines if the zooming area has to be identified by a rectangular selection on the map or by a point selection. In the rectangular selection, the user defines the zooming map area by dragging a dashed rectangle on the map, while in the point selection, the focused point becomes the map center and the map is enlarged by the *Zoom Factor* property.

Property	Value
x	87
Y	53
Widht	54
Height	43
Type	Point
Zoom Factor	2.0
Text	
Text AlignmentX	Center
Text AlignmentY	Center
Font	Arial, 12, Plain
ToolTipText	
Border Color	
Background	
Foreground	
Icon Visible	True
Icon	zi.gif
Icon Options	size 1:1

Figure 3. A portion of the *Property_Panel*, in *VIEW-GIS*

As for the *find supervised areas* button, it was provided by customizing the default properties of the *find* button. In particular, the image associated with the icon, its name and the new tooltip to supervised areas were added to the corresponding properties, and the query property value was set to the SQL query which implements the requested functionality. The *Build* button of *VIEW-GIS* was finally used to generate the code of the target Web GIS starting from the described property setting. As specified, the *find supervised areas* changes its visual representation upon a click down action and returns to the first representation upon a click up. Moreover, the *tooltip* text is set to "Find Supervised Areas." Figure 4 shows the resulting application. The Web GIS client interface consists of a map of the Campania region located in the centre, a map legend with the *Cities* layer, and a set of customized widgets, grouped according to the class of functions they belong to.

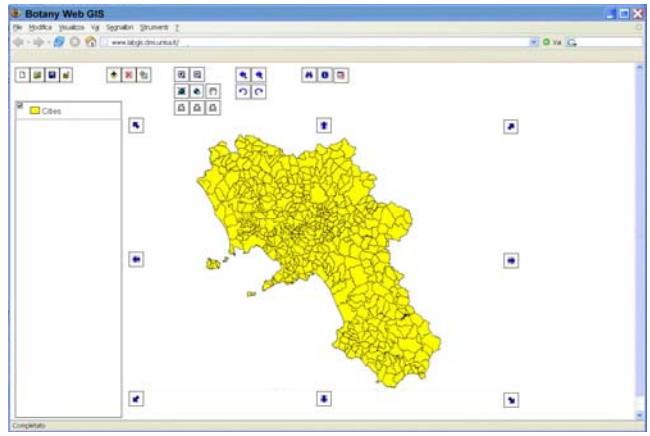


Figure 4. The Botany Web GIS developed with *VIEW-GIS*.

Once the design of the *Web GIS* interface and the customization of its functionalities are completed, the *Build* button invokes the code generation and the expected *Web GIS* application is created. The *Web GIS* users may also formulate queries to the underlying database by visually interacting with the corresponding functionalities that developers properly included in the interface through the widgets of the *Selection* tab.

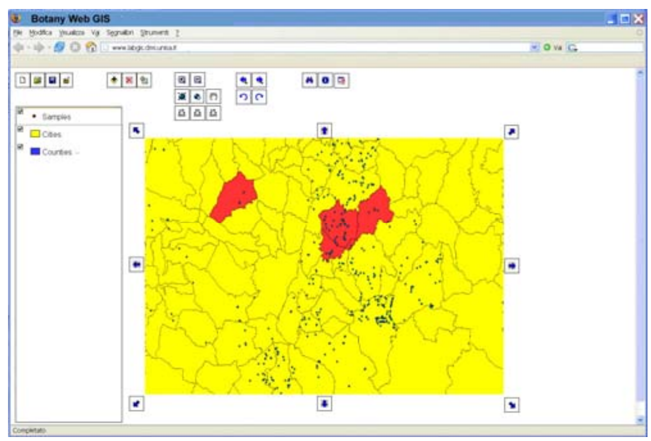


Figure 5. The areas selected by the query

Figure 5 shows the result of a query looking for the areas containing samples which belong to a given species. The area visualized in response to the query is red-coloured inside the *Map* area. The query has been solved on the basis of the architecture shown in Figure 6, where data transitions between client and server modules are depicted.

VIEW-GIS has been developed using the JAVA programming language, whose platform independency allows us to easily distribute the application across multiple operating systems with no need to implement different versions. Similarly, the resulting Web GIS application is based on a client/server architecture and on a set of both standard and open technologies, PHP, Postgres/Postgis, Mapserver and SQL, which guarantee the interoperability among server modules and the client browser.

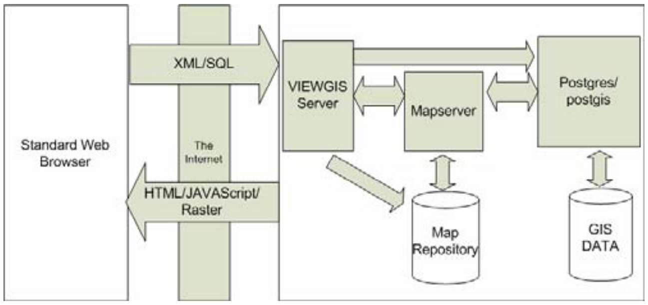


Figure 6. The architecture of the Web GIS generated

When a query is formulated on the client side, the JAVAScript client part composes the XML/SQL request and sends it to the server side where data satisfying the query are selected and sent back to the client side in the form of HTML, JAVAScript and image data. In particular, on the *VIEW-GIS* server side, the component capturing the request decompiles the query and creates the HTML and JAVAScript codes which represent the response wrapper to the user. Finally, it sends instructions to Mapserver to build the images corresponding to the query solution, which will be embedded into the code generated by *VIEW-GIS*. If the request also includes a SQL statement, a further step is needed before the Mapserver is called. In particular, the *VIEW-GIS* server creates a SQL view corresponding to the SQL code on the Postgres and then modifies the map file in order to provide some rendering information. At that point, Mapserver is called and returns the image.

4. RELATED WORK AND CONCLUSION

In the field of information systems, many factors have highly influenced the development of GIS as means to easily access, process and disseminate geographical information and spatial knowledge. The increasing popularity of the Internet, the strong progress of Information Technology (IT) and the merge of geographical information science and technology have determined a growing interest in investing in the area of Web GIS.

In order to understand the main innovative features in this work, the state of the art in Web GIS development has been examined. The traditional approach to Web GIS application development has been to implement ad hoc software solutions using both programming languages and Application Programming Interfaces (APIs) that manage spatial data. Available APIs have been widely used to build platform-independent customized applications. They allow to design several kinds of applications, such as simple viewers and tools to query both spatial and alphanumeric data. More recently, major GIS software companies have developed specialized software for web application development. As a matter of fact, ArcIMS by ESRI [8], MapGuide by AUTODESK [7], and WebMap by INTERGRAPH [9], can be used to build web applications which allow users to query and manipulate spatial information through browsers, such as Internet Explorer and Firefox. In [2], Lbath presents a case tool, named AIGLE, which is dedicated to the automatic generation of geographical software application. It is based on a specific formalism, named OMEGA, which is able to specify all the aspects of design by considering four general views: an organization view, a static view, a dynamic view and a function view.

In this work we have experimented a new way for developing Web GIS interfaces. As a matter of fact, VIEW-GIS has been conceived with the aim of enabling unskilled (yet domain expert) users to build personalized Web GIS applications on their own. This also yields the desirable benefit of reducing usability design costs. A user who wishes to build his/her own Web GIS, learns quickly the steps he/she is supposed to perform in order to accomplish the generation task. He/she performs a sequence of intuitive manipulation tasks applying the widgets he/she is interested in, and then specifying parameters needed to satisfy the personal requirements in the target Web GIS application. Besides the most diffuse GIS widgets, customization is also possible for the GUI layout, thanks to the algorithm adopted in order to overcome the problem of web absolute positioning.

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Collaborating through Computers: the Software Shaping Workshop Approach

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Abstract

Current work practices require end users to cooperate not only on their daily work, but also on the customization and tailoring of the software environments they use to better fit with their needs. To this end, software environments must provide visual computing and visual programming techniques in order to support two kinds of cooperative activities: 1) the cooperative design activity performed by the design team to generate software environments for end users and 2) the cooperative work activity performed by end users in their daily work. This paper describes a methodology for the development of such software environments.

Keywords: system design, end-user development, CSCW, customization, tailoring.

1. Introduction

The research in Computer Supported Cooperative Work (CSCW) is currently considering tailoring in cooperative contexts as a cooperative activity itself [2][20]. This is in accordance with Wilson's definition: "CSCW [is] a generic term which combines the understanding of the way people work in groups with the enabling technologies of computer networking, and associated hardware, software services, and techniques" [21]. The term groupware is often used as synonymous with CSCW, although, paraphrasing the definition provided in [8], it refers to computer-based systems that support groups of people engaged in a common task (or goal) and that provide access to some environments through a tailored interface. Groupware can be classified according to time, using the distinction between synchronous (same time) and asynchronous (different times), and to location, using the distinction between face-to-face (same place) and distributed (different places).

We are currently involved in projects in the medical domain [6][7], in which specialists in different disciplines, distributed in different places, need to cooperate to reach a diagnosis for various diseases. Consultations and diagnoses are obtained by the use of groupware systems.

Our approach to system development starts from the observation of activities of such kind of expert users during their daily work. The research we have developed in this field and the experience gained has brought us to develop software environments that support users in performing activities in their specific domains, but also allow them to tailor these environments for better adapting to their needs, and even to create or modify software artefacts. The latter are defined activities of End-user Development (EUD) [9]. EUD means the active participation of end users in the software development process. In this perspective, tasks that are traditionally performed by professional software developers are transferred to the users, who need to be specifically supported in performing these tasks [19].

We have developed a methodology to design interactive software systems supporting EUD activities [6]. The software system is composed of various environments, each one specific for a community of users, called *virtual workshops*. They are organized in analogy with the artisan workshops (i.e. blacksmith and joiner workshops), since the artisans have in their working environment all and only the tools necessary to carry out their activities. Such virtual workshops are called *Software Shaping Workshops* (or SSWs for short) to emphasize that they are virtual workshops allowing users to "shape" software artifacts. SSWs are designed by exploiting the approach based on the theory of visual sentences developed by some of the authors [3][4]. Indeed, SSWs propose interaction visual languages based on the notations end users have traditionally developed in their work practice and provide interaction tools that resemble those used in real environments.

In this paper, we show that SSWs support two kinds of cooperative activities: 1) the cooperative design activity to develop workshops to be used by end users for their daily work; and 2) the cooperative work activity performed by end users in their work tasks. In order to explain the two different kinds of cooperation, we discuss a project currently under development in the medical domain. The paper first presents the SSW methodology. Then customization and tailoring in SSWs through examples in the medical domain are illustrated. The last section discusses some related works and concludes the paper.

2. The Software Shaping Workshop Methodology

The following principles are at the basis of our methodology to design interactive software systems: i) the language in which the interaction with systems is expressed must be based on notations traditionally adopted in the domain; ii) systems must present all and only the tools necessary to perform the user work, without overwhelming users with unnecessary tools and information; iii) systems must be designed for co-evolution of users and systems [1].

In the SSW methodology, end users play two main roles in the lifecycle of the interactive software system: 1) on one side they perform their daily work tasks by carrying out visual computing activities; 2) on the other side they participate in the development of software environments as stakeholders of the domain.

In the first role, as users performing work activities, end users can tailor the workshop to their current needs and context. Professional people, such as mechanical engineers, geologists, physicians, often work in a team to reach a common goal. The team might be composed by members of different sub-communities, each sub-community with different expertise. Our approach to the design of a software system in a certain domain considers the system as composed of various environments, each one for a specific sub-community of users. Following the analogy of the artisans' workshops, end users using a Software Shaping Workshop find available all and only the tools required to develop their activities. A first type of SSWs, allowing end users to perform their daily tasks, are called *application workshops*.

In the second role, as members of the design team, end users participate directly in the development of the workshops for their daily work. In fact, even if they are non-professional software developers, they are required to create or modify application workshops. To this end, a second type of workshops are made available to them, called *system workshops*, which permit the customization of each application workshop to the end-user community needs and requirements. The concept of system workshop is more general. Actually, system workshops allow the members of any community involved in design and validation of the system (e.g., software engineers, Human-Computer Interaction (HCI) experts, and representatives of users) to participate in these activities.

Each member of the design team can examine, evaluate and modify an application workshop using tools shaped to his/her culture and to their visual notations. In this way, this approach leads to a workshop network that tries to overcome the difference in language among the experts of the different disciplines (software engineering, HCI, application domain) who cooperate in developing computer systems customized to the needs of the user communities without requiring all the stakeholders to become skilled in all the involved domains of knowledge.

In general, a network is organized in levels. In each level, one or more workshops can be used, which are connected by communication paths. Three levels always exist: a) the *top level* (the *meta-design level*), where software engineers use a system workshop to prepare the tools to be used and to participate in the design, implementation, and validation activities; b) the *design level*, where software engineers, HCI experts, and end-user representatives cooperate to the design, implementation, and validation activities; for example a user as a design member belonging to the community X participate in the design using a system workshop customized to the needs, culture and skills of the community X; c) the *use level*, where practitioners of the different communities cooperate to achieve a task; similarly, practitioners belonging to the community X participate in the task achievement using the application workshop customized to their needs, culture, and skills.

At each level, experts in a domain are allowed to communicate with experts in a different domain through communication paths. An expert using his/her application or system workshop can send data or programs to a different expert. These data and programs are interpreted and materialized by the workshop customized to the second expert. As we have shown in [6], currently the main tool for this kind of communication is electronic annotation, which plays a crucial role for two-way exchange of ideas among humans pursuing a common goal [12].

3. Supporting cooperation through SSWs

SSWs support cooperation both on software design and on task accomplishment. The first kind of cooperation is useful for creating application workshops and customizing them to the user community. We thus mean by *customization* the activity performed by the design team which generates application workshops for a specific community of users by exploiting users' notations, dialects, principles, and standard rules. Customization is thus an activity of cooperative design, since it involves different stakeholders using their own system workshops in the generation and modification of application workshops. Moreover, it is also an EUD activity because representatives of end users, as stakeholders of the application domain, are required to participate in system design and development.

The collaboration on task accomplishment can be obtained by tailoring application workshops. In our approach, *tailoring* is the activity performed by end users to adapt an application workshop to their current activity and context of work. The idea is to permit tailoring of systems, which are already specific and suitable to the needs of a community of users, because they have been designed through a cooperative activity performed by all stakeholders. More specifically, two types of tailoring can be devised: *tailoring for individual work*, concerning the activities that the end user can perform to adapt her/his environment during her/his own work; *tailoring for cooperative work*, including those activities that the end user performs to tailor the tools needed to permit the communication between end users. Such tools are necessary to send the information to another end user to whom collaboration is requested, such as for example, in medical cases, the exchange of consultations to reach a common diagnosis about the patient disease. We are interested here in this second type of tailoring: examples are provided in the case study discussed in the next section.

4. Customization and tailoring in the medical domain

In this section we describe a project in the medical domain, to which we are currently applying the SSW methodology.

The improvement of the quality of the medical diagnosis is the main goal of each physician. Thanks to the evolution of research and technology in the medical domain, each specialist may have the aid of medical examinations of different types, i.e. laboratory examinations, X-rays, MRI (Magnetic Resonance Imaging), etc. A team of physicians with different specialization should analyze the medical examinations giving their own contribution according to their "expertise". However, the increasing number of medical specializations as well as the increasing number of patients do not permit the team of specialists to meet as frequently as needed to analyze the clinical cases especially if they do not work in the same building or moreover they work in different towns or states. The information technology has today the potential of overcoming this difficulty by providing software environments that allow a synchronous and/or asynchronous collaboration "at a distance". In fact, tools for supporting the physicians in their daily work already exist, e.g. telemedicine, videoconference, etc. Thus, the specialists do not need to meet at the same place for analyzing the clinical cases on which they collaborate. However, physicians complain that these tools are very expensive and need large system resources, and that they are often difficult to learn and to use.

Our proposal of SSWs aims at providing the physicians with software tools that are first of all easy to use and adequate to the physicians' current tasks and that resemble their real tools. This will determine an increase in productivity and performance, with the achievement of competitive advantage for the organization they work in.

We are currently applying the SSW approach in a project we are involved, which is in collaboration with the physicians of the neurology department of the "Giovanni XXIII" Paediatrical Hospital of Bari. In this project, different communities of physicians are involved, namely neurologists and neuro-radiologists, in the analysis of clinical cases and in the generation of the diagnosis. The first step of our project was a field study with contextual interviews to identify how the physicians collaborate in the analysis of clinical cases and the environmental and organization factors influencing their work, as well as the categories of end users involved and their main tasks, their specialized medical dialects, their common languages [7].

We now describe the case in which a neurologist asks for a consultation to a neuro-radiologist to analyze cases by studying MRIs in order to make a better diagnosis for their children patients. Currently, consultations occur during a real meeting. Due to the busy schedule of the physicians, these consultations cannot be frequent, therefore when they meet they have to analyze several clinical cases. During the meeting, the cases are discussed one at a time and always with the same procedure. The neurologist chooses a case, gives the MRI plats to the neuro-radiologist and begins to tell the most relevant data about the clinical history of the patient. The neuro-radiologist puts 3 or 4 MRI plats on the diaphanoscope and begins to study them. During the study of the MRI, the neurologist and neuro-radiologist exchange information in order to clarify possible doubts and converge to an agreed opinion. At the end, the diagnosis on which the specialists agreed is written on the patient record and the next clinical case is considered. If the physicians cannot physically meet, the consultations occur through services of instant messaging or e-mail. Obviously, in this case, some problems arise, such as the limited capacity of the e-mail, the problem of connection and so on.

4.1 Customization of application workshops

We adopted the SSW methodology to build application workshops customized to the physicians' notation, language, culture, and background, that physicians themselves can further tailor according to their needs. These workshops allow the specialists to cooperate in virtual asynchronous meetings. The specialists may use their own application workshops to perform their daily work tasks: for example, a specialist may analyze the available Electroencephalogram (EEG) or MRI, perform annotations and/or computations on them, select parts of them, define diagnoses and/or consultation requests.

Considering the observations collected during the field study, each workshop is equipped with a certain set of tools necessary to carry out the work task and is customized to the specific user community. For example, both application workshops devoted to neurologists and neuro-radiologists have an overview area on the top of the screen, which may be used to browse MRI plats or EEG portions. The overview area is the electronic counterpart of the diaphanoscope used by the physicians in a real meeting. Since neuro-radiologists are only interested in MRI, in their application workshop, they find only the MRI overview area (see Figure 1) together with tools to process the MRI and to formulate the diagnosis. On the other hand, neurologists study primarily a great number of EEGs but in some cases, they analyze MRI plats. Thus, in their application workshop there are two overview areas, which are resizable (see Figure 2). In this way, the neurologists can reduce (or even close completely) the area containing the MRI plats, in order to expand the EEG overview area according to their needs.

Figure 1. The application workshop prototype devoted to the neuro-radiologist.

Each workshop is the result of a cooperative design performed by a team including representatives of end users (e.g. senior physicians), HCI experts and software engineers. To this end, representatives of end users interact with a system workshop to create the application workshops by visual composition of widgets prepared by software engineers and HCI experts. Details of such a visual composition are provided in [5] describing the application of the SSWs methodology in a mechanical engineering domain.

Figure 2. The application workshop prototype devoted to the neurologist.

Figure 3 shows a screenshot of such system workshop: the user has partially composed the application workshop devoted to neuro-radiologists by selecting from the repositories on the right side of the screen, the canvas on which the application workshop is composed, the overview area, the working area, the archive area, the Exit button and the "images" archive. Actually, the user is creating a program by visual interaction with the system workshop. Being not expert in computer science, s/he is not required to write any textual code.

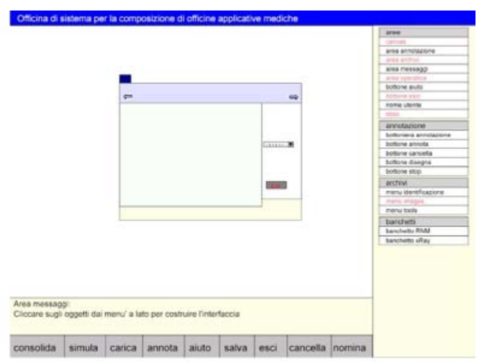

Figure 3: A representative of end users is interacting with a system workshop.

4.2 Tailoring for cooperative work

As already mentioned before, tailoring for cooperative work refers to tailoring activities needed to communicate efficiently and effectively with colleagues. To this aim, end users shape software artefacts to be used to make information available to another specialist to whom a consultation is requested. In the following, we describe how a neurologist may tailor the system in order to communicate with a neuro-radiologist and requests her/him a consultation. As the field study revealed, in their daily work, neurologists and neuro-radiologists request and provide consultations by indicating to their colleagues parts of EEG and/or MRI which may be of interest to formulate the diagnosis. This kind of activity is supported by the application workshops previously described. For example, the neurologist may find in a specific window, called work bench, a tool for highlighting a limited part of the selected portion of EEGs (see Figure 4). The tool can be selected by clicking the ninth button from left in the bench toolbar. The system reacts to this user action by presenting a red vertical bar that the user may position on the point of the EEG s/he would like to highlight. In Figure 4, the neurologist has positioned two bars on the EEG in order to identify a specific part of it concerning a certain period of time.

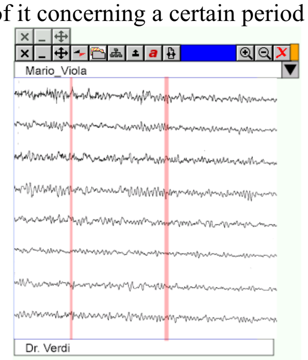

Figure 4: The work bench for EEG analysis.

A selected area can also be annotated and the annotation may be exploited to support the collaboration between specialists that want to reach a common diagnosis. For example, if the neurologist needs to consult a neuro-radiologist, s/he may create a request by clicking the eighth button in the bench toolbar (whose icon is “a”), thus opening a special type of annotation window, called consulting window. This window permits to articulate the annotation into two parts: the question to be asked to the colleague; and the description which summarizes information associated to the question. A third part can be tailored according to the addressee of the consultation request: if s/he is a physician who needs more details about the clinical case, the sender may activate the detailed description and fill it, otherwise he can hide it. Figure 5 shows a consulting window, in which all the three parts are activated. In other words, the physician who wants to ask for a consultation is allowed to prepare a tailored annotation specific to the physician s/he is consulting. In a similar way, a physician can make a different type of annotation in order to add a comment that can be stored and possibly viewed by her/his colleague. It is worth noting that both types of annotation never damages the original image.

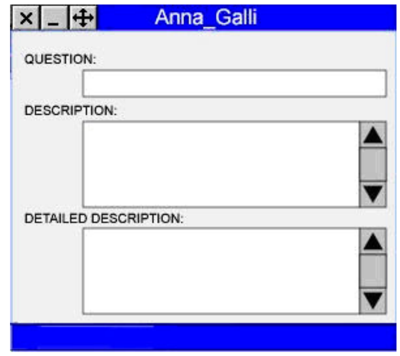

Figure 5. An example of consulting window.

Back to the example of a consulting request of the neurologist for the neuro-radiologist, the neurologist can save the annotation that can be successively viewed by his colleagues. When the neuro-radiologist starts working with her/his application workshop and finds the request of the neurologist, s/he reads all the information and answers by filling the proper fields in the consulting window (see Figure 6).

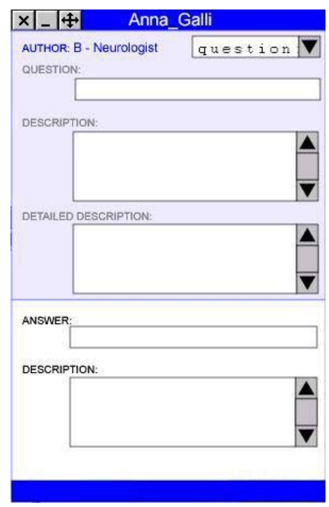

Figure 6. An example of consulting window for the neuro-radiologist answer.

5. Discussion and Conclusion

In this paper, we presented an approach to the design of interactive systems that support end-user development and cooperative work, and described its feasibility in a medical domain, by considering the work practice in the case of neurological diagnoses. Understanding current work practice is necessary in the design of new technologies. The challenge is to dissolve the barriers existing between designer knowledge and user knowledge and to search for adequate methods to guarantee the inclusion of practitioners and work practice knowledge in the design process. In [15], Karasti explores the integration of work practice and system design. Research with similar interests in work practice has been carried out within the field of CSCW [13][14][17][18].

Our approach foresees two kinds of cooperative work. One concerns system design and is performed by the design team, including software engineers, HCI experts and representatives of end users. For HCI experts and end-user representatives, design actually consists in customization activities performed by direct manipulation techniques. The other concerns the cooperative work performed by end users to achieve their goals in the system domain and to possibly tailor their software environment. Customization and tailoring are thus characterized in terms of the kind of cooperative work performed and of the goals that have to be pursued. In this sense, our definitions are different from those ones provided in [16].

The SSW methodology has some similarities with the work presented in [10][11], especially because it adopts a *meta-design* perspective, but it also emphasizes the need of providing personalized environments to all stakeholders, in terms of language, notation, layout, interaction features.

The approach has been applied to other domains, e.g., the mechanical engineering [5]; user-based evaluation in that domain has provided useful indications. The users feel that this novel way to design cooperative systems increases both their productivity and their performance.

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Visualization and Exploration of Landscape Architecture Project Information

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Abstract

Landscape Architecture project requires specific geographic and multimedia data management. To meet the landscape architect's needs, especially in the project analysis phase, we propose a *geographic file exploration* approach that improves visualization and exploration of landscape data. We have developed a prototype that incorporates our proposal. We are also realizing tests with potential users and first results are encouraging.
Key-Words: data visualization and exploration, interactive and visual interfaces, metaphors, multimedia, GIS, Landscape Architecture, soundscapes

1. Introduction

This paper presents a work that has been carried out thanks to the collaboration of the Laboratoire d'InfoRmatique en Images et Systèmes d'information (LIRIS, Research Center for Images and Intelligent Information Systems) of INSA of Lyon and the Ecole Nationale Supérieure de la Nature et du Paysage (ENSNP, National School of Higher Studies in Landscape Architecture and Nature). Landscape Architecture projects mainly handle multimedia and Geographic Information Systems (GIS) [1] data. After many discussions with landscape architects and students, we have noticed issues in the field of Landscape Architecture project management that led us to suggest solutions in this area. Especially, we truly believe that landscape data visualization and exploration can be highly improved with a novel approach that is introduced in this article.

The remainder of this paper firstly describes what a landscape project consists of and presents Landscape Architecture project requirements. The fourth section deals with background research. The fifth section presents our solution. The sixth section introduces the prototype we have developed and the tests we are realizing. The last section concludes and presents perspectives.

2. Landscape Architecture Project

Landscape Architecture projects can be summarized through five stages: site analysis, solution proposal and design, proposal communication, realization, and maintenance. This domain meets numerous requirements and offers huge research perspectives. The analysis phase is a decisive stage and this paper mainly focuses on it.

During the analysis phase, in order to formulate a diagnosis, the landscape architect first collects and measures a sufficient amount of information on site, such as natural information (e.g., vegetation, geology, hydrology), infrastructure information (e.g., buildings, architecture, roads, networks), and social and economic information (e.g., population, economic and geo-political factors and actors, resources, site history). To do so, the landscape architect collects information from all available sources such as the general public, local governments, cadaster, population census, the media, libraries, and the Internet. He also performs measures himself on site, especially pictures, videos, notes, sketches, and distance measures. After this diagnosis stage, issues are identified.

3. Landscape Project Requirements

Many different types of requirements concern Landscape Architecture project. This article mainly focuses on analysis phase and visualization needs.

The landscape architect needs to view the existing site and also to preview the result of his proposals. He needs a sufficient, not perfect, realism and needs to consider a certain *sensitive* aspect.

The architect essentially handles geographic information (maps, 3D maps) and multimedia information such as images, videos, texts, and 3D objects. The data are massively geographically structured: the collected documents are geographically linked, e.g., pictures are taken at precisely defined points of view and they are oriented in specific directions, videos and sounds are recorded at precisely defined locations, notes and images can relate to particular objects in the landscape, several maps can concern several neighboring places. The maps are stored as GIS data or as images, and handled through GIS interfaces or image software editors. Multimedia files are stored in the computer's file system, distributed in folders, and edited through related software editors.

Information storage, access, and file exploration are not well adapted to the landscape information structure. When exploring some document folder such as a picture gallery or other multimedia file set in the file system hierarchy, the architect must remember where each picture has been taken on the site, where each video has been recorded, where each sketch has been drawn, where each textual note has been written, etc. The architect must realize this geographic location correspondence himself. This effort constitutes a major difficulty that increases again when the architect manages several projects at the same time. Landscape project information strongly calls for solutions to be visualized, explored, structured and managed in an efficient way. Besides, as visiting time on the site is usually short, the architect usually takes a maximum amount of information for later analysis away from the site. The amount of information is then generally huge, unordered, and sometimes unnecessary. It strongly needs to be filtered and smartly structured. The architect needs an effective and global data visualization to perform this task.

Moreover, information is usually visual, but also presents an important audio dimension (landscape map of sounds often called *soundscape*, voice recordings) and temporal dimension (moving viewers in a car or on a train, walkers, animated or moving landscapes).

Finally, interfaces must be user-friendly and fast. The architect needs to quickly acquire a sufficient representation of the existing site and to quickly preview different project proposals.

4. Background

Existing systems present notable features for our field of interest [1]. 3-Dimensions landscape visualization systems [2] offer the advantage of exploring existing sites and previewing proposal results. Many 3D extensions of GIS exist [3] as well as non-GIS-based systems. Online solutions also exist such as Geo-VRML (http://www.geovrml.org). *Augmented Reality* is also interesting by adding virtual objects to the real world [4]. 3D presents advantages such as good communication abilities to show proposal result but 3D obliges architects to model the existing site and the project result in three dimensions. This commonly takes a long time, and architects find it quicker to touch up pictures. 3D offers realism, but realism requires expert skills and time to be achieved. Landscape architects also dislike 3D landscape images for their numerical *insensitive* aspect.

Metaphors present efficient abilities to visualize information and to handle interfaces in an intuitive and user-friendly way. Two metaphors are particularly interesting in this way. They also offer useful concepts to structure Landscape Architecture project information. *Hypermaps* [5] propose a *navigation* metaphor by geographically placing links on a map to other documents. The user can *navigate* from maps to maps. *Argumaps* [6] geographically locate information by placing metaphorical *pins* on maps and attaching information to them.

Three other systems from the industry also present interesting features. In the *MappyVisiocity* system (http://www.mappyvisiocity.com), the user can explore a street by passing from a front door image to another following a street map. With widely used 360-degree panorama technologies such as Apple's QuickTimeVR (http://www.apple.com/quicktime/technologies/qtvr), the user can virtually visit a place by turning and zooming on a 360-degree picture around a point. Datria (http://www.datria.com/demo.php) proposes an interesting vocal system for staff management. The system records voice reports of geographically moving employees thanks to a Global Positioning System and a wireless phone.

To increase interface user-friendliness, it is useful to keep in mind *Direct Manipulation* [7] advices. It recommends to always keep the focus on objects of interest and to directly act on this objects instead of using intermediate commands.

5. Proposal

In this section, we propose a solution that takes advantage of existing systems and extends some of them with new features.

5.1. Geographic File Exploration

We propose to extend usual file explorers with a new *geographic* feature. In our *geographic file explorer*, landscape project documents are positioned on a map at geographic locations. This approach well suits landscape project structure and offers an efficient way to quickly memorize and retrieve location of a large set of documents. This concept can be integrated into GIS interfaces and into file explorers of operating systems. We first concentrate our efforts on extending file explorers.

In our system, on any image document of a landscape project, the user can place icons (Figure 1). Each icon constitutes a link to any other document in the project. The user chooses the linked document in the file system. The documents can be of many different types: multimedia and other types. By viewing an icon,

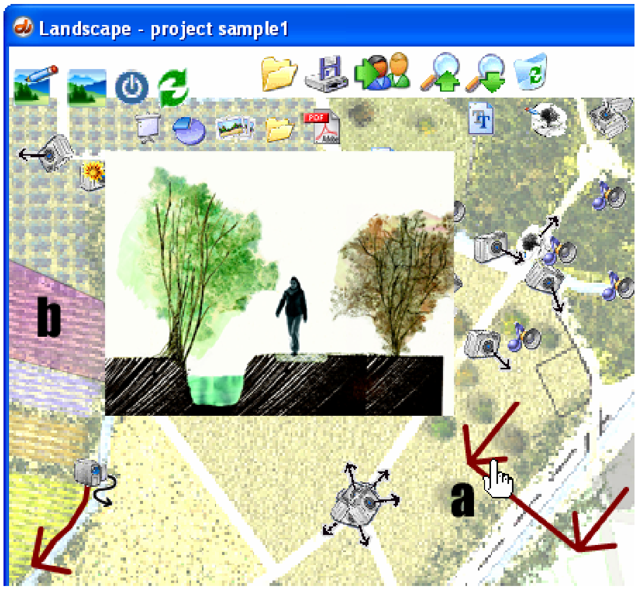

Figure 1. ***Geographic file explorer*** **– (a) Map section. As the cursor moves over the section, the linked image document can be previewed above (b) Document-linked area. Icons:**

	Video trajectory		Oriented sketch
	Oriented picture		Sound
	Text		Spreadsheet / Graph
	Slideshow		Pdf document
	Image gallery		Folder

the architect can understand the linked document type (text, video, another image). He can also personalize icons, e.g., map, picture and sketch icons can all represent an image document. To really integrate multimedia documents, icons represent images, texts and also videos and sounds such as landscape sound recordings and voice recordings. Other useful icons are also available for slideshow, spreadsheet, graph, image gallery, folder contents, and PDF file links. Icons give a way to navigate from an image document to another. This navigation is similar in usual file explorers when opening a subfolder. In our system, "*subfolders*" are other linked maps. Classical file system subfolders can also be linked on a map. By this way, the user can navigate between the conventional file system and our geographic structure. Moreover, like with usual file explorers, the user can edit documents through external editors.

To achieve this geographic exploration, our system adds geographic meta-data to each linked document, especially its location on the map. As we find location information insufficient, the system also adds other geographic meta-data, provided by the user: the user can indicate the orientations of the pictures he took on the real site and the trajectories of the videos he recorded. Arrows represent these orientations and trajectories. The user can indicate map sections that are linked to other images. He can also define interactive areas instead of icons.

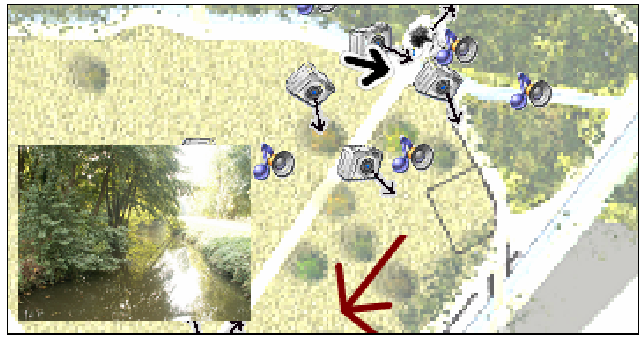

Figure 2. ***Virtual walker*** **preview**

To improve visualization abilities, our system reacts when the mouse cursor passes over the icons by directly previewing documents: images are viewed, videos are played, texts are shown, and sounds are played.

5.2. The *Virtual Walker* Metaphor

We found useful to extend our geographic file exploration by visualizing the interaction of the mouse cursor with every document on the site in the same time like if our mouse cursor becomes a *virtual walker* (*vw*, Figure 2). In the *vw mode*, the mouse cursor is an arrow representing the *vw*'s orientation. The mouse's movement simulates the *vw's* movement. The *vw* is especially useful with map images. When approaching icons on the map, the system reacts with the related documents according to certain conditions. With image and video documents, previews are displayed. To simulate the *vw*'s view, the size of the document preview depends on the distance between the icon and the *vw*. The shorter the distance, the larger the preview size is. Moreover, as the *vw mode*'s goal is to simulate real movement, only oriented pictures and videos are previewed and they are displayed only if the *vw*'s direction approximately matches their orientations.

In order to simulate the *soundscape* (sound landscape), the *vw* also hears every sound around it when approaching related sound icons. The closer the sound icon, the louder the sound is. Several surrounding sounds are mixed. This feature adds a real sound map dimension to usual visual maps.

5.3. The *Virtual Walker* 3D Mode

Our system also offers a *vw 3D mode* (Figure 3). The *vw* 3D mode offers the advantage of requiring no 3D modeling time by the user, unlike usual 3D systems that need a long time to model the ground and all the 3D objects on it. The *vw* 3D scene is automatically and instantaneously generated, providing a fast 3D preview. In the *vw* 3D mode, the map image becomes a flat *ground*

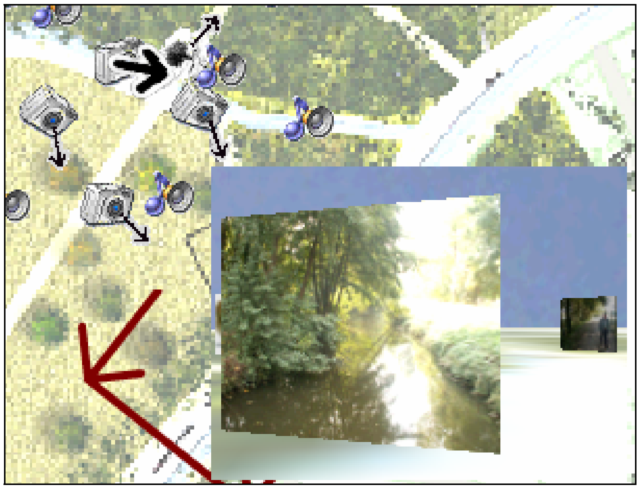

Figure 3. *Virtual walker* 3D preview

and the *vw* can explore it by moving across it. Oriented images are mapped as textures on vertical oriented planes. They are still only visible if the *vw*'s direction approximately matches their orientations.

Unlike already proposed 3D extensions of file explorers, in our system, spatial information on the interface expresses geographic semantics by corresponding to real world geographic locations and orientations.

6. Prototype and Tests

A recently developed prototype integrates all of the functionalities presented in the previous section. Illustrations of previous section are prototype screenshots. The prototype, called *Landscape*, is in Beta version. It is available on both Windows and MacOsX operating systems. It is downloadable with a project sample at its website location (http://franck.favetta.free.fr/landscape). Project files respect an XML format for better interoperability with future programs.

We are currently realizing tests with potential users. The tests consist of an online list of detailed questions related to different specific criteria. Criteria concern exploration and preview features and also other type of criteria such as interest of spatial information management, multimedia integration and interactivity features. The testers are invited to evaluate each criterion. They can also suggest improvements. ENSNP students and teachers are performing these tests. The teachers are professional landscape architects as well. Furthermore, a whole student class currently uses the prototype for a real Landscape Architecture project. This also constitutes a major experimentation that is quite instructive and is an efficient way to improve our system. First results are encouraging.

7. Conclusions and Future Work

This article has presented a novel approach that meets Landscape Architecture project requirements. A *geographic file explorer* is adapted to quickly and efficiently explore and preview geographically structured multimedia documents. A *virtual walker* metaphor constitutes a fast and useful way to visit a site and to interact with landscape elements. We have developed a prototype that incorporates these abilities and we are realizing tests with potential users to check its accuracy for landscape architects' needs.

As a first step, our work focuses on visualization of landscape project analysis phase. Our proposal also presents potential abilities for the project design phase and the project communication phase, and also for the management of the numerous actors of Landscape Architecture project. An interesting system extension consists in automatically measuring spatial information such as document locations thanks to a Global Positioning System.

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A Visual Approach to Develop 3D Interactive Environments

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Abstract

The development of software systems effective and simple to use is a complex and elaborated work which requires a proper analysis and a careful design. A key aspect for the success of an application is a good design of its user interface. 3D environments provide designers with a more powerful space to allocate interface components on multiple levels. In this way, the interface becomes more captivating, showing realistic sceneries to the user [3]. In this paper, we present a tool for the rapid implementation of 3D interactive visual interfaces. The proposed methodology supports the designer by a two level approach. The first phase is related to the application design in terms of a graph-based description, then the implementation phase is defined in terms of a component assembly mechanism.

1. Introduction

The rapid evolution of interactive hardware devices and software applications have brought developers to invest more and more financial and time resources in the realization of software engineering products to support the design of applications and interfaces. Nevertheless, often the end users has to interact with the resulting environments uselessly complex. A proper analysis and a careful design of the user interface should guarantee simplicity, completeness, intuitiveness and usefulness. 3D environments offer a variety of solutions for interactive application designers to allocate interface components in a powerful space, where multiple levels of visualization can be presented. However, user interaction through a three-dimensional space causes frequently navigation problems, such as disorientation and difficulties in wayfinding [4]. Some guidelines for environment design and electronic navigation aids have been proposed to solve these problems [6]. Experiments have shown that the effectiveness of a navigation aid depends on the specific environment and on the specific task to use [2]. The world scenery offers several tools to support the development of interactive graphic three-dimensional applications: often complex and integrated toolkit to design visual environments are related to specific domains or require knowledge of programming language and substantial coding efforts to perform any particular functionality, such as the implementation of interactive mechanisms.

In this paper, we present a design methodology that allows software developers to easily define the graphical and layout features of a 3D interactive visual application together with its behaviour in a guided and totally visual manner.

The approach is conceived to perform correctness and completeness controls during the two main phases of the development process. As a matter of fact, the proposed methodology integrates the advantages of graph-based design with a visual construction of software applications using a component assembly mechanism. In particular, starting from a top-level design of the visual environment, a usable form-based interface of the tool allows detailing the graphic aspects of each scene. A similar visual technique allows a designer to manage the interaction mechanisms, so that all the features related to an event (i.e., the source object, the action performed on it, and its effect on the application itself) can be easily specified. The paper is organized as follows. In section 2, we examine three tools to develop 3D environments. Section 3 summarize the visual methodology to develop 2D interactive visual application and describes the aspects of the customization to develop 3D environments. Section 4 presents some concluding remarks and further work.

2. Related work

Several graphical toolkits to develop 3D environments are available. Each of them integrates different functionalities and features that can be more or less preferable. *Art of Illusion* [11], for example, allows to the designers to define the static graphical aspect of a 3D environment, but does not allow to implement any possible interaction between objects and a user or any connections between different scenes or external files. In the *Blender* tool [12] a user interface shows the whole 3D environment under development in form of a grid in which to insert, modify, move or resize objects. The logic of management of the events involves the manual implementation of scripts in Python code.

Wings 3D [13] allows to insert several solid geometric figures in a three-dimensional space. The 3D rendering of a global scene is effective, but the tool needs external OpenGL graphical libraries to perform it.

However, if these environments allow to realize 3D software interface easily and quickly, in any cases, their use involves the knowledge of a programming language and many hours of work and experience to obtain a considerable level of efficiency of the developed systems [5].

3. The proposed visual development approach

In this paper, we propose a methodology to design and implement interactive visual environments, simple to use, flexible and that requires a limited amount of foregoing knowledge and learning time. TAGIVE (Tool for the Aided Generation of Interactive Visual Environments) is the prototype system that implements the proposed approach related to the two-dimensional interactive visual applications [1]. TAGIVE-3D is its customization to develop 3D environments. The approach is based on the definition of an interactive visual application in terms of a set of *scenes* and a set of *external components*, related to each other on the basis of the kind of interactions performed. A scene is made up of elementary components representing interface widgets and arranged on the scene according to a certain layout. Each elementary component appearing in a scene is said to be *dynamic*, if some event is associated with it or *static* otherwise. External components are instead any file that can be invoked by some dynamic component of a scene (e.g., image files, text files, video clips, etc…). The proposed approach exploits such a model in order to allow a two-level approach in the construction of an application. The former level is focused on the individuation of the main elements of the system and of the interactions between scenes or between scene-to-external components. For each scene, the latter level details its graphical properties and allows to implement actions and events related to the dynamic components. Then, the methodology integrates the advantages of a graph-based design with the benefits coming from a visual construction of applications using a component assembly mechanism. The integration supports the development of interactive visual environments by directly relating the design phase to the implementation phase. In fact, a graph-based design approach is used to build the "application map", in terms of a top-level transition diagram representing all the possible interaction paths. Indeed, oriented and connected graphs are a very good means to design and examine the number of scenes or external files and the interaction paths of an interface. The navigation technique is useful to manage maps with a limited number of the nodes, clustering technique is suitable to model more complex application [14]. The idea is that the application map guides the following phase of the development. The resulting environment is saved in terms of a markup language so to provide the additional benefits of a portable and version resilient system.

In a virtual environment, there are objects arranged in a 2 or 3-dimensional space. The objects appearing in a scene are solid figures, like parallelepipeds, spheres, pyramids, cylinders. In a 3D application, the interaction modality and the related events are more articulated than 2D ones, as several *transformations* on objects can be performed. The transformations are translation, rotation and resize and involve the manipulation of an object in a virtual space [7].

A 3D object can be moved along the x, y or z-axis and along the x and z-axes together. The shift is performed increasing the coordinates of the different points that define the element. The rotations have a centre of rotation corresponding to the coordinate of the same object or to a system of global coordinates, around which the rotation happens. That transformation can be performed around the x, y, z or x and z-axis. By the resizing transformation, it is possible to expand or decrease three-dimensional objects simply multiplying the coordinates of a point for resizing factor. When the factor is positive the size object is augmented, otherwise, a negative factor approaches the points to the origin and the figure is reduced.

In the following, we describe the adopted strategies to realize 3D interactive applications.

The first environment TAGIVE [1] is improved by means of the Java3D package classes so to allow the implementation of the features of the 3D environments. Figure 1 presents the structure of the TAGIVE-3D. TAGIVE-3D inherits from TAGIVE the Map Editor module by which to perform the general design of the application. It represents the top level of the development process. In this subsystem, a Work Area contains the graph that represents the application map (see figure 2). The nodes identify the components expected in the environment (i.e., 3D frames, *.bmp*, *.txt* and web or multimedia files). The edges represent the possible interactions paths that the end-user can to perform in the virtual environment. They are labelled by the possible actions by which to run an event (i.e., mouse single left click, mouse double left click, mouse right click, left mouse pressed and dragged, right mouse pressed and dragged, left mouse pressed and ALT key).

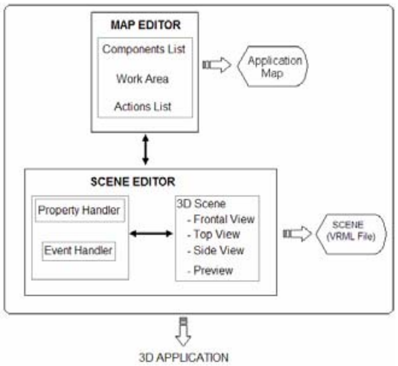

Figure 1. Schema of the implemented tool[1].

A guide helps the designer to understand the meaning of the different actions. The Application Map is the output released by this phase.

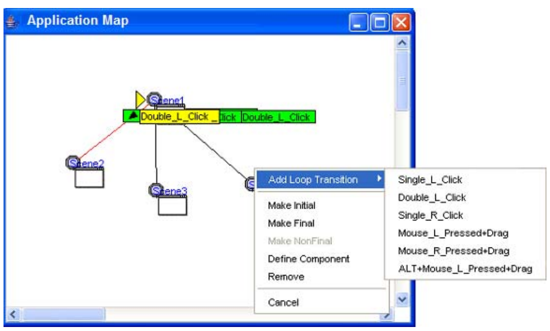

Figure 2. The Application Map.

The Scene Editor is the module at lower development level. The original version was modified to allow the visual implementation of a 3D scene in terms of the three two-dimensional views (side, top and frontal) of the environment perspective. That approach allows to arrange objects in the space in easy manner supporting a global view of the environment in the preview frame. As a matter of fact, in the proposed methodology, we have exploited two-dimensional sections of the objects, so to preserve the information related to the dimensions, the volumes and the forms of the introduced components, without modifying the properties of an object also if the point of view of the user changes. The designer can manage the feature of each 3D component inserted in the virtual space by the Property Handler module of the Scene Editor (see figure 3). For each object, it is possible to define colour, name, and location in terms of the x, y, z coordinates, and dimension in terms of height, width and depth and the designer can specify the rotation around each cartesian axis.

Figure 3. 3D component properties.

To guarantee correctness in the development process we propose a top-down technique so to check the insertion of actions in any scene. In fact, the designer establishes the scheduled actions and the related target events in each scene, already at the map level. At the lower level (the phase of the scene development), only such actions will be visible and will be associated to the particular elements of the scene (the *dynamic* components) so to detail the related event [1].
Loop transitions in the map define actions related to events that involve modifications of the properties of objects in the scene and also they identify possible transformations that the end user can to perform on a 3D component. According to the conventions generally adopted in the three-dimensional interactive environments, and included in the Java 3D package, our system implements the visual definition of the following actions: "left mouse pressed and dragged" to perform the rotation of an abject; "right mouse pressed and dragged" to perform the horizontal or vertical translation; "left mouse pressed and ALT key (or central mouse button pressed) and dragged" to shift an object along the axis of the depth. Selecting simple toggle button, the designer visually establishes if the end user can to perform a rotation of an object around the x, z or x and z cartesian axis by the related action.

Figure 4. X-Z Translation Handler.

[1] The shape ☐ indicates a tool module. The shape ⬭ indicates a graphical visualization unit of an interactive visual application. The arrow → denotes the interconnection between tool modules whereas the arrow ⇨ denotes the production of an output.

Figure 4 shows the Event Handler to implement the horizontal or vertical translation event, resulting from the dragging of the component in the virtual environment. The event is related to the right mouse pressed and dragged action. In the frame the designer defines if the end user can move an object along the x, z or x and z cartesian axis, and also he/she fixes the range of the translation (if the end user exceeds the permitted range, the object returns in the initial position on the scene). Similarly, the designer can implement the translation event along y cartesian axis. Actions not expected at the design level, cannot be implemented arbitrarily at the implementation level of the application. The approach guarantees correctness, completeness and usability checks and it prevents possible errors from the early design phase. Measures related to the quantity and the type of possible actions, or related to the number of possible transformations of 3D objects, could be checked before they are implemented. Similarly, nodes not connected in the graph denotes the presence of scenes or files expected but not achievable in the visual environment. Again, edges representing interactions, which have not been specified at the lower level, will have highlighted in the map. That controls allow to manage in advance metrics related to the efficiency of the systems in terms of the correctness and completeness of the achievement of a task that the user can to perform. After the 3D environment is implemented, during the running phase, the Java Virtual Machine processes the graphical information according to the defined operations [8]. Then, the 3D implemented environment is executable and the end user can to interact with it. The resulting environment can be saved in *.t3d* format (TAGIVE-3D own) or exported in VRML format [9]. The Virtual Reality Modelling Language is the standard adopted to save 3D applications to guarantee the portability and the reuse of the virtual components.

4. Conclusion and further work

In this paper, we have presented a methodology to visually develop 3D environments in terms of graphical, layout characteristics, and the related interaction mechanisms. A designer can exploit the system functionalities without any detailed knowledge or former ability. Graphic aspects management and interaction mechanisms development are simple and does not require learning of any particular programming language.

The approach, implemented in the TAGIVE-3D tool, guides the designer in the modelling and implementation process so to prevent incorrectness and incompleteness errors already from the initial design phase. The system is implemented in Java, adopting the Java 3D package, so that all the rendering algorithms and the 3D environment implementation make the tool simple to extend according to new specific requirements. Further evolution of this work will consider the introduction of new 3D objects in the component palette in addition to the actual spheres and parallelepipeds. The possibility of adding a particular texture to one or all the faces of 3D elements, the visual managing of the brightness and of the shape of the objects are other functionalities to improve. Actually, we have implemented the possibility to save a global interactive application in *.t3D* format (a native java format). Moreover, the VRML markup language used to export the target application ensures portability and reuse of components. In this perspective, another aspect of the presented research is the improvement of the characteristics of the X3D language and the implementation of functionalities to save developed 3D environments in this format [10].

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Formal Issues in Languages Based on Closed Curves

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Abstract

Three important questions arise when using visual languages: for any given piece of information can we draw a diagram representing that information, can we reliably interpret the diagrams and can we reason diagrammatically about that information? The desirable answer to all three questions is yes, but these desires are often conflicting; for example, well-formedness conditions can be enforced to assist diagram interpretation but this can result in drawability problems. In this paper, we focus on visual languages based on closed curves, which are used in numerous computing applications. Many such languages effectively use spatial properties such as containment and disjointness. We consider the consequences of enforcing various well-formedness conditions, such as simplicity and connectedness of minimal regions, in relation to the above questions. We suggest refinements of the conditions in order to find a balance between the conflicting desires.

1 Introduction

We will use the term Euler diagram in a very general sense, to mean any finite collection of closed curves which express information about intersection, containment or disjointness. Often, well-formedness conditions are imposed on Euler diagrams. These conditions are usually chosen in order to alleviate mental difficulties in the user's interpretation of the diagrams but they may also be due to application domain requirements. An example of one such condition, which is often enforced, is that the closed curves must be simple. We aim is to raise awareness of consequences that emerge as a result of well-formedness conditions.

Euler diagrams have numerous applications, including the visualization of statistical data [6], displaying the results of database queries [34] and representing non-hierarchical computer file systems [8]. They have been used in a visual semantic web editing environment [24, 35] and for viewing clusters which contain concepts from multiple ontologies [16]. Closed curves are a basis for many of the UML notations, including class diagrams and statecharts [9]. Another major application area is that of logical reasoning [5, 11, 15, 19, 20, 21, 26, 28, 30, 31, 33]. For example, the constraint diagram logic [21] is based on Euler diagrams and is used for formal object oriented specification [18, 22].

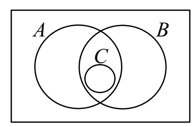

Figure 1. An Euler diagram.

Any Euler diagram can be described by listing the set intersections that are present in the diagram. For example, the diagram in figure 1 can be described by: $A \cap \overline{B} \cap \overline{C}$, $A \cap B \cap \overline{C}$, $B \cap \overline{A} \cap \overline{C}$, $A \cap B \cap C$ and $\overline{A} \cap \overline{B} \cap \overline{C}$ (where $\overline{A}$ is the complement of A etc). Each of the items in this list corresponds to a region in the diagram; for example $A \cap \overline{B} \cap \overline{C}$ corresponds to the region which is inside the curve A, but outside the curves B and C. A natural question arises: given an Euler diagram description, does there exist an Euler diagram with that description? In other words, is the Euler diagram description *drawable*? The answer depends on the well-formedness conditions enforced. Classifying which descriptions are drawable under each set of well-formedness conditions is important: it will allow us to inform users as to which conditions permit their information to be visualized. In this paper, we specify well-formdness conditions that allow all descriptions to be drawn.

When visualizing information, we may want to perform some logical reasoning or transform a diagram if information is updated. Ideally, transformation rules (of which reasoning rules are a special case) will modify diagrams in such a way that users can easily identify the change, preserving their mental map as much as possible. Whether transformation rules can be applied in such a way is, again, affected by the well-formedness conditions enforced.

The accuracy of diagram interpretation is also intertwined with the well-formedness conditions. We demonstrate that not enforcing any well-formedness conditions renders some diagrams ambiguous unless care is taken when defining semantics.

2 Describing Euler Diagrams

We describe Euler diagrams in terms of the labels associated to their curves. Given a finite collection of labels, $L = \{L_1, L_2, ..., L_n\}$, let W be a subset of $\mathbb{P}L - \{\emptyset\}$. The pair (W, L) is an **Euler diagram description**. The elements of W describe the minimal regions; a **minimal region** (called a *zone* in [11]) is a maximal set of points in the plane that are interior to some set of curves and exterior to the remaining curves. An element of W is the set of labels of the curves that contain the corresponding minimal region. For example, $(W = \{\{A\}, \{B\}, \{A, B\}, \{A, B, C\}\}, L = \{A, B, C\})$ describes the Euler diagram in figure 1. The minimal region which is inside A but outside B and C corresponds to the set $\{A\}$ in W. If $W = \mathbb{P}L - \{\emptyset\}$ then (W, L) describes a Venn diagram. All Venn diagram descriptions are drawable with simple closed curves and connected minimal regions [25].

3 Simple Closed Curves

The closed curves in Euler diagrams are often required to be simple [4, 6, 15, 19, 32, 34] but not always [2, 5, 9, 28, 30, 33]. Formally, a **curve** is a continuous function, f, defined on the interval $[0, 1]$. If $f(0) = f(1)$ then f is **closed**. If, for all $x, y \in [0, 1]$, $f(x) = f(y)$ implies $x = y$ or $|x - y| = 1$ then f is **simple** [3]; that is, simple closed curves do not self-intersect.

3.1 Consequences of Enforcing Simplicity

The Jordan Curve Theorem states that any simple closed curve with codomain $\mathbb{R}^2$ splits $\mathbb{R}^2$ into precisely two pieces, one bounded and the other unbounded [1]. Given the image of a simple closed curve, we can easily identify the curve's interior because the interior is the bounded piece. The identification of the interior of closed curves (simple or otherwise) is crucial in order to be able to interpret Euler diagrams. When formalizing the semantics of Euler diagrams, it is usually stated that the interior of each curve represents the set denoted by that curve's label. Many definitions given in the literature rely on the notion of interior [15, 19, 30, 33]; an example is given below.

Definition 3.1 *The set of all points interior to a closed curve is a* ***basic region****. A* ***region*** *is defined using operations union, intersection, difference and complement on basic regions.*

For example, in figure 1, the basic region interior to A consists of the three minimal regions inside A. We can safely use definitions that rely on the interiors of simple closed curves because there is a well-defined (and intuitive) notion of what constitutes the interior.

Unfortunately, enforcing simplicity has the consequence that not every Euler diagram description is drawable [23, 34]. This has implications when defining transformation rules. An example of such a rule allows the removal of a minimal region; this is used when reasoning (see [19, 33], for example) and is also useful when information being visualized is updated. There is no guarantee that such a region can be nicely removed from a diagram (under a continuous transformation of the plane), maintaining the simplicity of curves. A naive technique to remove a minimal region, which does not work in general, is to shrink the region to a point, thus ensuring that the resulting diagram looks similar to the original diagram. For example, in figure 2, the shaded minimal region can be nicely removed from d_1 to give d_2.

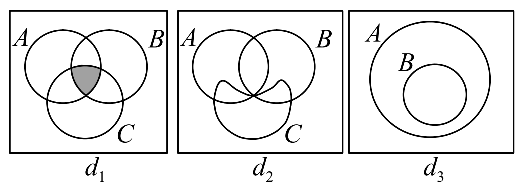

Figure 2. Shrinking minimal regions.

The ability to shrink a region to a point depends upon the local geometry; for example a star like region, unlike a non-simply connected region, can be contracted to a point. In figure 2, d_3 contains a non-simply connected minimal region – interior to A but exterior to B – which cannot be shrunk to a point. Even if it is possible to shrink a given minimal region to a point, this may yield a diagram, d, that contains non-simple curves. In some cases, it is not even possible to draw a diagram using only simple closed curves that has same description as d. For example, Venn-(9) is drawable with simple closed curves, but removing all minimal regions except for those described by $\emptyset, \{A, B, C\}, \{D, E, F\}, \{G, H, I\}, \{A, D, G\}, \{B, E, H\}$, $\{C, F, I\}$ leaves a diagram whose description is not drawable when simplicity is enforced [23, 34].

The undrawability of some collections of set intersections can have profound effects on logical reasoning systems. Reasoning rules are examples of transformation rules which specify, syntactically, when a diagram, d_2, can be obtained from another diagram, d_1. A reasoning rule is

valid if the semantics of d_2 can be deduced from the semantics of d_1. Such rules are usually defined in terms of a pre-condition and a post-condition (sometimes implicitly), as in [19, 31, 33]. The expectation of such a contract is that if the pre-condition holds for a well-formed diagram d_1 then there exists a well-formed diagram d_2 that satisfies the post-condition. Therefore, the pre-condition should be made strong enough, or the post-condition weak enough, so that this is indeed the case.

However, being able to specify a strong enough pre-condition can be difficult. This is because it is currently unknown which diagram descriptions are drawable under simplicity: to specify a strong enough pre-condition we need to know that applying the transformation rule will produce a well-formed diagram in return. Furthermore, specifying a weak enough post-condition so that a well-formed d_2 exists can result in the rule not being valid, meaning that the logic is unsound.

A **proof** is a sequence of diagrams $\langle d_1, d_2, ..., d_n \rangle$ such that, for all $1 \leq i < n$ each d_{i+1} is obtained from d_i by applying a reasoning rule [13]. Some reasoning systems allow a set of premise diagrams (as opposed to a single premise diagram), as in [30, 33], and the definition of a proof can be adapted. Ideally, reasoning systems will be **complete**: for any diagrams d_1 and d_n, if the semantics of d_n can be inferred from the semantics of d_1 then there is a proof of d_n from d_1. Suppose that the semantics of d_2 can be inferred from those of d_1 and we wish to write a proof from d_1 to d_2. It is possible that the undrawability of some diagram descriptions can prevent there from being a proof from d_1 to d_2 (if any 'proof' of d_2 from d_1 has to pass through a non-wellformed diagram), thus making the system incomplete. Even if the system is complete, it may be the case that some 'proofs' would naturally pass through diagrams that fail the well-formedness conditions and so some natural 'proofs' are unobtainable.

Many completeness proof strategies are constructive, giving a sequences of reasoning rule applications that transform the premise diagram into the conclusion diagram, such as those in [15, 19, 30, 31, 33]. A potential source of error in this type of completeness proof arises if the pre-conditions are not strong enough; in this case rules are not always applicable even when the pre-condition is satisfied but such completeness proofs sometimes ignore this issue. It is possible to overcome the undrawability issue and its consequences by not enforcing simplicity.

3.2 Consequences of Not Enforcing Simplicity

Theorem 3.1 shows, as a benefit of not enforcing simplicity, that all descriptions are drawable. This removes the potential problem of reasoning systems being incomplete because of the non-applicability of reasoning rules.

Theorem 3.1 *Let $(W, L = \{L_1, ..., L_n\})$ be an Euler diagram description. Then there exists an Euler diagram, d, with description (W, L).*

Proof To construct d proceed as follows. For each $S_i \in W$, draw one simple closed curve C_i labelled by S_i, such that if $|W| > 1$ then

1. there exists a unique point, p, in the image of all of the C_i's and
2. no other point is in the image of two (or more) distinct C_i's and
3. the interiors of the C_i's are pairwise disjoint.

For each $L_j \in L$ such that there is no $S_i \in W$ satisfying $L_j \in S_i$, draw a line in the plane, C_i, labelled by $\{L_j\}$, so that C_i does not intersect any curve already drawn. The diagram d consists of $|L|$ closed curves K_j (with label L_j) where the image of K_j is the union of the images of the C_i's for which $L_j \in S_i$. The resulting diagram has description (W, L) by construction, since each required minimal region appears in exactly one of the curves C_i and the only other minimal region present is outside all the $K_j's$.

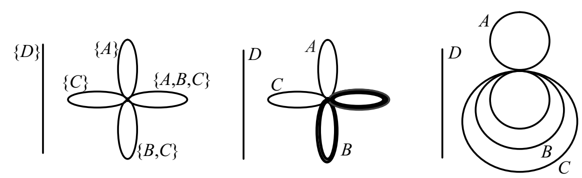

Figure 3. Diagram construction.

An example of this construction process can be seen in figure 3. Starting with the description $(W = \{\{A\}, \{C\}, \{B, C\}, \{A, B, C\}\}, L = \{A, B, C, D\})$, we draw four curves labelled appropriately (the C_i's, shown in the lefthand diagram). To construct the required Euler diagram d (the middle diagram) we use the images of these four curves. For example, the image of the curve in d labelled A is obtained by taking the union of the images of the simple curves labelled $\{A\}$ and $\{A, B, C\}$. The rightmost diagram, where the curve labelled A is a figure of eight, also has description (W, L) but better exploits the containment properties of Euler diagrams.

From the construction process given in the proof of theorem 3.1 we can extract a refined set of well-formedness conditions and maintain the drawability of every Euler diagram description: the closed curves either self-intersect at most once or are lines and, in addition, each minimal region is connected. Furthermore, we can weaken these well-formedness conditions and still maintain drawability: the closed curves either self-intersect a finite number of times or are lines.

Our focus now turns to the interpretation of diagrams when simplicity is not enforced. Formally, the interior of a closed curve is defined by using *winding numbers* [3]. Knowing the image of a closed curve is not sufficient information to determine its interior. In practice we are only given the images so a method to identify interior points is required (discussed later in this section).

Various reasoning systems based on Euler diagrams use additional syntax to represent elements or individuals [5, 11, 19, 30, 33]. For example, the Euler/Venn system uses *constant sequences* to represent individuals [33]. The Euler/Venn diagram d_1 in figure 4 is ambiguous: is Jean a software engineer? It may well be the case that many people would say Jean is a software engineer because Jean is seemingly placed inside Software Engineers. Furthermore, it might appear that there are two curves, one of which is labelled by Jean; we are not necessarily able to correctly identify the syntactic components of diagrams in the non-simple case, causing further semantic ambiguity.

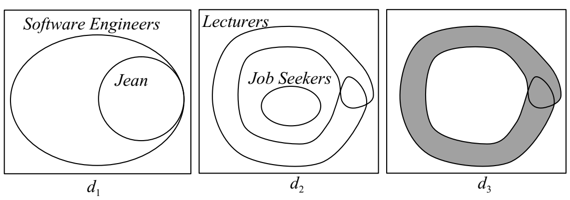

Figure 4. Ambiguous diagrams.

Ambiguity also arises when using self-intersecting closed curves in Euler diagrams (even without any extra syntax). The Euler diagram d_2 in figure 4 is ambiguous for a similar reason: are all job seekers also lecturers or are none of them lecturers? In this case, even though the curve labelled Job Seekers is placed in a bounded component of $\mathbb{R}^2$ minus the image of the curve labelled Lecturers, there is not an intuitive notion that the Job Seekers curve is 'inside' the Lecturers curve: the shaded part of d_3 indicates a likely 'interior' of the Lecturers curve.

We conclude that additional information is essential for the unambiguous interpretation of d_2 (and d_1). One may identify the interior and exterior points given only the images using some canonical method. Such a method needs to be clearly stated because there are various choices that give rise to different interiors; we now give two such methods.

Method 1 If we only allow curves, C, to have a finite number of self intersections then we can define the interior of the image of C as follows. Pick a point, p, in the unbounded region and let x be a point not equal to p and not in the image of C. Let γ be a path from p to x that does not pass through any point where C self-intersects and γ only intersects C transversely and a finite number of times. If γ intersects C an odd number of times then x is interior to the image of C (this is well-defined because the parity of the number of crossings is the same for any such path γ). Using this method, no job seekers also happen to be lecturers, agreeing with our intuitive interpretation of d_2, but, for d_1, Jean is not identified as a software engineer.

Method 2 A point, x, is interior to the image of C if x is in a bounded face of $\mathbb{R}^2$ minus the image of C. This method agrees with the intuitive interpretation of d_1 that Jean is a software engineer, but gives the non-intuitive interpretation of d_2 identifying all job seekers as lecturers.

Our two methods give different notions of the interiors of the image of closed curves. Together with our examples in figure 4, this highlights the importance of specifying such a method when not enforcing simplicity. No method for identifying interior points from the images has been stated in the publications on Euler diagram reasoning where simplicity is not enforced.

As well as affecting semantic problems, not enforcing simplicity affects the way we can define reasoning systems. In figure 5, the basic region interior to A in d_1 is the set of shaded points. This shading frequently is used to assert that A represents the empty set. In d_2, A has no interior and, therefore, also represents the empty set.

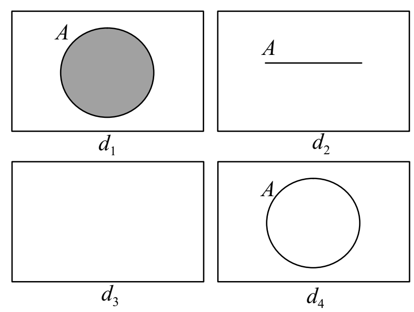

Figure 5. Reasoning with Euler diagrams.

A reasoning rule in the Euler/Venn system (which is similar to a rule in [19] for spider diagrams) states that any shaded minimal, but not basic, region can be removed from a diagram [33]. So, the *removing shaded regions* rule cannot be applied to the diagram d_1 in figure 5 to give d_2 because the only shaded region in d_1 is also a basic region. The pre-condition ensures that after an application of the rule there is at least one minimal region inside each curve because of the 'not basic' constraint. Since the diagrams d_1 and d_2 are semantically equivalent, if the reasoning system is to be complete then we must be able to write a proof of d_2 from d_1. There is a sequence of rule applications to deduce d_2 from d_1: erase A from d_1, giving d_3; introduce A to d_3 giving d_4; unify d_1 and d_4 to give d_2 (see [33] for details of these rules). In this instance, completeness may not have been affected by the overly strong pre-condition, but a complex sequence of rule applications is required in order to make a seemingly trivial deduction.

A reason for not allowing the removal of basic regions in [19] where simplicity is enforced is to avoid applications of rules yielding non-wellformed diagrams like d_2. When allowing non-simple closed curves, as in [33], we can relax the pre-condition of the removing shaded regions rule to allow the removal of basic regions.

When applying reasoning or, more generally, transformation rules it is a great advantage, from a usability perspective, if the rules can be applied in such a way that a user's mental map is minimally disrupted. The following theorem tells us that, when no well-formedness conditions are enforced, a minimal region can be removed under a continuous transformation of the plane, helping to preserve a user's mental map.

Theorem 3.2 *Let d be an Euler diagram. Any minimal region, m, can be removed from d by shrinking m.*

4 Connected Minimal Regions

One well-formedness condition, nearly always enforced, is that minimal regions must be connected components of the plane. If we enforce connectedness then we cannot necessarily delete any curve, which is a typical reasoning rule [15, 19, 30, 33], and maintain well-formedness. For example, in figure 6, the deletion of any curve will result in disconnected minimal regions.

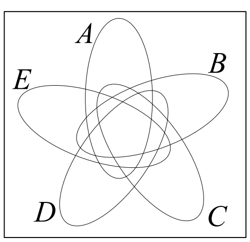

Figure 6. Venn-5.

Enforcing connectedness comes with a price: to get complete reasoning systems, such as Venn-II [30], we must redraw the diagram where necessary after deleting a curve; for example, deleting a curve from Venn-(5) gives Venn-(4) which is drawable, but we may have to completely redraw the diagram rather than simply deleting the curve. This places a larger burden on the user in terms of understanding (due to mental map difficulties when presented with a redrawing) or in terms of effort (when the user is forced to redraw). In fact, there are few choices of curve that can be deleted from Venn-(n) whilst maintaining well-formedness.

Theorem 4.1 *Let d be a Venn diagram that has connected minimal regions. There are at most three choices of curve that can be deleted from d without leaving disconnected minimal regions [29].*

5 Inductive Definitions

Some definitions of Euler diagrams are inductive [5, 28, 30, 33] and we can think of this as placing another well-formedness condition on Euler diagrams.

Definition 5.1 *An Euler diagram is* ***inductive*** *if it can be constructed as follows. A rectangle is an inductive Euler diagram. If d_1 is an inductive Euler diagram and d_2 results by drawing a closed curve, C, completely within the rectangle of d_1 so that all of the minimal regions of d_1 are split by C into at most two new minimal regions then d_2 is an inductive Euler diagram.*

The diagrams in figure 7 are 'inductive diagrams'. For example, d_3 in figure 7 is obtained from d_2 by adding B. The curve B splits the minimal region inside A into two minimal regions, one of which is disconnected: the minimal region interior to A but exterior to B in d_3 consists of two components of the plane minus the images of the curves. In definition 5.1, it is stated that the new curve splits each existing minimal region into at most two new minimal regions. We observe that this condition is redundant: a curve can only split minimal regions into at most two regions. We believe there is confusion between the notion of minimal regions in the usual combinatorial sense (a minimal region is interior to some set of closed curves and exterior to the remaining curves) and in a topological sense (a connected component of the plane minus the images of the curves). It is likely that the intention of the definition writer is to enforce the connectedness of minimal regions; if this is the case d_3 should not be an inductive diagram.

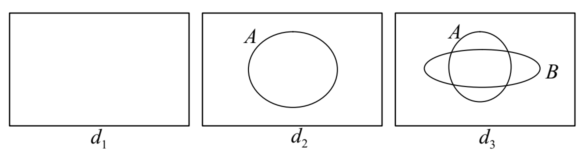

Figure 7. Inductive Euler diagrams.

The diagram in figure 6 does not comply with the inductive definition when connectedness is enforced since deleting any curve leaves disconnected minimal regions. Given any diagram, it is not immediately obvious whether it satisfies the inductive definition. This is likely to affect the usability of the notation because testing to see if a diagram is inductive can be time consuming and some visually pleasing images (such as that in figure 6) are not inductive.

Perhaps the motivation for inductive definitions of Euler diagrams came from inductive Venn diagram definitions where there is no drawability problem (all Venn diagram descriptions are drawable under the inductive definition). However, it is not even clear whether it is possible to delete an arbitrary curve from an inductive Euler diagram and produce an inductive diagram in return (even if you redraw).

6 Precise Language and Abstraction

Concrete (drawn) level formalisms are difficult to work with, causing a tendency to use imprecise or informal language. This can easily lead to ambiguities or oversights such as relying on being able to identify the interiors of non-simple closed curves given only their images. By contrast, the use of precise language necessitates a thorough understanding of the problem domain and permits a proper analysis of any consequences arising. The act of formalization often brings to light issues that are not apparent when working informally.

In order to understand the consequences of enforcing well-formedness conditions in their entirety, specialist knowledge of the application domain and some knowledge of geometry and topology is required. For example, a logician is likely to be focused on identifying a complete set of reasoning rules and, in order to achieve this goal, may choose not to enforce simplicity whilst being unaware of the topological consequences.

An alternative to the difficult approach of formalizing at the concrete level is to use an abstract syntax [10, 17] (like an Euler diagram description). Defining transformation rules at an abstract level facilitates a greater level of rigour and precision, which is essential in order to be certain that the reasoning systems are sound and that the rules can be applied correctly in the sense that our expectation of the pre/post contract is met. Using an abstract level is advantageous in that it separates the problems of reasoning from drawability: the rules can be defined independently of any concrete level well-formedness conditions. The reasoning systems in [19, 31] are defined using an abstract syntax but many are defined at the concrete level, as in [5, 15, 30, 33].

A major problem with defining reasoning rules (or any transformation rules) at the concrete level is that specifying the pre-condition completely will require a classification of drawable diagrams under the chosen well-formedness conditions. When transformation rules are defined at the concrete level, sometimes we must redraw a diagram after the application of a rule in which case one may as well have used an abstract syntax so working at the abstract level in general is sensible.

Of course, the concrete diagrams must be generated from the abstract syntax and this may not always be possible under a specified set of well-formedness conditions. However, reasoning at the abstract level allows us to be certain that proofs exist and, because of theorem 3.2, we know that all proofs can be visualized when no conditions are enforced. Furthermore, it is computationally less expensive to apply rules at the abstract level. This computational efficiency is essential when automating the search for proofs; even in some simple cases many thousands of diagrams are produced that are not part of the proof [13], so they do not need to be drawn. There is ongoing work in the drawing community attempting to address the issue of being able to generate diagrams under various well-formedness conditions [7, 6, 12, 14, 34] and also attempting to make diagrams look similar [27].

7 Conclusion

This paper provides a discussion of various issues that arise in the many visual languages based on closed curves, of which there are numerous examples in computing [8, 9, 16, 21, 22, 24, 35]. We have investigated the consequences of enforcing various well-formedness conditions that appear in the literature, especially in the areas of drawability, semantic interpretation and reasoning. Not enforcing the simplicity condition causes problems interpreting Euler diagrams. Completely removing this condition is not sensible: it allows any closed curves ranging from space filling curves [1] to straight lines or even points to be used. This not only causes difficulties in the formalization of, for example, semantics but may lead to confusion, especially when lines represent disjunction as in [5, 11, 19, 30, 33] and dots represent elements as in [11, 19]. If the simplicity condition is not enforced or refined then it is necessary to specify a method for determining the interior of curves given just the images.

We suggest that refinements of the conditions are used (such as refining simplicity to allow only a finite number of self-intersections) in order to provide a balance between conflicting desires. From a reasoning perspective, permitting a finite number of self-intersections allows rules to be applied to more diagrams by enabling the relaxation of the pre-conditions. This may enhance usability in certain circumstances; for example, a minimal region can be removed using a natural process so that the resulting diagram looks similar to the original diagram.

We have provided a construction process which generates a diagram from any Euler diagram description. This will enable the visualization of proofs in logical reasoning systems which are defined at an abstract level; the use of an abstract level separates the issues of drawability from those of reasoning. Further work on the generation of diagrams under various sets of well-formedness conditions is underway, and will enable the visualization of proofs containing diagrams which satisfy conditions specified by a user.

There are other standard well-formedness conditions and in future work we plan to conduct an analysis of them. This may lead to further refinements of the conditions as well as provide a better understanding of their effects. We expect that issues similar to those raised in this paper will occur in other visual languages even if different well-formedness conditions are imposed.

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Semantic Visualization for Business Process Models

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Abstract

Based on an analysis of the requirements for visualizations of business process models and the foundations of the concept of Semantic Visualization it is shown how different Ontological Visualization Patterns can be specified and semantically linked to business process conceptualizations to achieve the vision of semantically described visualization services.

1. Introduction

When regarding the environment in which business decision makers have to accomplish their tasks today it becomes immediately obvious that the notion of a *knowledge and information society* is not only a common catch word but clearly highlights the challenges that have to be faced when aiming for the success and therefore the sustainability of an enterprise.

To enable decision makers to master the huge amounts of knowledge and information that circulate on all levels of modern businesses several disciplines have developed methods and procedures which encompass technical as well as organizational approaches. The use of visual representations is a common way that is applied to facilitate the comprehension of complex processes and interrelated data in many of these approaches.

The field of Enterprise Modeling is an area that provides methods of resolution for the representation, management, and analysis of the strategic goals, activities and organizational relationships as well as the technological basis of a business. The visual representation of business processes shall be selected in the following to serve as an exemplary application field. However, the statements made here are applicable to a wide range of enterprise modeling approaches that make use of visual representations (e.g. in performance management [12], workflow management or integrated process and IT architecture management [10]).

The goal of the approach presented in this paper is to introduce an innovative view on visualizations that is exemplarily applied to Business Process Models. The approach is seen as an evolutionary step that is fully compatible to existing ways of specifying visualizations but takes into account new paradigms such as service orientation and automated information processing. It is envisaged that the way of dealing with visual representations is thereby leveraged to the level of open, standardized and therefore interchangeable components, i.e. in the sense of technology independent, semantic visualization services.

2. Related work

The foundations for this work lie in the field of visual language theory (c.f. [11, 9, 1]), which can be viewed as a starting point of analysis for every type of visual representation, and information visualization [8]. The idea of tracing back visual representations to their very core elements has a long philosophical and geometric tradition (cf. the axioms in Euclid's Elements) and has recently regained attention by attempts of defining ontologies for visualizations [3], which, however, seem to be to generally formulated to lead to actual implementations but are rather taxonomies for clarifying terms in the area of visualization. Related approaches for business process methodologies are seen in Event Driven Process Chains [7] or recent efforts for a worldwide standardization of business process modeling such as BPMN [2].

3. Semantic Visualization

As stated in the introduction the concept of Semantic Visualization is positioned as a unification and extension of previous approaches for defining visualizations. In analogy to the well known semantic web stack visualizations in this approach are specified in a hierarchical order based on primitive entities that can be combined to generate complex dynamic representations (see figure 1). These representations can then be enriched with a distinct semantic specification of their state and behaviour which permits not only an automated assembly of visual representations based on domain conceptualizations but also for the realization of technical visualization formats that can be exchanged between different parties (similar to current XML based document formats).

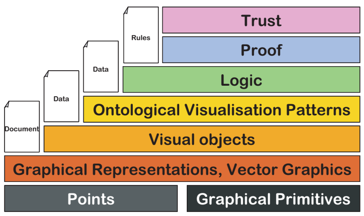

Figure 1. Semantic Visualization Stack

In detail the Semantic Visualization stack contains on its bottom layer the core elements of any visualisation: *Points* as the smallest visual entity and *Graphical Primitives* that are composed of a number of points. On the next layer reside *Graphical Representations* in the form of vector graphics that are composed of graphical primitives. To allow for a dynamic change of the graphical representations the *Visual objects* layer adds variables and control structures to the graphical representations. Thereby a representation can be changed according to a variably assigned value. On the *Ontological Visualizations Patterns* layer one or more visual objects are combined and positioned according to a layout procedure. The internal variables of the visual objects are either directly exposed as variables of the pattern or via a transformation function. The Ontological Visualization Pattern therefore also has to contain control structures and variables, but in contrast to the visual objects the variables as well as the pattern itself are enriched with a semantic specification. On the basis of this semantic specification that describes the nature and properties of a visualization a mapping to an ontology can be established that is the basis for possible visual inferencing mechanisms on the higher layers such as *Logic*, *Proof* and *Trust*. By the linkage to an ontology a visual language can be specified: Syntax and semantics of the visual language are defined by the ontology, the appropriate graphical representation by the Ontological Visualization Pattern.

To show the approach in details these concepts and the linking to a semantic description can be formally expressed as follows: A Point P has coordinate values in $\mathbb{R}^2$ (1), and a variable V in $\mathbb{R}$ (2). Points can then either be specified in the standard way by values or by variables (3) by which variations of the graphical representation are realized. Primitives $PRIM$ can either be described by standard points (4) or in visual objects by a combination of variable or standard points VO (5). The variables within the point primitives are used to influence the graphical representation, the additional variables are required for the normalization of the point variables to allow for a mapping to ontology values[1]. This abstract specification can then be instantiated (6).

A simplified ontology O consisting of classes C, object properties OP, datatype properties DP and values V (8-13)[2] can also be instantiated and then linked in the simplest case to the visual object as shown in (14,15), thereby establishing a semantic relationship with a class of the ontology and a variable of the Ontological Visualization Pattern.

$$P = (x, y \,|\, x, y \in \mathbb{R}) \quad (1)$$
$$V = (z \,|\, z \in \mathbb{R}) \quad (2)$$
$$P^{VO} = (\alpha, \beta \,|\, \alpha, \beta \in \mathbb{R} \vee V) \quad (3)$$
$$PRIM = \{P_1, P_2, \ldots, P_n\} \quad (4)$$
$$VO = \{E_1, E_2, \ldots, E_n \,|\, E \in P \vee P^{VO} \vee V\} \quad (5)$$
$$VO_1 :: VO \quad (6)$$
$$VO_1 = \{P_1, P_2^{VO}, V_1\} \quad (7)$$
$$O = \{C, OP, DP, VAL\} \quad (8)$$
$$C = \{C_1, C_2\} \quad (9)$$
$$OP = \{OP_1\} \quad (10)$$
$$DP = \{DP_1\} \quad (11)$$
$$OP_1 = \{C_1, C_2\} \quad (12)$$
$$DP_1 = \{C_2, VAL_1\} \quad (13)$$
$$C_2 \leftrightarrow VO_1 \quad (14)$$
$$VAL_1 \leftrightarrow V_1 \quad (15)$$

To fully realize the vision of Semantic Visualization, which is seen in the availability of semantically described visualization services that can on demand and automatically create dynamic visualizations that are appropriate for a specific use case the mapping between Ontological Visualization Patterns and a domain conceptualization such as an ontology or a meta-model has to be further specified. For this purpose four dimensions have been identified that characterize this mapping: The *Functional Implementation*, the level of *Standardization*, the type of *Deployment*, and the *Time Reference* (see figure 2). The Functional Implementation describes whether the mapping takes place fully automatically (e.g. through intelligent agents that receive a request for a visualization and deliver the result), semi automatically (e.g. by offering visualization alternatives that can be chosen by the user) or manually (e.g. when the visualizations for the mapping are manually selected based on the subjective assessment of a user). The Standardization dimension determines to which amount the mapping

[1] A simple example that shows this normalization requirement would be the graphical height of a bar in a barchart that has to be normalized to e.g. a range from 0-100 to be able to represent percentage values.

[2] This would correspond to a simplified conception of an ontology as existent in the Web Ontology Language OWL.

is performed by using standardized technology for the description of the conceptualization of the Ontological Visualization Patterns, the description of the domain conceptualization and the mapping itself. Again, for fully realizing Semantic Visualization standardized technologies are required to enable the direct cooperation of all three parts. The two types for the Deployment reflect whether the visualization can be dynamically altered after the deployment (whereby e.g. the change of an attribute status in the domain conceptualization can influence the visualization after the mapping has been defined) or whether the mapping is static and cannot be changed. The Time Reference dimension expresses whether the visualization is assembled on demand (i.e. directly upon the request of a user) or is pre-configured and then accessed at a later point in time.

<table>
<tr><td>Functional Implementation</td><td colspan="2">Automatic</td><td colspan="2">Semi automatic</td><td colspan="2">Manual</td></tr>
<tr><td>Standardization</td><td colspan="2">Fully Standards based</td><td colspan="2">Partly Standards based</td><td colspan="2">Proprietary</td></tr>
<tr><td>Deployment</td><td colspan="3">Static</td><td colspan="3">Dynamic</td></tr>
<tr><td>Time Reference</td><td colspan="3">On demand</td><td colspan="3">Pre-configured</td></tr>
</table>

Figure 2. Dimensions of the Mapping

4. Requirements of Business Process Modeling

To practically illustrate the approach of Semantic Visualization the field of Business Process Modeling has been selected as a field of application that is not only very well researched but is certainly (as stated in the introduction) of major interest for meeting future business challenges.

The modeling of business processes is a complex task that does not only require sound knowledge of the field of business that shall be depicted but also of the used modeling method and its application procedure. From the viewpoint of visualization we have identified three main influence factors that determine the requirements for the visual representation of business processes: First, the *Modeling Method* as the basic definition which elements may occur in a business process model, how they are syntactically arranged and what semantics is assigned to them as well as the used notation (e.g. graph based) [6]. Second, the aspects of *Human Computer Interaction*, i.e. how the interaction of a user and the representation of the business process model takes place and thirdly which *Technology* is available and suitable for implementing the visualization.

To narrow down the large number of possible approaches for modeling methods in business process management we build in this paper upon the concepts of Business Graphs [5] as an elementary and intuitive approach for representing business processes and their organizational embedding.

A Business Graph is a formal representation of a clearly structured and comprehensible design of a business process including all important elements [5]. These elements are structured in two components: a business process model and a working environment model. The business process model contains *activities*, i.e. atomic units of a process (e.g. the working units which cannot or should not be divided any more), *subprocesses*, i.e. the combination of activities in order to achieve reusability and a higher level of abstraction which are both necessary for distinctely structuring the process, and a *control flow* which is characterized by variables and predicates that determine the logical subsequence of the activities and allow for the description of parallelisms (or synchronizations), decisions, sequences and loops. As the focus of this paper is visualization the control flow is limited to three elements (*start*, *end*, and *decision*). The working environment model consists of *actors* (persons), that represent the performers of activities, *groups* which are used to describe organizational structures such as positions, functions, roles, responsibilities and units of organizations, and *resources* which are defined as all means that are necessary for the realization of activities such as documents, data or services. Between the business process and the working environment model mappings can be established such as *responsibilities*, i.e. the definition who is carrying out an activity or *requirements*, i.e. the regulations which resources are required to perform an activity.

Formally Business Graphs can be described as follows: Let $\Gamma = \{\beta_j, \omega, \rho_{ij}\}$ be a Business Graph with

- a number of i business processes $\beta_i = \{\theta_i, \kappa_{ij}\}$ in which θ_i signifies process element $i, i \in \{1, 2, 3, \ldots, n\}$ and κ_{ij} stands for a control connector $ij, i \in \{1, 2, 3, \ldots, n\}, j \in \{1, 2, 3, \ldots, n\}$ between process elements. Process elements are defined as $\theta_i = \{A_i, \beta_j, \sigma, \eta, \delta_k\}$ where A_i signifies activity $i, i \in \{1, 2, 3, \ldots, n\}$, β_j signifies subprocess $j, j \in \{1, 2, 3, \ldots, m\}$, σ signifies start, η signifies end, and δ_k signifies decision where $k \in \{1, 2, 3, \ldots, l\}$.
- a working environment $\omega = \{P_i, G_j, R_k, \pi_{ij}\}$, with $i \in \{1, 2, 3, \ldots, n\}, j \in \{1, 2, 3, \ldots, m\}, k \in \{1, 2, 3, \ldots, o\}$ and where P_i signifies a person $i, i \in \{1, 2, 3, \ldots, n\}$, G_j signifies a grouping $j, j \in \{1, 2, 3, \ldots, m\}$, R_k signifies a resource $k, k \in \{1, 2, 3, \ldots, o\}$ and π_{ij} the relations between the elements of P_i, G_j and R_k with $i \in \{1, 2, 3, \ldots, n\}$, $j \in \{1, 2, 3, \ldots, m\}$
- and the relations ρ_{ij} between the elements of β_i and ω.

Business Graphs are a syntactical conceptualization of the domain of business process models. For a concrete usage the semantics of the entities of a Business Graph has to be specified e.g. by mapping them to an ontology as shown

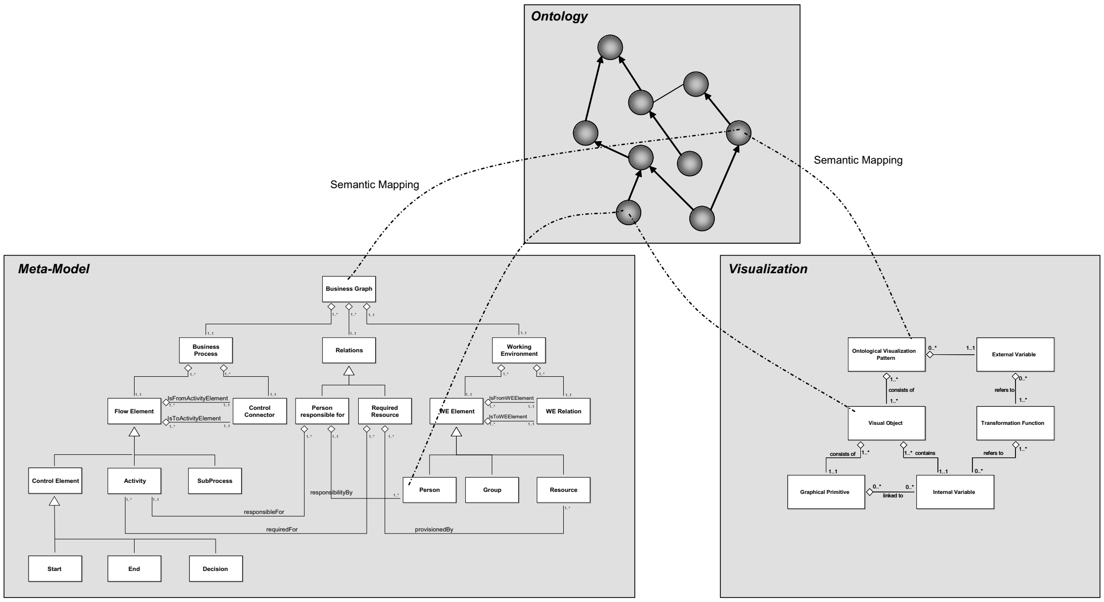

Figure 3. Semantic Visualization Framework for Business Process Models

in figure 3 and distinct rules for the arrangement of the elements in the business process models have to be defined. For the purposes of illustrating the relation to the visualization of the models we have instantiated the formal concepts to a meta-model (figure 3) that defines the cardinalities between the entities and can also provide a basic definition of syntax and operational semantics via a meta-meta model from which it is instantiated and that defines the core elements of the underlying directed graphs (as e.g. described in [4]).

For the discussion of the impacts of human computer interaction (HCI) we refer to the definition of HCI as "a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them." (by ACM SIGCHI[3]) and focus on three aspects that are derived from the accomodations to human diversity as described by Shneiderman [13]. These are: *Semiotic aspects*, *Pragmatic aspects*, and *Physiological aspects*.

By Semiotic aspects we take into account human cultural factors that determine either the meaning of as well as the interaction with visual representations. This is particularly relevant in today's international business environment where the exchange of information concerns many different countries and cultures. Culture in this context refers not only to national culture (e.g. as expressed by different orientations in parsing text and visual representations) but also to group cultural factors (e.g. by different professional views on the functioning of an enterprise where technical experts prefer clear 'engineering'-like representations they are used to (as the UML notation) vs. managerial decision makers who require visual representations that can be used for special argumentation purposes e.g. to shareholders who are not familiar with technical visualizations). For examples of different visualizations of business processes see figure 4 that shows in (A) a standard business process model based on the Business Graph concepts in the ADONIS BPMS notation, in (B) a UML activity diagram and in (C) a visually enhanced version of (A) that additionally encodes activity costs by color gradients.

This directly leads to the Pragmatic aspects of business process visualizations. Here the requirements concern the purpose of the visual representation which might range from knowledge codification and transfer to professional analysis (cf. the methods of information visualization) and public communication purposes and strongly depends on the role of the recipient (e.g. technicians, external stakeholders or customers).

By the Physiological aspects it has to be considered how interaction possibilites can be met so that a wide range of users can access the visualization in the intended way - which may for example be achieved by reverting to common interaction metaphors as used by standard software that also brings the advantage of defining extensions for disabled people.

The third requirement concerns the technological factors that need to be considered when deploying visualizations of business process models in an enterprise. An important fac-

[3] See the website of ACM SIGCHI Curricula for Human-Computer Interaction at http://sigchi.org/cdg/cdg2.html.

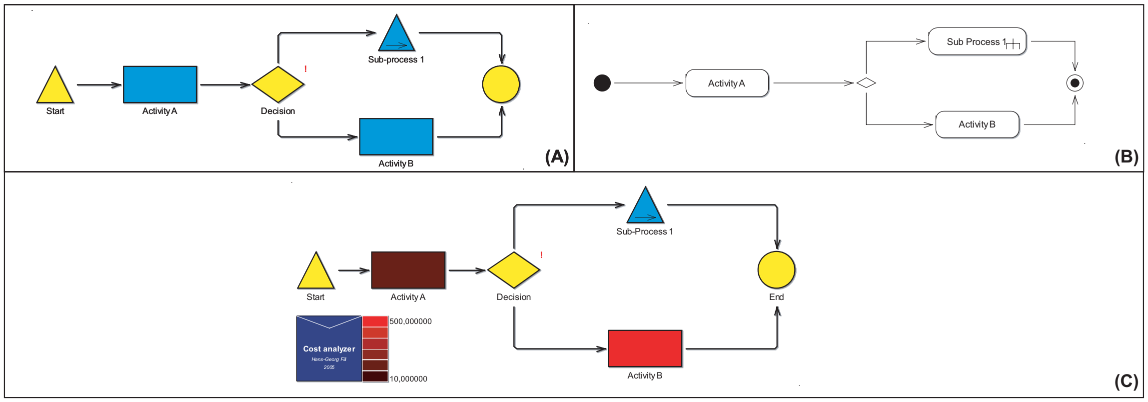

Figure 4. Different visualizations of business processes

tor is the *Organizational Embedding*, i.e. which technologies and systems are already in use in an enterprise, which security and economic constraints have to be obeyed and whether additional hardware or software components are required for a successful installation. Furthermore aspects of *Mobility* may play a role, i.e. whether the visual representations need to be web-accessible, stand-alone or available on mobile devices. A more strategic aspect of technology which is not to be underestimated is the *Relation to current paradigms*, i.e. whether the chosen technology is highly innovative for an orientation towards the future and with the chance of benefitting from first mover advantages or whether an experienced and highly reliable technology is chosen.

5. Application to Business Process Models

With these foundations it is now possible to apply the concept of Semantic Visualization to the area of business process modeling: At first appropriate Ontological Visualization Patterns have to be created that contain the required functionality based on the requirements of the modeling method and the HCI and technological aspects (e.g. for representing arrows with bendpoints for control connectors, representations that can show a cost value by a color gradient for analysis purposes, black and white representations for simple PDA displays etc.).

In detail for the needs of business process modeling such patterns have to correspond to the exact semantic requirements of the modeling method. In the case of Business Graphs this implies that there exist patterns that semantically match to the concepts in the graph as shown in figures 3 and 6, which can be achieved by reference to a common ontology that either specifies the semantics of the Ontological Visualization Pattern as well as the semantics of the concepts in the meta-model, and that there are patterns that can represent the operational semantic requirements as demanded by the control connector classes of directed graphs.

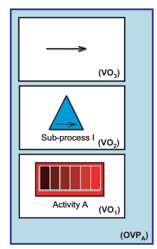

Figure 5. Ontological Visualization Pattern using a color-coding visual object for activities

Furthermore the patterns have to be in line with the requirements from HCI and satisfy the semiotic, pragmatic and physiological aspects. The advantage of Semantic Visualization is clearly visible in this respect as it allows for the definition of multiple Ontological Visualization Patterns that can fulfill different requirements and can (if the technological foundation does not restrict it) be chosen on demand based on individual user preferences (for an example of an alternative pattern that is used for an analysis case see figure 5).

As the vision of Semantic Visualization is the automatic interaction with Semantic Visualization services the aim would be to use standardized formats for the description of the Semantic Visualization Stack. However, with the currently available standards only parts of the requirements for Semantic Visualization can be met: For the specification of visual objects SVG can be partly used for the creation of templates, although it has to be extended with custom namepaces to take into account the need for externally ac-

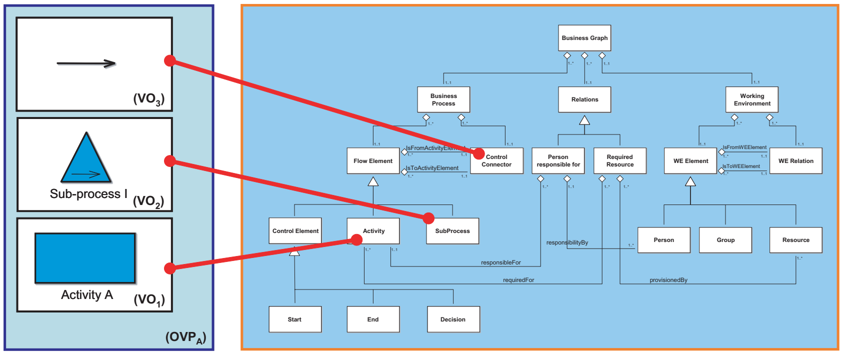

Figure 6. Mapping of an Ontological Visualisation Pattern to a Meta-Model with implicit semantics

cessible variables and control structures.

Currently a prototype for a visual object editor is available in Java. It has similar functionality as any graphic editor for vector graphics with the additional possibility of integrating variables and control structures. Visual objects can therefore be easily designed and exported as Java Swing components which allows for an easy integration in other applications as well as for achieving a first realisation of visualization web services by using them in a web application.

6. Conclusion

In this paper it has been outlined how the paradigms of service orientation and semantic service description can be applied to the area of visualization. To fully realize the vision of the proposed idea of Semantic Visualization in analogy to the Semantic Web internationally aligned open standards would be required. A student project using SVG and web service technologies is currently being conducted to evaluate the practicability of adapting common standards to the needs of Semantic Visualization.

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Visualization and Clustering of Author Social Networks

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ABSTRACT

We visualize author information in a social network to alleviate the burden of researchers in their literature search. A user interface has been implemented allowing users to submit an author name for which they wish to begin the query process to article databases. Co-author, referenced author, and article keyword information are extracted from the search results. Directed edges connect with edge weights are computed based on the level of collaboration. We hypothesize that the author information in the social network structure is partitioned into cluster groups based on two criterias: (1) authors that tend to work in similar areas of research are grouped together, (2) authors that tend to work together frequently are grouped together. Used in combination, the visualized social network is separated into clusters of authors with topic labels summarizing the general area of study for those groups.

1. INTRODUCTION

A difficult task in any research project is to accumulate the related articles in a particular area of research, which in most cases are done with keyword searches into journal database, such as Citeseer. We apply social networks to the area of medical journal articles without loss of generality, to improve the effectiveness of such searches. Researchers that often find themselves scouring references of relevant papers manually can use social networks to facilitate their research efforts. Even search engines which offer users the ability to follow links to other authors that cite a certain paper require tedious navigation through different results and memorization of the relationships discovered. Instead of manually exploring each reference individually, we present a system to visualize author information and relationships simultaneously. Thus, with the social network visualization, researchers can easily identify the authors involved in particular research topics and find numerous papers relevant to a particular topic.

1.1 Related Works

Being a popular area of interest, social networks have previously been investigated in the realm of author networks in other applications. While each application begins with similar foundations, the actual functionality and features available differ greatly. Three applications in particular, ReferralWeb, Netsight, and PubSearch, are discussed.

ReferralWeb [1] generates a social network of authors for recommending and finding experts in a particular field. The original motivation for creating such a system came from the tediousness of having to manually search referral chains. Instead of bothering authors with inquiries regarding their highly regarded referrals, ReferralWeb uses data available on the World Wide Web to determine experts automatically. Using the co-occurrence of author names in web documents, direct relationships between authors within close proximity on the pages is formed. ReferralWeb uses links on personal home pages, coauthors and references from papers, and messages sent between people in news archives to extract relationships and generate the social network [2].

ReferralWeb's proposes experts in areas as well as familiarizes users with the social network in which the user belongs. Thus, the main purpose of this system is quite different from what our system hopes to accomplish. Our system focuses more on forming clusters of subcommunities for all authors rather than finding particular experts. Additionally, our system is able to generate labels for entire clusters. Despite these different focuses, both systems obtain author relationships through the web and support incremental extensions to the graph.

Netsight visualizes and analyzes large-scale author data obtained from CiteSeer [3]. With large relational datasets, the graphs become so large that it is often necessary to perform filtering techniques. Netsight offers three types of filtering: KNeighborhood filtering, degree filtering, and vertex set filtering. With the KNeighborhood Filter option, vertices that are within a user specified k steps away from the selected vertices remain while the rest are filtered out of the displayed graph. With the Degree Filter option, those vertices with degree outside of the user defined boundaries are filtered out. Finally, with the Vertex Set Filter, the user selected vertices are not included in the final graph. Netsight additionally offers statistical analysis features such as Page Rank and S-T Betweenness. While Netsight focuses more on visualizing and analyzing large datasets, utilizing Page Rank and filtering algorithms, our system revolves around clustering algorithms instead.

The most closely related system is PubSearch [4]. Research web sites, such as CiteSeer, are queried to obtain relevant scientific publications. Reference author information is extracted from the "Bibliography" or "References" section of retrieved articles. After storing the obtained information in the database, the PubSearch system applies two types of clustering techniques to generate the experts in the fields: document clustering and author clustering. The document clustering step clusters documents based on keywords whereas the author clustering step clusters authors based on co-citation analysis. By combining the two clustering techniques together, a visualization is obtained, where both authors and their fields are represented as nodes. The distance separating the author node and the research label indicate the rank for that author in the particular area. Like the PubSearch system, our implementation also uses a variation of the multi-clustering technique to obtain clusters based on co-citation, co-authorship, and research area topics. However, our system places added emphasis on generating and using the social network idea when clustering. In PubSearch's visualizations, there are no edges that link authors together. Thus, unlike our system, relationships and collaborations between authors are not the main focus of PubSearch's implementation.

Each of the three applications discussed have many promising features that our system has taken into account. Using these preexisting systems as a foundation, we are able to implement an application to accomplish our goals.

1.2 Intuition

This study revolves around co-authorship and co-citation of medical journal articles. By starting with a seed author, various search engines are used to obtain the articles written by the specified author. The coauthor and reference information is extracted from the documents and visualized in a social network. By progressively expanding the network to include more coauthors of coauthors and references of references, an author social network is formed illustrating the relationships and extent of collaboration among authors. Given vast amounts of author data, we would like to determine the clusters of meaningful author nodes groups. The authors are grouped together using the cosine distance measure [5]. The generated clusters are therefore formed based on common areas of study. Along with clustering based on author keywords, our system also attempts to take advantage of the nature of social networks and cluster by the actual authors. With the author relationships already organized in the form of vertices and edges in the graph, a second clustering method makes use of the physical closeness of the author nodes. The reasoning behind this algorithm is that frequently, authors that publish works together and reference each other repeatedly form natural groups or clusters since they generally perform related research [6]. So, by using the Euclidean distance measure to determine the proximity of author nodes, cluster collections are discovered from the graph. The final method explored is a multi-clustering technique that merges the cluster results from the keyword and author clustering algorithms together.

2. SYSTEM ARCHITECTURE

The following sections expand on the system architecture. Figure 1 illustrates the general overview of the architecture employed for this author social network. The architecture mainly consists of three portions: the web portion is needed to collect the author and works information, the database portion is needed to store the results from the search, and the social network analysis portion is needed to analyze, cluster, and visualize all the information. Details pertaining to the web crawler and social network analysis are discussed.

2.1 Web Crawler

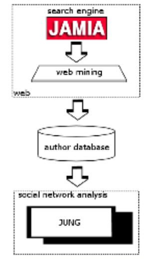


Figure 1: System architecture.

The first step in generating the author social network is to obtain the author, coauthor, and reference author information from the web. Since the system focuses on extracting citation information, it is necessary to select a search engine which has a references section readily available for each work found. Additionally, a medical search engine is required because our system focuses on medical journals and works in particular. Given these constraints, the Journal of the American Medical Informatics Association (JAMIA) [7] is the search engine chosen for this task.

JAMIA provides users the ability to query the database of works based on author name, work title, abstract, and text. In our system, the user provides an author name to begin the searching process. From this query term, a list of the specified author's articles is returned. Using a custom HTML wrapper developed with the HTMLParser package provided by [8] to extract the HTML content from the result pages, we extract coauthor and reference information for an article.

3. COLLABORATIVE WEIGHT COMPUTATION

The following section discusses the formulas used to compute author relationship weights between searched authors and coauthors as well as searched authors and referenced authors. Since different information is available in both cases, different techniques are needed for weight calculation. Once the formulas are chosen, the weights can be used in the visualization layout to determine the node positions as well as the edge thickness.

3.1 Notation

The author social network is a directed graph $G = (V, E)$ with nodes V and edges E where $|V| = n$ denotes the number of nodes and $|E| = m$ denotes the number of edges. In a social network, vertices represent the entities, or more specifically the authors. The edges represent the relationships between entities, or in this case co-authorship and co-citation collaboration. A network consisting of n authors, is visualized as a graph composed of n nodes $V = a_1, a_2, \cdots, a_n$. A directed edge between two author nodes, a_i and a_j, indicates either a co-authorship or co-reference relationship between the two authors. An edge between authors is written as $a_i \rightarrow a_j$, and as is expected, the existence of an edge $a_i \rightarrow a_j$ does not imply $a_j \rightarrow a_i$. The in-degree of a vertex is the number of edges which point to this node while the out-degree of a vertex is the number of edges which flow outwards from this node. The degree measure is simply the number of edges incident to this particular vertex. Figure 2

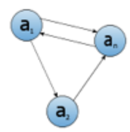


Figure 2: Social network notation.

provides an example of a simple social network.

3.2 Coauthor Weights

To connect two authors together, a similarity measure needs to be chosen to quantify the strength of the relationship. The simplest approach is to compute Jaccard's coefficient [9] which calculates tie strength based on the number of results obtained from a search engine, such as Google [10]. A variation of this approach is taken in our author social network. To begin with, instead of using the Google search engine and establishing friend links, the JAMIA search engine is used to establish coauthor and co-citation relationships. Additionally, our social network is inherently directed in nature. We modify Jaccard's coefficient to the following where a_i and a_j represent the authors whose weight is being calculated for the edge $a_i \rightarrow a_j$.

$$weight(a_i \rightarrow a_j) = \frac{|a_i \cap a_j|}{|a_i|} \tag{1}$$

As mentioned earlier, when the user proposes an author to be queried or extends the graph to search more authors, the returned results are stored in the author database. Performing this calculation for each author pair, therefore, simply amounts to counting the number of entries in the database tables. Jaccard's coefficient is consequently used as the edge weight between searched authors and coauthors as well as between two searched authors.

3.3 Reference Author Weights

The edge weights between searched authors and referenced authors are calculated in a different manner and do not use Jaccard's coefficient. Since referenced authors have not been searched in JAMIA yet, the system has no way of knowing how many works they have actually written. Thus, we developed a different approach to determine the relationship strength of searched author a_i and referenced author ar with edge $a_i \rightarrow a_r$. In essence, the weight is calculated as the sum of the ratio of the number of times a_i references ar over the total number of referenced authors for all works written by a_i. This translates into the following equation, where a_R represents all the referenced authors and w represents all of author a_i's works:

$$weight(a_i \rightarrow a_r) = \sum_{w} \frac{|a_r|}{|a_R|} \text{where } a_r, a_R \in w \tag{2}$$

When the referenced author becomes a searched author, the weight calculation connecting to this node defaults back to Jaccard's coefficient. Also, all weight values range from $[0, 1)$.

3.4 Weighted Layout

Given the tie strength formulas, we will use these weights in the visualized graph. The key component in the social network visualization is the Layout. The Layout specifies the vertex locations so they appear at certain parts of the visualized graph. Our implementation uses a variation of the Fruchterman-Rheingold algorithm [11], which distributes vertices in the graph so that connected nodes remain close together yet maintain a level of separation at the same time. Using an analogy from physics, vertices are equated to atomic charged particles exerting repulsive forces between nodes. Edges, on the other hand, are equated to springs causing attractive forces that instigate the movement of the edges' connected vertices [12]. To start, the vertices' initial configuration begins randomly on the graph. The attractive forces on each vertex are computed next, followed by the repulsive forces. The process concludes with a cooling stage which limits the displacement to some maximum value. As time progresses, this maximum temperature cools so that the adjustment becomes finer as the layout improves. After repeated iterations on all the nodes of the graph, a final resultant force is determined and each node is moved accordingly. The FRLayout provided by JUNG already accounts for these attractive, repulsive, and temperature cooling components [13].

However, to incorporate the relationship weight between authors, the FRLayout has been extended to the WeightedFRLayout. To account for the additional weight information, we created a new function to calculate the force constant for the edge $a_i \rightarrow a_j$:

$$F_C(a_i, a_j) = (1 - w(a_i \rightarrow a_j)) * 100 \tag{3}$$

When calculating the attractive force F_A between vertices a_i and a_j, the force constant is used in the JUNG implementation as follows, where ϵ is defined as 0.000001, is the x-coordinate position in the graph for vertex a_i, $a_i^y$is the y-coordinate position in the graph for vertex a_i, and analogously for a_j.

$$F_A(a_i, a_j) = \frac{\left(max(\epsilon, \sqrt{(a_i^x - a_j^x)^2 + (a_i^y - a_j^y)^2}\right)^2}{F_C^2} \tag{4}$$

Thus, the higher the weight between vertices is, the smaller the force constant becomes. The smaller force constant causes the attractive force to be stronger, and the vertices become closer in the visualized graph. For completeness, the equation to compute the repulsive force F_R between any two vertices a_i and a_j remains unchanged from the original specification. The F_C used is the original force constant based on the window height and width:

$$F_R(a_i, a_j) = \frac{F_C^2}{\overline{max(\epsilon, \sqrt{(a_i^x - a_j^x)^2 + (a_i^y - a_j^y)^2}}} \tag{5}$$

4. KEYWORD EXTRACTION

Before clustering, the authors must be associated with a set of keywords describing their general area of research. Because of the nature of JAMIA, keywords are not provided in the document metadata and must be generated explicitly. The general approach taken for all searched authors is to preprocess the authors' work titles and abstracts to produce a list of keywords. The occurrence of these keywords are then counted and stored in the database. A summary

1. For each searched author, read from the database and obtain the author's works.
2. For each document, obtain the title and abstract.
3. Ignoring stop words, stem the remaining words in the title and abstract.
4. For every keyword in the title, count the number of occurrences in the abstract.
5. Sort the keywords based on the number of occurrences.
6. Take the first 20 keywords and store them in the database.

Figure 3: Keyword processing algorithm for searched author.

1. For each searched author, read from the database of stored keywords
2. For the searched author's references
3. Ignoring stop words, stem the remaining words in the title.
4. For every stored keyword, count the number of occurrences in the title.
5. Sort the keywords based on the number of occurrences.
6. Take the first 20 keywords and store them in the database.

Figure 4: Keyword processing algorithm for references.

of the algorithm steps that we developed for the keyword processing is listed in Figure 3.

All work titles and abstracts written by each searched author are tokenized and stemmed, discarding stop words are ignored. The initial list of stop words were obtained from [14]. We use the PorterStemmer developed by Porter [15] for stemming. Next, the words extracted from the title are used as the keywords and as the words are encountered in the abstract, the occurrence count is incremented. After processing each document, the keywords obtained are sorted by their occurrence counts and the top 20 keywords are selected and stored in the database.

Once the keywords are extracted for the searched authors, the occurrences of the terms in the referenced authors can be computed. Since the abstract information is not available in the case of referenced authors, only the titles are used. All of the searched author's references are analyzed based on the searched author's keywords. Thus, for each keyword from the searched author, the referenced author's titles are preprocessed and as the words are encountered in the references' titles, the count is incremented. A summary of this algorithm is given in Figure 4.

Since coauthors collaborate with searched authors on the same work, the keywords obtained for the searched author is also used for the coauthors. After performing these computations, the database is populated with document vectors for all authors. These values and counts can be used in the clustering algorithms described in the next section.

5. CLUSTERING

Our system incorporates two types of clustering, keyword clustering and author clustering, to identify the relationships and groupings of authors in a graphical manner. After each clustering method is performed on the data individually, the results from both techniques must somehow be combined. Using a multi-clustering technique, clusters can be formed that group the authors working in related fields and labels can be generated for these groups. We developed the keyword and author clustering algorithms and adapted the multi-clustering technique from [4].

5.1 Keyword Clustering

Previously, we described the process by which keywords are extracted from an author's works. These keyword counts can now be used as part of the keyword clustering process. The algorithm begins by assigning each node a cluster state of UNCLASSIFIED. Then, each searched author is examined to determine which authors should be clustered together. Each searched author is assigned an integer cluster state number based on its unique identifier authorId from the database. The list of keywords and the counts associated with this searched author are obtained, and the same is done for each of the searched author's references. To judge the closeness of the authors, a variation of term frequency $\times$ inverse document frequency (TF-IDF) is utilized. TF-IDF is modified to accommodate authors instead of documents and can be referred to as term frequency $\times$ inverse author frequency (TF-IAF). In our adapted version, a list of reference authors that are cited by the target author is generated for each searched author. TF-IAF can be used to match the keywords of the reference author against the keywords of the target searched author. The new equation becomes the following, where the term frequency measures the number of times the keyword appears for each author, n is the number of authors, and author frequency (AF) is the number of authors that use the keyword:

$$tf - iaf(kw_i) = |kw_i \in a_j| * log\left(\frac{n}{AF(kw_i)}\right) \quad (6)$$

Similar modifications to TF-IDF were also explored in [5].

The results of term weighting computation for the searched and reference authors are stored in separate vectors so that they can be compared. Because of the nature of social networks, the $n(n1)$ comparisons that are usually required can actually be reduced. From the social network, it is already known which authors are collaborating, so it would not make sense to compare authors that have no direct relationship at all. Thus, only searched authors and its connected authors need to be evaluated. Our system utilizes a popular similarity measure [5], the cosine distance metric, to determine the extent of the relationship between the author and the author's references. The cosine distance between two vectors, X and Y, of length i can be determined using this equation:

$$cos(X,Y) = \frac{\sum_i X_i * Y_i}{\sqrt{\sum_i X_i^2 * \sum_i Y_i^2}} \quad (7)$$

If the cosine distance for that particular reference author is better than any set before, then the cluster state can be changed to the current author's identifier. This cosine distance calculation and comparison between searched authors and references continues until all the searched authors have been evaluated. By the end of the algorithm, clusters have been generated based on common keywords. A summary of this procedure is given in Figure 5.

5.2 Author Clustering

In social networks, clusters can also be formed based on the patterns of the relationships. From a relational standpoint, a strong direct relationship between individuals increases the likelihood that these individuals should be clustered together [16]. In the case of authors, the more they write papers together and the more they reference one another, the more cohesive they become, forming a definable group

1. Assign a cluster state of UNCLASSIFIED for all authors
2. For each searched author
3. Assign the searched author a cluster state of authorId (the author's unique identifier).
4. After obtaining the list of keyword counts, weight the terms using the TF-IDF variant.
5. For each referenced author connected to the searched author in the social network
6. After obtaining list of keyword counts, weight terms using the TF-IDF variant.
7. Determine the similarity between the searched and referenced author using the cosine distance measure.
8. If this distance is smaller than the previously set minimum cosine distance
9. Update the cluster state to authorId.

Figure 5: Keyword clustering algorithm.

of collaborators. Our system takes advantage of this property of social networks to help in generating clusters based on author relationships.

In a previous section, the strength of the authors' relationship ties are taken into account when visualizing the social network. In other words, author nodes that have a larger weight, indicating a close relationship, are visually drawn closer together whereas author nodes with a smaller weight are drawn farther apart because the relationship is not as strong. The clustering procedure begins first by setting the cluster states of all nodes to UNCLASSIFIED. Then, each searched author is examined to determine which authors should be clustered together based on location. As in the keyword clustering algorithm, each searched author is assigned an integer cluster state number based on its unique identifier authorId from the database. Subsequently, each of the searched author's directly connected authors are evaluated. Since the actual x and y coordinates of the author nodes are used to determine cluster membership, the Euclidean distance metric is used. The Euclidean distance between two authors, a_i and a_j, can be computed with the following formula:

$$dist(a_i, a_j) = \sqrt{(a_i^x - a_j^x)^2 + (a_i^y - a_j^y)^2} \quad (8)$$

The smallest Euclidean distance between a searched author and a particular reference author indicates that on the graph, the two nodes are closer together than any other pair. This closeness implies that the relationship between them is stronger than anyone else's. Therefore, when processing the searched authors, if a smaller distance is found, the cluster state can be changed to that author's identifier. This distance calculation and comparison between searched authors and references continues until all the searched authors have been evaluated. By the end of the algorithm, all authors are assigned to a cluster based on the proximity to a searched author.

5.3 Combined Clustering

Up to this point, two separate algorithms have been used to generate clusters. The next logical step would be to develop yet another algorithm to combine the cluster information from both the keyword clustering and the author clustering algorithms together. We have adapted a multi-clustering technique from [4] which analyzes generated cluster data from multiple clustering methods and merges them together through a vectorization, distance evaluation, and vector clustering process.

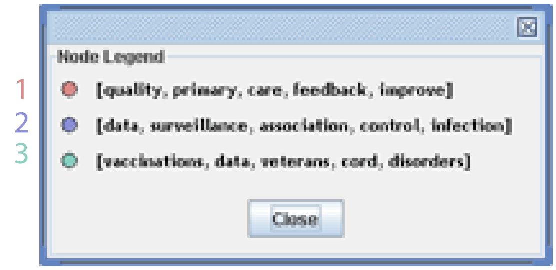


Figure 6: Node legend after clustering.

6. OBSERVATIONAL RESULTS

We present our observational results with an example author social network and manually check the validity of the keyword labels generated. The system utilizes JUNG for visualizations.

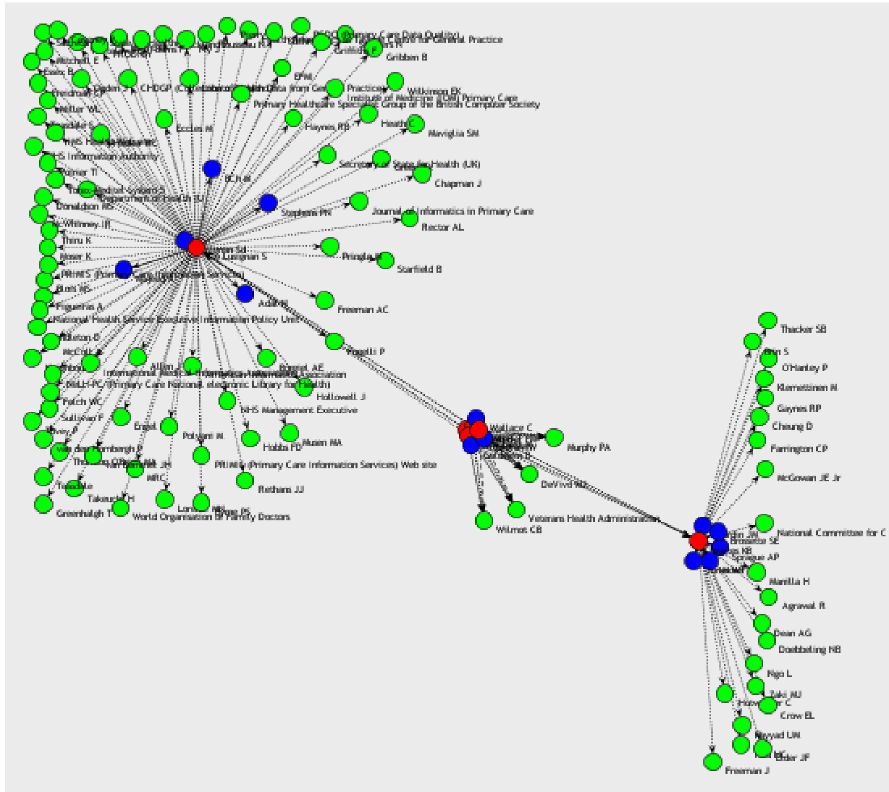
We ran several observational runs with different authors to determine the qualitative effectiveness of the system. In one of the example runs, we searched for author "Frances M. Weaver" and find the works he has published in JAMIA. To generate more clusters, we expand the graph to search Weaver's coauthors and references. The initial graph generated from these searches is illustrated in Figure 7(a). After selecting the cluster option, the graph changes into what is depicted in Figure 7(b). The leftmost cluster is associated with the keywords "quality, primary, care, feedback, improve." The middle set of authors is associated with "vaccinations, data, veterans, cord, disorders." And the rightmost cluster is associated with "data, surveillance, association, control, infection." The node legend summarizing this data is given in Figure 6.

To verify the accuracy of the labels, we look at Weaver's areas of research. He is assigned to the center cluster group associated with spinal cord disorders and vaccinations. When we submit "Frances M. Weaver" into Google, the professor's biography page lists his research interests as "chronic diseases (i.e., Spinal Cord Injury, Parkinson's Disease), long term care, program evaluation, surgical risks and outcomes" [17]. Therefore, from the work submitted into JAMIA by Weaver and his associates, the system was able to determine that one of his general areas of study is in spinal cord disorder research. Inspecting even further, a page for the "Spinal Cord Injury Quality Enhancement Research Initiative (SCI QUERI)" [18] research coordinating center is discovered which among the participants, include Weaver, Evans, LaVela, Wallace, Goldstein, Legro, and Smith, who are all clustered together in our system's social network. We evaluate other cluster groups in a similar manner.

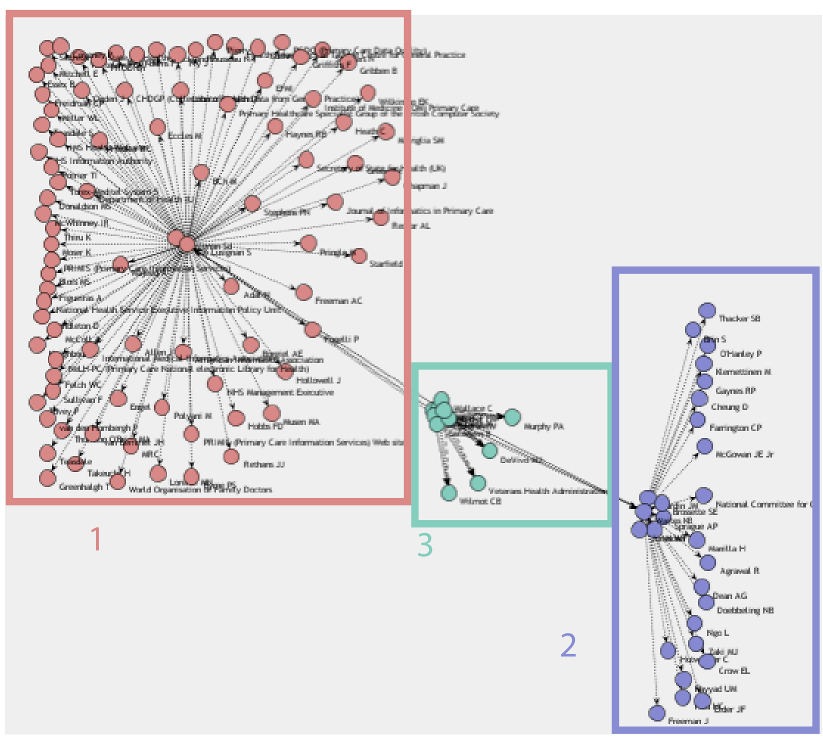
Under manual inspection, the clusters and labels generated by the system are able to describe the authors' research interests in most of the cases. The clustering and keyword generation system, however, is not perfect and possible future work is described in the next section to improve keyword extraction part of the system.

7. FUTURE WORK

Since this work was a first attempt at developing a social network capable of producing author clusters based on common



(a) Before clustering.



(b) After clustering.

Figure 7: Frances M. Weaver's social network.

topics, future work should still be done on the system. Possibilities include using different search engines, improving the keyword extraction process, implementing more clustering methods, and handling author ambiguity issues.
Enhancements can also be made to the keyword extraction process. In particular, along with stop word removal and word stemming, future implementation may also incorporate knowledge sources provided by the National Library of Medicine's Unified Medical Language System (UMLS) [19]. UMLS provides a metathesaurus to link common medical terms and synonymous words together. Additionally, the SPECIALIST lexicon converts words with inflected forms into the common root word. This lexicon can be used in place of the PorterStemmer.
Other clustering methods are currently being evaluated for their effectiveness and correctness.
Problems of entity resolution can occur due to the method in which we collect authorship information. Future work should be done to account for ambiguities in the author data. In addition to the author name, work title, and work abstract, the web mining process can also extract institution locations and email addresses for the authors.
In our experiments, we manually verified several examples. To manually verify all possible test cases would be too time-consuming and not very rigorous. A more comprehensive and rigourous validation methodology for verifying the accuracy of the clusters and their associated keywords is currently being evaluated.

8. CONCLUSION

We have implemented a system to translate author, coauthor, and citation data obtained from the web and generate a visual representation of a social network. We have also developed and implemented clustering methods to group authors together based on mutual research interests. After evaluating example runs, it is found that authors tend to be grouped together correctly because the co-citation and joint publications imply an extent of collaboration between the authors in the same clusters. In some occasions, two clusters may have somewhat similar keyword labels that could possibly be merged into one. In terms of the cluster labels, there is more variability in terms of the accuracy. There are cases when the labels match very well with all the authors in the group; the label results returned from the system match closely with the results returned from manually using Google to determine the research interests for every single author in the cluster. However, there are also cases when the keyword label only describes a portion of the group. In these cases the topic description covers the majority, but not all, of the authors in the group.

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GeOlaPivot Table:
a Visualization Paradigm for SOLAP Solutions

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Abstract

Pivot tables are the de-facto standard paradigm for the visualization of data in the context of multidimensional OLAP analysis. However it is recognized that they are not suited, in their original definition, to support spatio-temporal data analysis. In this paper, we propose the GeOlaPivot Table, an extension of the pivot tables specifically conceived to assist decision makers in analyzing spatial information of data warehouses. Moreover, we present a mock-up of user interface exploiting this new paradigm, by an example of application to a multidimensional dataset.

1 Introduction

Organizations are collecting always increasing amount of data, which usually contain lots of hidden but precious knowledge. To support the decision makers in discovering these concealed information, OLAP (OnLine Analytical Processing) tools provide the ability to interactively explore these multidimensional data by presenting detailed and aggregated data. Results are usually shown through some OLAP Visual Analysis tools, aimed at supporting analytical reasoning. Indeed, data are displayed using the best practices of information visualization, without requiring the decision maker to master a query language or understand the underlying structure of the database [17]. The right presentation makes it easy to organize and understand the information. Data visualization facilitates the extraction of insight from the complexity of the phenomena and processes being analyzed, as well as it offers a better understanding of the structure and relationships contained within the dataset.

However, some research is still needed on OLAP Visual Analysis tools, specially when the multidimensional analysis subject is spatio-temporal information. This is a fundamental issue, since it has been estimated that about 80% of the data stored in corporate databases integrates spatial information [5].

Previous researches on integration of spatial information into multidimensional models leaded to the definition of the Spatial OLAP (SOLAP) concept [2]. SOLAP solutions usually lie on coupling OLAP functionalities used to provide multidimensionality and Geographic Information Systems functionalities used to store and visualize the spatial information [14]. The numerous on going works [11], [3], [4], [9] confirm the importance and the innovating character of SOLAP. Indeed, SOLAP can not be reduced to a simple coupling architecture, but implies a real re-thinking of OLAP concepts. Among others, how to visualize and explore the spatio-temporal multidimensional dataset is an emergent and critical open issue [2]. Indeed, without a visual interface for viewing and manipulating the geometrical component of the spatial data, the analysis turns out to be incomplete [13]. On the other hand, it is widely recognized that existing Geographical Information Systems are not adequate for decision-support applications when used alone, but alternative solutions must be used [3]. As a result, there is a strong need for new visual tools, enabling to exploit the full potential of the spatial and temporal dimensions and measures of data warehouses.

Based on the examination of visual analysis capabilities and limitations of current SOLAP solutions, we propose in this paper a new visualization paradigm for SOLAP tools, named *GeOLAP Pivot Table* especially suited to deal with spatio-temporal measures. In particular, the interface exploits the concept of Pivot Table adding to it a 3D dimension by using the *Space-Time Cube* [7] 3D representation.

The remainder of the paper is structured as follows. Section 2 describes the main OLAP concepts. In Section 3, after introducing the visualization requirements for a SOLAP client tool, we describe the

GeOlaPivot *Table* visualization metaphor, which permits to conduct an effective spatio-temporal multidimensional analysis. Then, in section 4 it is proposed a mock-up of user interface we designed, together with a case study scenario and a comparison with alternative SOLAP visualization solutions. Some final remarks and future work conclude the paper.

2 OLAP key concepts

A data warehouse is a collection of data suited to support management's decisions [8]. These data are usually modelled conforming to a multidimensional model, which make possible navigation and analysis, by introducing the concepts of *dimensions* (analysis axes) and *facts*. Dimensions can be organized following hierarchies' schemas, which allow us to modify the detail level of analysis, while facts are described by *measures* which represent the analysis subject. The OLAP approach provides the ability to interactively explore these multidimensional data to encourage knowledge discovery, supporting in the meantime the iterative nature of the analysis process, allowing the decision makers to navigate across the different dimensions at different levels of detail. With OLAP tools, the analyst visually interacts with the data, focusing on the results of the analysis rather than on the procedure required to perform it. This analysis process is conducted by "navigating" into the multidimensional cube through some OLAP operators (*Roll up, Drill down, Slice, Rotate etc…*).

In order to effectively support OLAP analysis of multidimensional databases, a visual presentation of data is required. The most adopted data presentation paradigm is the *Pivot Table*. A Pivot Table is a 2D spreadsheet with associated subtotals and totals that supports viewing more complex data by nesting several dimensions on the *x*- or *y*-axis and displaying data on multiple pages. Pivot tables generally interactively support the selecting of data subsets and the changing of the displayed level of detail. The success of the pivot tables is due to their capabilities of incorporating multidimensional concepts into their structure, generating a set of small multiple displays, which permit to compare easily data, and visually encapsulate the structure of the analysis process. Graphical representation of data coupled with pivot table permits to OLAP client tools to query and analyze in an interactive, effective and useful way multidimensional data. As a result, OLAP operators are translated into interaction with pivot table and/or graphical displays.

Among the many commercial [12] and free OLAP [19] solutions some tools (such as POLARIS [17]) have extended the pivot table concept with graphic representations and visual variables (shape, size, etc…). Following this approach, cells of the pivot table are graphic canvas which collapse using visual variables measures associated to different members of a same hierarchy level into a unique visual description. The main advantage of this approach is to effectively support the user in data comparison.

3 The GeOlaPivot Table

With the development of spatial data warehouses, a fully exploitation of spatial data into decisional process has become inevitable. Thus, SOLAP applications adds new analysis capabilities to OLAP ones.

SOLAP is defined as "a visual platform built especially to support rapid and easy spatio-temporal analysis and exploration of data following a multidimensional approach comprised of aggregation levels available in cartographic displays as well as in tabular and diagram displays" [2]. The SOLAP paradigm reformulates the concepts of measure [4] [16] [13] and dimension [3], allowing spatial information to be integrated in multidimensional models as axis and/or subject of analysis.

It is obvious that if the spatial dimension is treated as any other descriptive dimension, without consideration for the cartographic component of the data, OLAP tools will present serious limitations in support of spatio-temporal analysis. Indeed, in the context of information exploration, maps and graphics are active instruments in the end user's thinking process [10]. Thus, the introduction of geographical data as measure in OLAP implies a reformulation of classical visualization paradigms, to support a multidimensional analysis using maps, tabular and graphical data representation in a concerted and synchronized way. Moreover, it worth pointing out that common Geographic Information System (GIS) techniques, such as *Overlay* or *MultiMaps*, are not appropriate. This because the Overlay, even if reveals spatial relations, hides the precious information that a measure could belong to different layers (a spatial measure could be associated to different combination of level members), while MultiMaps is conceived to emphasize thematic relations rather than spatial ones. Consequently, there is a strong needing for a visual technique suited to compare spatial measures, according to different members of the same hierarchy level, and to effectively understand spatial/thematic relations between measures. Moreover, spatial measures can be associated to a spatial context that permits to localize them in the space. In other terms a spatial dimension can be present in a SOLAP application with spatial measures. Finally, thematic attributes of geographical data are necessary for an effective decision-making process. For example, what characterize a particular area can help decision-maker to understand the causes of a particular localization of a phenomenon.

To address the above issues, we propose the metaphor of *GeOlaPivot Table*, intended as a 3-Dimensional extension of the OLAP Pivot Table. The main idea is to exploit the 3rd dimension to provide insight on how a spatial phenomenon evolved in function of another factor (such as time, or products), by overlapping data onto a map. To this aim, we have combined the concept of *Space-Time Cube* [7] [6] and *Pivot Table* giving rise to the notion of *GeOlaPivot Table.* Indeed, cells of the *Pivot Table* related to spatial data are cubes, representing into a single, visual description measures associated to different members of a same

hierarchy level, like previously described OLAP tools. A cube can be rotated to obtain the best point of view, avoiding screen and information cluttering. So, user can freely rotate the cube on 3 axes, to analyze the dataset. The base of the cube is associated to a spatial dimension (if it exists) and its 3rd dimension to another alphanumeric dimension. Spatial measures associated to the same fact are depicted by the same color. All the data that do not match the query parameters, set by the user, are removed from the visualization cube.

As a result, the main characteristics a SOLAP client tool based on *GeOlaPivot Table* are:

1. Visualization of spatial geometric dimension and spatial measure at same time.
2. Adoption of a visualisation technique to compare spatial and thematic relations between measures associated to different members of a same hierarchy level.
3. Explicit visualization of spatial relations between measures and dimensions members.
4. Visual encapsulation of the structure of multidimensional application.
5. Visual representation of OLAP operators
6. Display of thematic attributes of measures.

4 A Visualization Tool based on the GeOlaPivot Table metaphor

To clarify the main aspects of the *GeOlaPivot Table*, we have developed a mock-up of the User Interface (UI) of the visualization tool meant to support the proposed metaphor (see figure 1). This UI is aimed at providing an interactive environment which graphically encapsulates the structure of the multidimensional application and translates interactions with the visual interface into operators. In this environment the knowledge engineer can query the Spatial Data Warehouse by defining the analysis dimensions and the level of detail to use, to get insight on spatial relationships occurring among data. In particular, a direct manipulation of both attributes and depicted values is allowed.

To this aim, the interface proposes some widgets to carefully select the information to deal with, which will be rendered in 3D using the *GeOlaPivot Table* metaphor.

The UI is composed of three main panels:

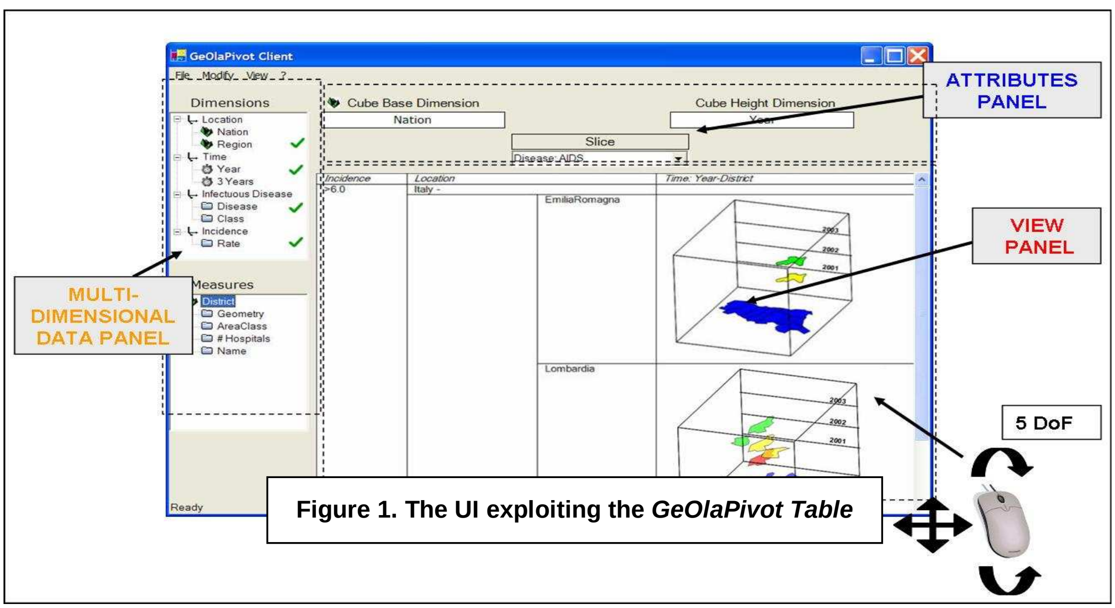

Figure 1. The UI exploiting the *GeOlaPivot Table*

- *Data Panel*: This is a vertical panel, located to the left of the window, which allows to select the data to be analyzed. , to query and filter data, to get the specific information that the user wants to view. In detail, it embeds two Tree-View controls, providing a hierarchical representation of Dimension and Measures attributes contained in the dataset, respectively. Among the dimensional attributes, the ones representing spatial information are depicted by a corresponding icon.
- *Attribute Panel*: This panel allows the user to identify the attributes to be used as base and height of the cube, respectively. To this aim, he/she can drag & drop an attribute from the Data Panel to some specific areas of this panel.
- *View Panel*: This is the *GeOlaPivot* Table, used to show in 3D, at an arbitrary zoom level, the spatial data. The user simply drags attribute names from the Data Panel into a cell, and the resulting report is updated on-the-fly. Upon completion of the analysis, the analyst can quickly drill into the report. It allows for 5 Degree of Freedom, achieved through combination of mouse clicks and gestures.

This user interface could be very flexible, being able to deal with a large variety of spatio-temporal phenomena.

4.1 A scenario of use

In order to illustrate the fundamental characteristics of the *GeOlaPivot Table*, we describe a possible scenario of use considering as an example the supervision of infectious (as for example AIDS, tetanus, etc…) diseases in Italy. The multidimensional application presents as dimension:

- *Location*: (Region, Nation) Spatial geometric dimension, i.e. Lombardia, Italy.
- *Time*: (Year, 3 Years), i.e. 1991, 1990-1992
- *Infectious Disease*: (Disease, Class) A classification of diseases according to the International Classification of Disease, i.e. AIDS
- *Incidence*: (Rate) Rate of incidence of deaths by population per 100000 inhabitants, i.e. 2,5-3,0

Districts are measures. A district is characterized by some attributes, as the *Name*, the *Geometry*, the *Number of Hospitals* and the *Areaclass*. The latter one is a social-economic classification of the district, such as “cities and services”. Aggregation functions are spatial union for geometry, sum for the number of hospitals and a ratio function for the areaclass. An example of the fact table is presented in Table 1. Data reported in this example, as well as complete data and statistics about mortality, is taken from documents available on the web site of the Italian Health Institution “*Istituto Superiore di Sanità*” (www.iss.it).

Disease	**Time**	**Incidenc e**	**Location**	**District**
AIDS	2001	>6.0	Lombardia	Piacenza
AIDS	2002	>6.0	Lombardia	Brescia, Piacenza
AIDS	2003	>6.0	Lombardia	Lecco, Piacenza
AIDS	2002	>6.0	Emilia-Romagna	Ravenna
…	…	…	…	…

Table 1. Fact table of the Infectious Diseases Spatial Data Warehouse

Let us suppose that years taken in consideration for this example are only 2001, 2002 and 2003. If user wants to know what districts have an incidence rate superior to 6.0 for AIDS the UI configuration shown in figure 4 permits to answer to this question. We notice the *AIDS* value in the SLICE component and *Region* and *Year* in the Cube Base Dimension and Cube Height Dimension components respectively. The *GeOlaPivot Table* permits to see that for the region “Lombardia”, three districts are present and in particular the district Piacenza is always present from 2001 to 2003. Moreover these districts are all neighboring. Changing year does not imply changing of geographical area. Examining all other regions of Italy using the *GeOlaPivot Table* curiously we notice that only Emilia Romagna have a district (Ravenna) with this incidence rate. Consequently user could wish to analyze this problem from a less detailed geographical point of view. He/she can apply the Roll-up operator on the *Location* dimension, by clicking on the ‘-‘ operator at the right of Italy in the *GeOlaPivot Table*. By drag the level *3 Years* from the Multidimensional Data Panel into the Cube Height component he/she applies the Roll-up operator to the *Time* dimension too. Finally he/she clicks on level *Rate* and he/she drags the “>6.0” member into the Slice component applying the Slice OLAP operator to data. So, now the *GeOlaPivot Table* will contain only one cell showing the cube represented in figure 2. It shows that the highest incidence rate for AIDS from 2001 to 2003 regards at most north Italy districts. What characterize this area? Answers could be found in thematic attributes. Showing thematic attributes for the new aggregated measure it can be noticed that the areaclass for this area is classified as “cities and services”.

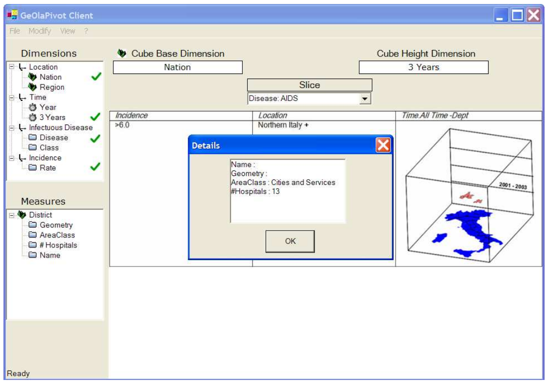

Figure 2. Aggregation of Districts in *GeOlaPivot Table*

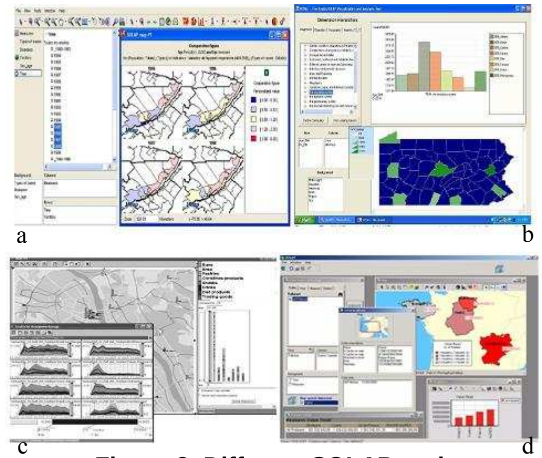

Figure 3. Different SOLAP tools

5 Related Work

Several SOLAP visualization tools have been developed until now. All of these have at least one common feature: spatial dimension is the main visual instrument to explore, interact and analyze multidimensional data. In other terms, supported SOLAP applications provide one spatial cartographic dimension, and many classical dimensions and alphanumeric measures. User interacts with the map to show measures with graphical display or visual variables on the map. The following brief summary of the analysis capabilities of the main SOLAP tools will better describe this feature.

In [14] authors describe a SOLAP client tool (figure 3a) which supports a tabular data representation, 7 different types of diagrams and maps, composed by visual variables and maps superimposed with graphical diagrams. These techniques are applied to spatial dimension. Spatial data represents inputs of multidimensional analysis and the result of this analysis is an alphanumeric data spatially related to it. Moreover, some particular SOLAP operators (spatial drill down or thematic roll up) have been realized. Synchronization of maps and tabular representation of data permits to links spatial and OLAP features. User works on tabular data clicking on maps and vice versa. Another effort to support multidimensional spatial-numerical decision process is SOVAT (figure 3b) [15]. This tool permits to navigate into multidimensional databases, and to analyze spatio-temporal data using graphical displays, maps, and tabular representation. In contrast with the previous tool, in SOVAT cartographic representation of spatial dimension is predetermined in the user interface, limiting the kind of different visual possible representations, but linking more strongly the spatial dimension to the tabular representation.

In [20] is presented CommonGIS, a powerful tool for interactive visual geo-analytics, extended to process hierarchical multidimensional data from OLAP warehouses (figure 3c). This approach is very different from the previous ones, since it is GIS-compliant. Thus, no tabular representation of data is provided for the multidimensional navigation, which is permitted by means of some parametric geovisualization techniques. Finally, the prototype named GéOlap [18] (figure 3d) handles spatial dimensions and allow OLAP navigation into synchronized tabular, cartographic and diagram representations. In conclusion, in all these tools the classical OLAP features (pivot table, graphical displays, visual variables) are used to visualize alphanumeric data as dimensions and/or measures, whereas some other different and dedicated geovisualization techniques (a wider panorama of geovisualization tools and visualization-based techniques for exploratory analysis of spatio-temporal data is provided in [1]) are used for spatial dimensions. The adoption of a real implementation of the *GeOlaPivot Table* in a tool for Spatial OLAP could be an improvement of these solutions because it permits to coherently merge, in a single visual environment, the key concepts of pivot tables and Space-Time Cube. This allows us to represent and effectively analyze spatial measures defined as geographical objects [4] according to spatial and alphanumeric dimensions.

6 Conclusions and Future Work

The growing amount of spatial data in data warehouses leads to the formulation of Spatial OLAP (SOLAP) concept. In this work, we have introduced the metaphor of *GeOlaPivot Table*, which coherently merges, in a single visual environment, the key concepts of pivot tables and Space-Time Cube.

Moreover we have presented a mock-up of User Interface exploiting the *GeOlaPivot Table,* showing how it could be applied to a case study concerning the supervision of infectious diseases in Italy. This approach represents a first effort in adapting advanced geovisualization techniques to SOLAP ones, in order to create a specific visual paradigm for Spatial OLAP able to effectively support and fully exploit spatial multidimensional analysis process. Currently we are working on the implementation of a Server SOLAP to couple with a future real implementation of the *GeOlaPivot Table*. This will permit us to apply the proposed SOLAP visualization paradigm to a real spatial data warehouse and so to conduct usability tests. Our future work will also concerned with the extension of *GeOlaPivot Table* with adequate graphic semiology rules to visualize thematic attributes of spatial dimensions and measures and the introduction of chorems in order to visualize spatial trends.

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A scenario driven decision support system

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***Abstract* - Query languages for multi-sensor data sources are generally dealing with spatial-temporal data that in many applications are of geographical type. Such applications are quite often concerned with dynamic activities where the collected sensor data are streaming in from multiple sensors. When applied to dynamic processes where the main purpose is to create a basis for decision making it generally becomes difficult to demonstrate the feasibility of the system and to handled the extra tools that may be required. To overcome this problem the query language *ΣQL* has been attached to a simulation framework that can be set up to form the basis for demonstration of the query language and eventually also its usage in decision making processes. In this work the query language will be discussed together with some other services useful as complements to the query language. The system will be illustrated and discussed by means of a scenario that has been run in the simulation environment.**

1. Introduction

Query languages dealing with dynamic processes in geographical environments are hard to evaluate in realistic situations. This is especially complicated as the input data generally come from various sensors that cannot produce exact data. This is due to limitations that are inherit in all sensors. Sensors can be seen as specialized tools that never includes complete information with respect to the observed objects, e.g. a video can be used to determine the colour of an object whereas an IR-camera cannot. Thus to get a complete description of an object, in which a user can have confidence not just a single sensor but a number of sensors are required. Due to the uncertainty in the multi-sensor data the result must be subject to sensor data fusion [11]. The main reason for this is that it must be determined up to some reasonable level of certainty that the target object is the same that was observed by all the sensors, which is a classical problem in sensor data fusion. ΣQL [18], [19] has capabilities for handling multiple sensor types and a method for data fusion [14]. As sensor data systems cannot be seen as user friendly if they require sensor and sensor data user competence it is of utmost importance for their usage to make them sensor data independent. This concept, that is discussed subsequently can be seen as an important aspect of ΣQL that must be of concern to most systems that uses sensor data as input. Clearly, this is further motivated by the fact that an end-user, that is not a sensor expert, have better things to do then to care about which sensor(s) that should be used by the system. Another aspect related to the problem of sensor technique concerns the fact that few sensors can be successfully used under all weather and light conditions. Thus sensor data independence is motivated to let the users concentrate on their main activities and let the sensors be dealt with by the system.

Sensor data are generally collected to determine what is going on during specific dynamic processes.These process are quite often of complex nature and cannot be carried out without spending much time and system resources unless they can be simulated in some way. To illustrate how a number of decision support tools (services), of which the query languages is the most powerful and general, can be used to monitor such dynamic processes, a simulation framework has been used. This particular simulation framework is called MOSART [20] and it is a central part of this system; it includes a scenario engine that keeps track of a large number of events while monitoring a large number of moving objects, i.e. basically vehicles. The input data to the simulation framework come from a set of sensor models that, for each sensor type, correspond to a piece of software that simulates the real sensor and generates data corresponding to the ongoing situation at hand in the simulation framework. As a consequence, scenarios with a number of ongoing events can be run while applying the various decision support tools over time. The information used for decision making thus comes from the sensor models observing the area of the scenario. Thus it becomes possible to determine the various events as they occur and in parallel to this it also becomes possible to build up and maintain an operational picture of the scenario. This gives the users of the system an understanding (awareness) of what is going on and on the basis of the operational picture they can make their decisions in order to solve the problems implied in the scenario. A fairly related approach is presented by Louvieris et al [15] that describes a method based on case based reasoning that uses input from a scenario and where the user interaction is carried out by a query language.

Many attempts have been made to visual interfaces, e.g. for SQL, but only a few have touched the issues of spatial and/or temporal queries and few cases are concerned with data from sensors. An attempt to handle temporal data is given by Dionisio et al. with the tool MQuery [9], but this approach is very simple and does not, for instance, handle

Allens [2] time intervals. Chittaro et al [8] have developed a system for handling those time intervals, but it is not a complete query language. Abdelmoty et al [1] have made a representation of visual queries in spatial databases with a filter-based approach. Bonhomme et al [3] have proposed a visual representation for spatial/temporal queries based on a query-by-example approach. Chang [6] has made an approach to use c-gestures for making spatial/temporal queries in what he calls a sentient map. These rapproaches have all partly influenced our approach to a visual query language for spatial and temporal queries.

In this paper the problem of the work including its context is discussed in section 2. The query language is briefly presented in section 3 while section 4 discusses the simulation framework including the sensor models as well as the planning and association services available in the system. Section 5 describes the scenario used in the demonstration. Finally, section 6 discusses the outcome of the scenario and section 7 presents the conclusions.

2. The problem and its context

The main problem in this work has been concerned with how to query multiple sensor data sources observing dynamic environments in a way that makes it possible for end-users to determine events of dynamic processes and eventually get a situation understanding that can be used for relevant decision making. To achieve this goal many complex subtasks must be solved. Among these are the design of a user interface. Of concern is not only, which input information to be given to the users but also how it should be given. The question also arises how the information returned by the system should be presented. These problems are all of particular importance when considering that the queries are applied in order to determine events in a complex dynamic process. It is also of importance to remember that most data are of spatial/temporal type. Thus, an aspect that a user must consider when applying a query concerns what will be asked for. The general answer to this question is of various types of objects extracted from the sensor data. The objects may, for instance, correspond to vehicles but it is not sufficient to just return the object types since the user may also be interested in different *spatial and temporal relationships, status* and *attribute values*. Of concern is also the fact that since the input data is generated by sensors various types of data uncertainties must be considered. As the activities of the observed objects correspond to events in dynamic processes means for demonstration of these aspects must be available. The approach taken to demonstrate the dynamic aspects of the query language has been to attach it to a simulation framework with a built-in scenario generator and where the sensors are simulated by sensor models.

3. The query language ΣQL

The query language discussed in this work is called ΣQL [7]. ΣQL deals generally with data from multiple sensor data sources with capabilities for sensor data fusion. A further aspect of importance is *sensor data independence* meaning that an end-user should be able to apply queries without being aware of which sensors involved in the process of answering the queries. Furthermore, the various sensors may be of different types and generates heterogeneous sensor data images. For this reason, a large number of algorithms for sensor data analysis [13] must be available to the system. It is thus necessary that selection of sensors and sensor data algorithms must be carried out autonomously. This is controlled by an ontological knowledge based system [14]. Repetitive queries without interference from the users are also possible. In this way, queries arbitrarily be repeated and as the light and weather conditions change the selections of sensor types may change. E.g., at daylight a video camera can be selected but as the day shifts to night the video needs to be replaced; perhaps by an IR-camera.

The query language allows classification of objects but it also allows cuing, i.e. detection of possible candidates as a first step towards classification. Sensors used for cuing can, for example, be a ground senor network or a synthetic aperture radar (SAR), while sensors for object classification can be IR-cameras, laser radar and CCD-cameras. Observe that in this context classification means determination of the object class *not s*trictly determination of the identity of a specific object. A distinction between these two classes of sensors is that the former generally covers a much larger areas than the latter. Thus, the former can be used to quickly search through the AOI for object candidates much faster than the sensors used for classification. That is, the detection sensors can be used to scale down the search areas for the classification sensors in which case the classification step can be carried out much faster. Thus the classification sensors have a low coverage and a high resolution opposite to the detection sensors.

The basic functionality of the query language can be described as follows. A query is inserted by a user and the input is fed in to the query processor, which in a dialogue with the ontological knowledge module generates a set of sub-queries; one for each of the selected sensors. The subqueries are then refined and executed by the query processor. Once the sub-queries have been executed instances of their result are inserted in a database. The execution of the sub-queries goes on until the set is

empty, i.e. when there is no further sensor data available to process. In a final step data fusion is, if applicable, carried out using the results of the sub-queries as input and then the process terminates.
Sensor data fusion [14] is another, quite unique, property of ΣQL that does not occur in traditional query systems. The motivation for sensor data fusion is to allow information from multiple sensors to eventually support identification of the requested objects, but also to complement the information since different sensors can register different object properties.

4. The simulation framework

In this section the simulation framework MOSART, the sensor models and the decision support tools that have been integrated with the framework be discussed.

4.1 MOSART

The primary objective of MOSART [20] is to simplify integration of research results to allow increasingly larger simulations and demonstrations. MOSART has a modular environment providing basic simulation functionality and enabling efficient integration of own and commercial software. It contains four main parts:

- software for integration,
- basic features for simulation,
- integrated results from other research projects,
- a gateway to reality.

These main parts make it easier for research projects to evaluate the results in a larger context by setting up more advanced simulations and demonstrators. This is accomplished by integration of research results, basic features and other research results integrated in the framework.

4.2 Sensor models

CARABAS

CARABAS [12] is an airborne synthetic aperture radar (SAR) [5]. Compared to traditional radars CARABAS uses a much longer wavelength. The wavelength is typically 3 - 15 meter, unlike common microwave SARs that uses wavelengths in the size of centimeters. Objects that are much smaller than the wavelength does not significantly affect the result of the radar. The effect is that CARABAS can see through vegetation, i.e.tree trunks and branches in a forest does not prevent the radar from seeing what is on the ground. CARABAS flies typically at a distance of 12 km and at an altitude of 6 km.

IR-sensor and processing

For this scenario we have used a simulated IR (infrared) sensor that has been developed for use in simulations concerning network centric warfare [16]. The sensor model is developed for simulated helicopter or UAV attachment. It is fast, but still gives realistic results. The images produced by the IR-sensor are processed by an algorithm that uses particle filtering and has the possibility to track moving vehicles seen by the sensor.

Ground sensor net

A sensor network for ground surveillance can be used for detection, tracking and classification of vehicles. It is made up by arrays of acoustic and seismic sensors, i.e. microphones and geophones. Signal processing can be carried out by each of the sensor nodes. All sensors know their position and orientation and can communicate with other nodes, associate and fuse object data [4].

4.3 Tools for decision support

SB-plan

SB-plan is a tool for supporting and improving the work of planning for a decision maker. Nowadays a lot of the planning is made by the help of pen and paper. Thus the main idea of SB-plan is to support the decision maker transferring this work to the computer.
One possible use of SB-plan is sensor management. In this case SB-plan can aid the decision maker in calculation of an optimal path for a UAV, where the UAV needs to visit certain places along a certain route. The optimal locations of ground sensor networks can also be calculated, e.g. to monitor movements in an area while considering the known information about other parties, their positions and assumed goals.

Association analysis

A tool for association analysis of observations of vehicles [17] is also available. Association is the process of deciding which observations that concern the same vehicle. This is motivated for various reasons. General associations, if possible, returns fewer tracks, and is thus a less complex situation to analyze and understand. One important question to determine is the number of vehicles that occur. Without association analysis they may seem a lot more than they really are. With association analysis it is possible to make guesses about which route a certain vehicle has taken.

5. The scenario description

In the country Crisendo there are two ethnical groups A-people and B-people. A-people is a minority and live in small enclaves. One of these enclaves contains the mountain Great Wredski Peak. This mountain was the place of a big battle between the ethnic groups in 1455. The battle finished on the 12th of November and A-people was defeated. A small group of B-people annually celebrates this victory by marching to a place just south of the peak. During the last few years the celebrations have been rather small and only a small group of nation-

alists have participated. Because of increasing tension between the ethnical groups the enclave is now under the protection of the UN.
This year there has been rumours that the nationalists has been able to get the sympathy from a larger group of people. Thus, there may be a problem to protect the enclave. The scenario begins at midnight November 12, 2005, the year of the 550 years anniversary of the battle

5.1 Purpose and goal

The purpose of this scenario is to show how information about the process can be gathered and presented to a decision maker to assist him in his decision process. The goal is to have as correct information as possible to make possible to the decision maker to take correct decisions about which measures to take during the scenario.

5.2 Resources available to the UN troops

The UN troops have half a platoon deployed at an observation post at a point near the route to the peak. The UN company is stationed a few km south of the mountain. The company has a UAV (Unmanned Aerial Vehicle) which carries an IR-sensor and has the possibility to carry and deploy six small ground sensor networks. In total the UN company has 10 ground sensor networks available.These networks are all unattended, i.e. of, so called, unattended ground sensornetwork type (UGS).

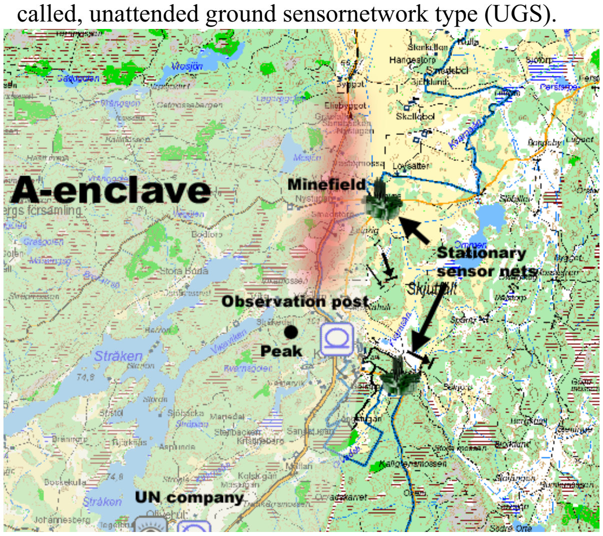

Figure 1. The initial setup on the morning of the 12 November 2005.

Two permanent ground sensor networks has been deployed at the probable routes to the peak. The road leading north from the peak is covered by a minefield, thus preventing vehicles and people from entering the area by that route. If needed an air plane carrying a CARABAS system can be requested. The general start situation can be seen in figure 1.

5.3 Tools

The scenario is simulated in the simulation environment MOSART. It uses several sensor models to produce realistic data. Three different tools for aiding the decision process has been used, i.e. the query language ΣQL for information search, the association service that uses object information found by ΣQL as input and SB-plan d to decide where to deploy the sensor nets.

6. Course of events

The scenario begins at midnight on November 12, 2005. The UN troops have received rumors about a demonstration larger than usual this day, but the rumors are unconfirmed. With the support from ΣQL they monitor incoming data in search for vehicles in the area. For this a fairly simple query is applied:

AOI: A rather large area covering the vicinity of the peak, but none of the nearby towns.
IOI: From midnight and continuously forward.
Object: Vehicles

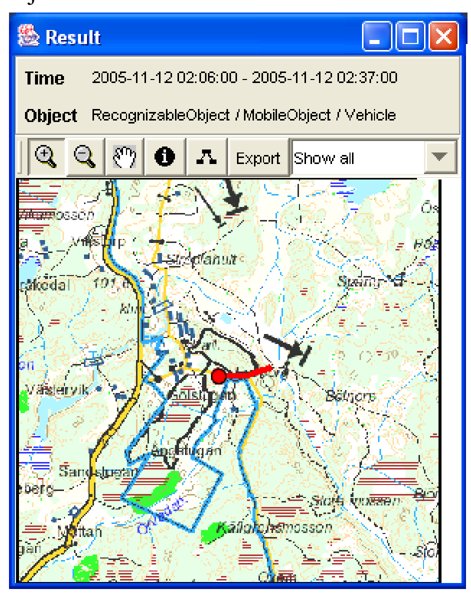

Figure 2. The result from ΣQL at 2:37

Figure 3. The estimated location of the vehicles that arrived at 2:30.

At half past two in the morning three vehicles pass the southern most stationary ground sensor net from east to west. As the observation post has not detected any vehicles on the big soar going south the conclusion is that the vehicles have stopped between the sensor nets and the big road, see figure 3. The vehicles has been classified by the net as one large vehicle i.e. a truck or a bus, and two small vehicles, probably passenger cars.
At dawn, 6.12, the observation post reports that a roadblock has been setup during the night north-east of the observation post. It consists of one truck and three cars. The conclusion is that the people in the vehicles, southeast of the observation post, which arrived during the night also have set up some kind of roadblock. Together these two roadblocks, see figure 4, are probably meant to keep the UN troops locked in to stop them from patrolling the area. Since the UN troops have flying reconnaissance support this will be used instead of forcing a confrontation. The CARABAS is requested to fly across the area to collect further information about the situation.

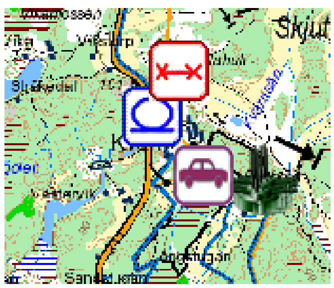

Figure 4. The known situation at 6.12.

When the CARABAS data are delivered they are found to include too much data of which some probably are false due to uncertenties but with the help from ΣQL the vehicles on roads can be determined. The query to ΣQL was (see also figure 5):

AOI: The are covered by CARABAS, but excluding the nearby towns.

IOI: The time for the CARABAS detections.

Object: Vehicles on road.

Since CARABAS only gives detections and no detailed information about the observations it is time to use a further sensor, that is the UAV with the IR-camera. Its mission will be to take a look at all the observations. Since there are obvious activities in the area the UAV will also be used to drop some additional sensor nets. To find out the best positions for the nets SB-plan is used. SB-plan contains information about the roads in the area. The commander also adds information about the most probable sources for “enemy traffic” which in this case is the nearby towns and the most probable goal that is the peak. This tool finds which places, usually crossings, that will cover the most possible traffic. Then SB-plan is used to find a route between the places for the new nets and the observations from the CARABAS system.

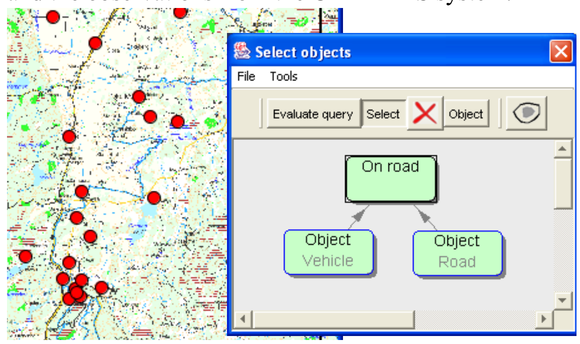

Figure 5. The vehicles on roads found by CARABAS (left), and the conditional part of the *on the road* query (right).

Around 8:30 detections from the new nets start to arrive into the system. This time larger vehicles like trucks or buses have detected. The result determined by ΣQL can be seen to the left in figure 66. It is not easy to know from the information given by ΣQL how many trucks or buses there are in the area. ΣQL gives all detections from all possible sources. In this case the sources were the sensor nets and the IR on the UAV. To facilitate the interpretation of the detected vehicles data are fed into the association analysis tool. This tool then tries to determine which of the observations that probably correspond to the same vehicle. The tool then approximates the routes taken by the vehicles. Then the tool animates the course of events to make it easy for a human to understand. The verified detections to the left and the approximations to the right in figure 66.

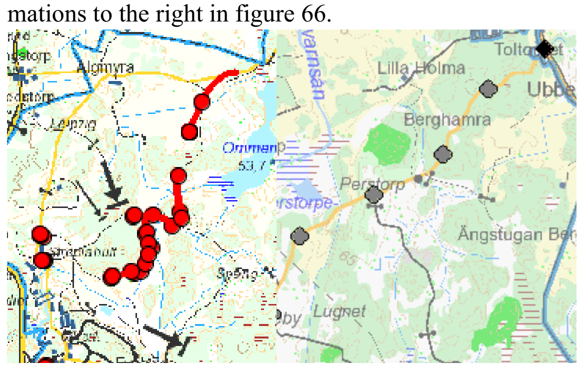

Figure 6. The vehicles that was detected between 8:30 and 8:45. To the left the presentation in ΣQL, to the right the presentation in the tool for situation analysis.

Between 10 and 10:30 additional vehicles are detected and visualized and associated with the association tool. By now a lot of probable demonstrators have arrived and in addition some vehicles that can be assumed to contain armed persons. This is the end of the simulation since now the UN troops have gathered enough information to take their decisions. The situation as presented with the combined information from the tools can be seen to the left in figure 7. The ground truth given by the simulation engine is presented to the right in figure 7. Both cases are schematical but the tools have determined the correct number of vehicles in all cases except for one bus that was missed by the sensor nets since it managed to chose a route that was not covered. The situation presented by the tools is consequently very close to the “real” situation in the simulation.

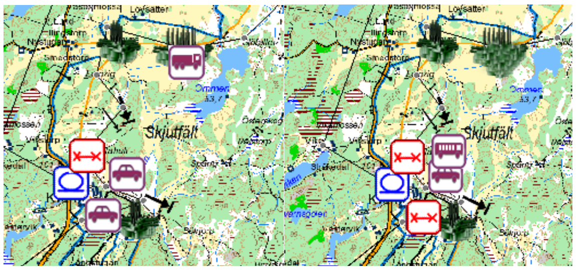

Figure 7. The end of the scenario, as given by the system (left) and the ground truth from the simulation engine (right)

7. Conclusions

The system described in this work can basically be seen as a system that supports decision making in dynamic processes that take place in geographic environments and where the used data sources correspond to multiple sensors of various types. The system contains a set of services (tools) of which the query language is the dominant and most powerful. However, the system cannot only be used for test and demonstration purposes but for system development purposes in a recursive way where the purpose should be to develop and apply new services during controlled forms. As demonstrated the query language can systematically be used over long periods in time and consequently it can also be subject to future research for development of extended facilities in query languages such as e.g. how to apply queries about various types of time dependent object behavior.

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A visualization tool for spatio-temporal data mining

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Abstract

Spatio-temporal datasets are often very large and difficult to analyze and display. Since they are fundamental for decision support in many application contexts, recently a lot of interest has arisen towards data-mining techniques to filter out relevant subsets of very large data repositories as well as visualization tools to effectively display the results. In this paper we propose a tool supporting visualization of spatio-temporal datasets, which exploits Google Earth to render in 3D the resulting knowledge and associated data overlapped onto a satellite image and an arbitrary number of cartographical layers. This tool is particularly useful to highlight spatial relationships among the considered datasets and their spatial context, in terms of geographical layers, such as cities, roads, etc., as well as to show how the phenomenon evolves during the time.

1 Introduction

During the last decade, our ability to collect and store data has far outpaced our ability to process, analyze and exploit it. Many organizations have begun to routinely capture huge volumes of historical data describing their operations, products and customers. As a result, the coverage and volume of digital geographic datasets are extensive and steadily growing (it is estimated that about 80% of the data stored in corporate databases integrates spatial information [6]), leading to huge amounts of geo-referenced information, that need to be analyzed and processed.

This data is often critical for decision support, but its value depends on the ability to extract useful information for studying and understanding the phenomena governing the data source. Consequently, the need for efficient and effective analysis techniques on spatio-temporal datasets has recently emerged as a research priority [3]. Data mining is a good approach that can contribute enormously to providing viable solutions for this problem [5]. It is a user-centric, interactive process, where data mining experts and domain experts work closely together to gain insight on a given problem. In particular, spatio-temporal Data Mining is an emerging research area [12], encompassing a set of exploratory, computational and statistical approaches for analyzing very large spatial and spatio-temporal datasets. Presently, several open issues can be identified in this research field ranging from the definition of suitable mining techniques able to deal with spatial information to the development of effective methods to analyze the produced results.

In particular, Visualization Techniques are a widely recognized powerful approach for data analysis and mining [9], since they take advantage of human abilities to perceive visual patterns and to interpret them [11], [5], [1]. The basic idea is to complement the computer processing capabilities with the great human pattern-recognition ability, to provide new insights on the considered phenomena [6]. However it is widely recognized that spatial visualization features provided by existing geographical applications are not adequate for decision-support systems when used alone, but alternative solutions have to be defined [3]. Indeed, these novel solutions should not only include a static graphical view of the results produced by the mining algorithms, but also the possibility to dynamically obtain different spatial and temporal views as well as to interact in several ways with them. This could allow the discovery of details and patterns that might otherwise remain hidden. As a result, nowadays the most critical research challenges include how to visualize the spatio-temporal multidimensional dataset [2], and how to define effective visual interfaces for viewing and manipulating the geometrical components of the spatial data [16].

To address these issues, we have developed a system suited to interactively visualize in 3D the outcome of the mining process. It exploits Google Earth [7] to render the mining outcomes, overlapped onto a satellite image enhanced by an arbitrary number of informative layers. This tools is targeted to domain expert users, and it is particularly useful to highlight spatial relationships among the considered datasets and their spatial context, in terms of geographical layers, such as cities, roads, mountain chains, seashores etc., as well as to show how the phenomenon evolves during the time.

This newly created tool has been tested against a large real-world dataset (Hurricane Isabel, which struck the US east coast in September 2003, see [13]), trying to solve the critical issue of uncovering characteristics and behavior of a destructive natural phenomenon. The Hurricane Isabel dataset is freely available and describes the main characteristics, sampled each hour along the two days of greatest intensity of the storm. The resulting dataset is huge, containing more than 25 millions real-valued points in each timestep, resulting in 62.5 GBytes of data, and thus representing a significant case study.

The remainder of the paper is structured as follows. Section 2 introduces the main aspects of visual data mining, and then presents the developed tool, both in terms of User Interface and in technical aspects. Section 3 is dedicated to the case study selected and to a discussion of experimental results. Finally in Section 4 we present some conclusions and ideas for future work.

2 The Proposed System

The Data Mining process usually consists of three phases, or steps: 1) pre-processing or data preparation, 2) modeling and validation and, 3) post-processing or deployment. The third step can take the greatest benefits from data visualization, since its basic objective is to represent as much hidden information as possible. In this case, efficient visualization algorithms and tools should also be provided to assist the user in decision-making and data interpretations.

Visual Data Mining refers to methods, approaches and tools for the exploration of large datasets by allowing users to directly interact with visual representations of data and dynamically modify parameters to see how they affect the visualized data. This is usually achieved by means of techniques from information visualization, visual perception, visual metaphors, diagrammatic reasoning, and 3D computer graphics [5], without requiring the decision makers to have knowledge on technicalities.

Visual Data Mining techniques have proven to be very valuable in exploratory data analysis and they also have a high potential for mining large databases [11], since they shift the load from the user's cognitive system to the perceptual system [4]. As a result, visual data mining is a crucial area in explorative data mining, aimed at enhancing the effectiveness of the overall mining process, by supporting analytical reasoning.

We have developed a visualization tool, suited to render the outcome of mining on large spatio-temporal datasets, describing the behavior of some natural phenomena, which have been monitored and recorded at several time instants. The system is mainly intended to deal with datasets characterized by thematic properties, expressed through some values of attributes that change over the time [1].

Since the output of a mining process requires instruments for the interpretation, in our system we envision feeding the results of the mining process to several alternative visualization tools, possibly providing complementary interacting functionality. In this paper we focus on a tool that to render the outcome of the mining process in a 3D virtual environment, allowing the user to freely change his/her viewing perspective. The goal of this application is to enhance the overall knowledge discovery process, allowing decision makers and knowledge engineers to better understand and discuss the logic behind the models, by supporting analytical reasoning.

This tool is focused on highlighting the spatial relationships between the considered data and the real-world geographical entities involved in the phenomenon, allowing users to validate the spatio-temporal mining process, and the discovered patterns.

From a data visualization point of view, the two tools follow in many respects the same approach. Geographical data are arranged in many different *layers* – one for each theme (*variable*). Rules are intended substantially as sets of items, each identifying a range of values for a specific variable; hence displaying an item means painting an *isocloud* of points (a 3D scatter-plot) with the same value. Moreover, both tools allow for some degree of customization in the presentation of data (for instance in the colors used to represent a specific attribute).

2.1 The Google Earth-based tool

This tool is meant for domain-expert users. Indeed, it is aimed at providing an interactive environment, where these users can get insight on relationships between the mining outcomes and nearby geographical entities. To this aim, the tool propose some widgets to carefully select the information to deal with, which will be rendered in 3D over a map and other layers provided by Google Earth.

Google Earth (shortly GE) is a virtual globe, currently freely available for personal use. For commercial and professional use, many purchasing options are available, ranging from basic licenses to enterprise services. Google Earth combines satellite raster imagery, with vector maps and layers, in a single and integrated tool, which allows users to interactively fly in 3D from outer space to street level views. A very wide set of geographical features (streets, borders, rivers airports, etc.), as well as commercial points of interest (restaurants, bars, lodging, shopping malls, fuel stations, etc.), can be overlaid onto the map. A key characteristic of this tool is the fact that the geographical data are not stored on client computers, as they are streamed, upon request, from Google's huge server infrastructure, ensuring fast connections and almost 100% up time. Moreover, this guarantees that data are always up-to-date. The application uses data from NASA databases to render 3D terrain models, thus providing also Digital Elevation Model features.

We have exploited the 3D capabilities provided by Google Earth, together with the updated geographical information layers available on the web, to combine dataset themes and variables with real world infrastructures and geographic features. This application turns out to be very flexible, being able to deal with a large variety of spatio-temporal phenomena, ranging from worldwide (e.g.: weather, pollution, epidemic diffusions, etc…) to local ones (e.g.: local health, traffic, economics, etc…). The tool we developed embeds GE and presents the same ease of use, resulting very suitable for domain-expert users.

For data presentation, we exploit the "focusing" visualization technique [1], where the user can freely move his/her perspective view in a 3D environment, to analyze the dataset. Indeed, data are shown in a 3D animated perspective canvas that can be rotated, zoomed and moved. A left panel allows the decision maker to query the dataset, in order to define the specific (set of) themes/rules to render, and to customize the way the information is depicted. A bottom panel provides a widget to see how the phenomenon evolved over the time.

Each considered variable is rendered as an *isocloud* with a different color. The application works accordingly to the principle that all the data that do not match these query parameters, set by the user, are removed from the visualization canvas. This filtering is immediately applied, thus providing direct manipulation features.

Moreover, each rendered point can be made an hyper link, in order to answer query of the form "When + Where → What", which is a typical analysis task in exploratory spatio-temporal data-mining [14].

The resulting User Interface, shown in Figure 1, is composed of three main panels:

- *View Panel*: This is the GE application, used to show in 3D, at an arbitrary zoom level, the data. It allows for 6 Degree of Freedom, achieved through

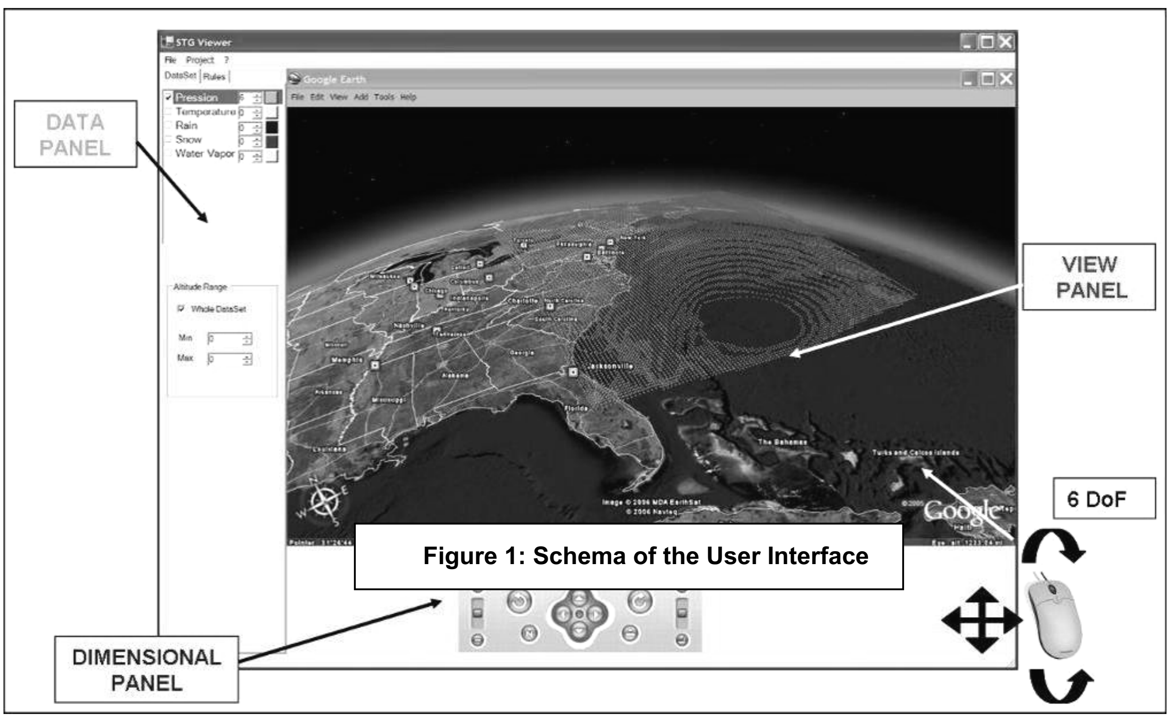

Figure 1: Schema of the User Interface

combination of mouse clicks and movements, or through a lower panel.

- *Data Panel*: This is a vertical panel, located to the left of the window, which allows to query and filter data, to get the specific information that the user wants to view. Through a Tabbed control, the user can choose to deal with the attributes of the whole dataset (the first tab), or with the association rules inferred by the mining engine (the second tab).
  a. In the former case, the system lists all themes contained in the dataset (see Figure 1), and for each of them, the user can indicate if it should be rendered, and selects both the specific value to render as an isocloud, both the color to be used to depict the data. For instance, in Figure 1 the isocloud of hurricane's points having "Pressure" equals to "3" has been rendered in the "Cyan" color. Moreover, to overcome some visualization problems (basically occlusions) that might arise when dealing with 3D representations, the system allows to render only a "slice" of the dataset, based on the altitude. Yet, the user can select to view all the points satisfying a criterion, or clip the representation to the set of points falling into a specific range of altitude.
  b. In the latter case, the system lists the set of discovered association rules. As soon as the user selects one of them, the interface presents the antecedent and the consequent variables for the considered rule, in two different visual controls. Again, the user specifies which of them should be rendered as isoclouds, together with the respective colors to be used to depict the data. For instance, in Figure 2, the association rule "Cloud = 0, Precipitation= 0, Pressure=3 → QVapor=4, Temperature=2" is being displayed. Then, the Cloud and QVapor variables are selected to be rendered, respectively, in "Cyan" and "Light Green" colors.
- *Dimensional Panel*: This panel allows the user to move in four dimensions, namely the 3D permitted by GE (by exploiting six degree of freedom), and the time dimension, through a sliding bar. To this aim, the horizontal panel, located at the bottom of the window, realizes a unique control panel/set of commands to follow out the data painted on screen.

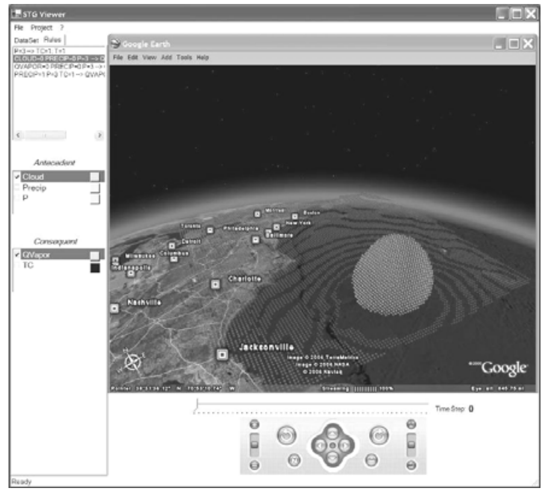

Figure 2: Visualization of dataset themes (Top) and rules (Bottom). Notice the different widgets provided in the left panel.

2.1.1 Technical Aspects

The development of an environment exploiting Google Earth technologies to render mining outcomes posed two main challenges:

1. How to arrange the information of the dataset and/or the rules in a way that it could be displayed by Google Earth, and
2. How to improve the Google Earth user interface, to provide the tools to carry out the exploratory spatio-temporal data mining and visualization.

To address the first issue, we exploited the ad-hoc language provided by GE, named Keyhole Markup Language (or KML) [10], which is an XML grammar and file format suited to model one or more spatial features to be displayed in GE. For instance, through this language, a user can assign icons and labels to a location on the planet surface, specify camera positions to define views, and so on. KML supports some basic geometrical shapes, which appearance can be manipulated by defining coordinates (Longitude, Latitude, and Altitude), or extrusions, as well as they can be grouped together into collections, to create and manage complex 3D objects consisting of numerous shapes. These files are then processed by the Google Earth client in a way similar to how HTML files are processed by web browsers. Consequently, GE can be viewed as a browser of KML files. A lot of documentation and tutorials on KML are available over the web. By exploiting this language, the user community is defining a wide set of other points of interest, which can be seamlessly accessed and integrated over the web. In our application, we designed and implemented some routines for an on-the-fly generation of KML files, basing on user input specified in the Data Panel. Each generated KML file contains the coordinates of each considered point of the data (or item) set. Knowing the bounding box of the whole dataset, these coordinates are calculated basing on the position of the specific point in the dataset. The generation of a file containing more than 100,000 points is almost instantaneous on a notebook based on a Pentium M 2.0 Ghz, with 768 Mb of RAM.

In relation to the second issue, there are two main ways to programmatically interact with GE. The former requires the definition of ad-hoc KML files, specifying the starting point of view. This approach is straightforward, but does not provide an effective management of the user interactions. The alternative solution is to use the set of API provided by GE. Indeed, once such an application is installed, a new COM component is available in the Windows system, namely the *KEYHOLELib*. Once this is imported in a programming environment as a reference library, a new namespace is available, which exports two main classes, i.e. the *KHInterfaceClass* and the *KHViewInfoClass*. They grant respectively a full control on the User Interface and the active point of view in GE. In particular, an instance of the KHInterfaceClass permits to start-up the application, to load a KML file, to enable/disable other active layers, to resize the window, and to take screenshots. Moreover to get/set the current point of view, an instance of the KHViewInfoClass allows to set its coordinates, azimuth, tilt and zoom.

To embed the GE windows within our C# application, we wrapped in .NET the *FindWindow* and *SetParent* Win32 systems calls, available in the User32.dll, suited to get the handle of an arbitrary window, and to control it, respectively.

3 A Case Study: Hurricane Isabel

We have tested our system on a large spatio-temporal dataset. This section detail the data format and the experimental results obtained.

3.1 The Dataset

Hurricane Isabel was the only Category 5 hurricane of the 2003 Atlantic hurricane season (see [13]). Official reports state that an official damage estimate of 3.37 billion of US Dollars.

All the key data about this phenomenon were logged for two days by the National Center for Atmospheric Research in the United States. The corresponding dataset was produced by the Weather Research and Forecast (WRF) model, courtesy of NCAR, and the U.S. National Science Foundation (NSF), and is freely available. All variables are real-valued and were observed along 48 time steps (once every hour for 2 days), in a space having 500 x 500 x 100 = 25×10^6 total points. Each variable, in each time step, is stored in a different file, resulting in 624 files of about 100MB each. Therefore, the Hurricane Isabel Dataset is a proper instance of a massive geographical spatio-temporal dataset, and is widely adopted for data visualization studies, such as the ones made for the IEEE 2004 Visualization Contest [8].

3.2 Visual Results for Exploratory Analysis and Decision Support

In this section we show an example of result gained by applying an adapted *Apriori* algorithm to the Hurricane Isabel datasets and by viewing them with the visualization tool previously described. We analyzed many results and are reporting here a subset of them, which are most meaningful. In our analysis we tried to discover specific patterns/characteristics that were either well known about hurricane data (such as the existence of an area in the centre of the dataset, called the eye of the hurricane) or that were not known but might have significance for an expert study.

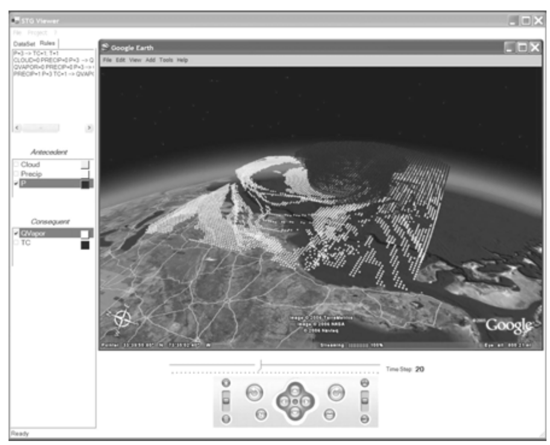

Figure 3: Effects of the dry land on the Cloud Water

For instance, meteorological phenomena are usually highly influenced by the morphology of the area where they occur. Since the hurricane Isabel struck a coastal area, lacking of significant mountain chains, it did not encountered strong barriers limiting its proceeding. It is however really interesting to analyze the effect of the landfall, onto the themes of the dataset. We used our visualization tool to gain insight into these relationships. By analyzing the results, we found that Cloud Water and Water Vapour were the parameters most affected by the seashore. This is clearly visible in Figure 3, where the clearer points represent the locations of the dataset where the Cloud Water has a low level. Darker points basically represent the eye of the hurricane. From this figure it is possible to notice how the altitude with a low level of Cloud Water suddenly drops, as soon as the phenomenon impacts the dry land.

4 Conclusions and Future Work

In this paper we have described a tool we developed for viewing and interacting with the results of the mining process on spatio-temporal datasets, meant for the domain experts.

This tool exploits Google Earth to render in 3D these data, overlapped onto a satellite-image map and an arbitrary number of cartographical layers which can be seamlessly downloaded and integrated. It allows to highlight spatial relationships among the considered datasets and their geographical context.

One of the advantages offered by this tools is the fact that data are displayed using the best practice of information visualization [15], while users can interact in a visual (and thus more natural) fashion, without having to master a query language or understand the underlying structure of the dataset. The right presentation makes it easy to organize and understand the information. As a result, this data visualization facilitates the extraction of insight from the phenomena being analyzed, while offering a better understanding of the structure and relationships within the dataset.

Our system has been tested on a large, real-world spatio-temporal dataset, related to Hurricane Isabel, and has produced interesting results.

We are currently planning to perform additional testing with other large datasets and to improve the types of customization on the rendered data as well as the functionality of the system with the aim to provide a more complete analysis and a higher level of interactivity with the data.

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REPRESENTING TOPOLOGICAL RELATIONSHIPS BY USING 3D OBJECTS: AN EMPIRICAL SURVEY

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Abstract

In this paper we present a survey conducted in order to understand how simple 3D objects, named geometaphors, can be composed for building a model that permits to represent topological relationships in a 3D space. The research was conducted on twenty participants who were familiar with geographical information systems (GIS) and the notion of topological relationship.

The subjects participating to the survey were asked to put in relation textual labels related to topological relationships with visual compositions of geometaphors pairs. The result is an interpretation model of the visual compositions that represents an important component for the building of visual query environments compliant with the users' mental model, contributing therefore to augment significantly the usability of such systems.

Keywords. 3D Environments, GIS, Human Factors, Topological Relationship, Visual Language

1. Introduction

Query by Example [10] (QBE) is a method of query creation that allows the user to search for documents; the search is triggered by an example chosen by the user in the form of a selected text string, a document name or a list of documents. Because the QBE backend formulates the actual query, such method, while still enabling powerful searches, it is easier to learn than formal query languages, such as the standard Structured Query Language (SQL).

Such methodology has been successively extended to the composition of queries through visual representations; such approach is particularly interesting for GIS, where the spatial properties of the objects are relevant. In the last decade many efforts have been directed to this aim. As stated by [7], "visual languages are today being widely used as a means for reproducing the user's mental model of the data-manipulated content". A great deal of work has already been carried out for designing such languages for traditional and object-oriented databases: iconic, diagrammatic, graph-based and multi-modal approaches are available in literature. In the spatial domain some of these approaches have been coupled with sketch based interfaces [1, 3].

Most of the work done takes advantage of 2D visual iconic queries. A difficulty arises from the fact that 2D icons are effective only for the retrieval of objects inhabiting a 2D space; such icons don't not allow an exact definition of spatial relationships where the third dimension is a relevant feature.

That is the reason why in this work we take into consideration 3D icons. Such introduction has been necessarily coupled with the definition of a 3D environment where such objects can be manipulated. In fact, as demonstrated by research in experimental and cognitive psychology, the mental processes of human beings simulate physical world processes. Computer-generated line drawings representing 3D objects are regarded by human beings as 3D structures and not as image features; as a consequence, humans imagine that spatial transformations, such as rotations or shifting, happen in the 3D space.

Although spatial relationships have been largely studied and many visual languages have been presented there have been only a few attempts to examine, from a user centered perspective, the relations between such visual representations and the use of spatial predicates in natural language. Three interesting works have been presented by Mark and Egenhofer [2, 4, 5], although the focus of such studies is on 2D space relationships. Later, Zlatanova [9] provides a formal categorization of topological relationships between multidimensional simple objects in 0, 1, 2 and 3D spaces, but her work, while interesting for the association of topological relationships to real world object combinations, doesn't take into account the user perspective.

In this paper we attempt to fill the gap by exploring the relations between the visual compositions of simple 3D objects and the topological relationships expressed in terms of natural language; such work is done in order to provide a solid basis for the definition of a 3D visual language for GIS exploring.

The model for binding visual representations to topological relationships is derived from a research we have performed on a group of potential users.

Basically, we asked to the subjects to provide a *resemblance value* between images representing pairs of geometaphors composed in a 3D abstract environment and textual labels expressing topological relationships. The answers were used for building a model compliant with the users' perspective.

The remainder of this paper is organized as follows: Section 2 presents the concept of 3D geometaphor; Section 3 describes the topological model survey; the results obtained by the interviews, coupled with a set of rules taking into account several parameters, are used to build an interpretation model to query spatial data; Section 4 draws the final conclusions.

2. The 3D Geometaphor

Following the traditional approach of visual query languages, queries are expressed in terms of spatial composition of visual elements, representing objects, operators and functions. This section illustrates the association of visual counterparts to the geographical objects, which represents is an important design choice for the definition of a visual environment for selecting and manipulating such objects.

The visual representations are composite visual elements named *3D geometaphors*. They derive from previous research work [7] and have been extended in order to take into account the role of the third dimension. The geometaphors can be moved in the 3D space in order to build visual compositions.

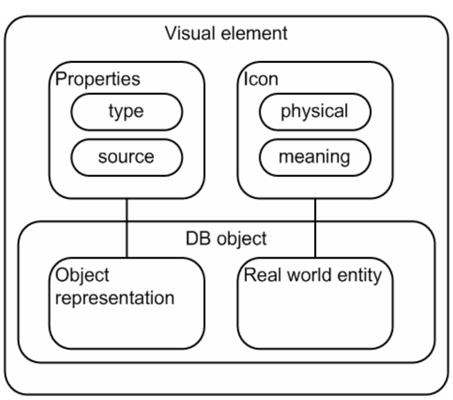

Figure 1. A representation of the Geometaphor components

Geometaphors are characterized by iconic and property components, as shown in Figure 1.

The first component is characterized by the *physical description* of the object, a textured 3D cube, with an associated *meaning*. The presence of textures is an important feature in order to stimulate the visual and textual cognitive styles of the end users. In such a way, users understand the meaning at once and are immediately able to use them.

The property part is divided into *type*, representing the object type used to store the data (e.g., a REGION for parking areas or a LINE for roads), and *source*, indicating where data should be retrieved. The source field can contain a table, a view name, an SQL query or a function.

Different geographical objects, such as points, lines and regions, can be represented by the geometaphor.

Table 1. The components of the geometaphor *Parking Area*

Physical description	
Meaning	Parking Area
Type	Region
Source	SELECT * FROM ParkingArea WHERE city = "Rome"

Table 1 illustrates the components of the geometaphor *Parking Area*. The 3D image represents the physical part, *Parking Area* the meaning, *Region* the object type and *SELECT * FROM ParkingArea WHERE city = "Rome"* the source. The example represents a theme corresponding to all the *Parking Area* instances contained in the *Parking Area* layer and associated to the city *Rome*.

3. The Topological Model Survey

The visual elements described in the previous section have been used in an empirical study where the geometaphors' pairs have been composed obtaining different spatial configurations. Subjects partecipating to the survey were asked to put in relation such spatial compositions with textual labels related to the topological relationships defined by the OpenGIS standard [6].

The aim of the survey was to find out a satisfactory matching between visual compositions and topological relationships in order to define an interpretative model as precise as possible. Such work represents an important prerequisite for improving the quality of the interaction in visual query systems where visual compositions represent geometric objects and their relations.

3.1 The Subjects

We selected twenty participants among the students and the researchers of the University of Salerno. The subjects were males and females between the ages of 20 and 50; all the participants were usual users of PCs and were familiar with GIS technology and the notion of topological relationship. The test was conducted in a quiet classroom after courses. A lap-top computer was used for displaying the visual compositions, which were built using a custom application implemented for the survey. In order to record the interaction on the screen and the subjects' talking aloud we used the Camtasia Studio™ software by Techsmith ™. The survey team was present at the test and included a test assistant and an observer/note-taker. We wrote a script that the test assistant read to each participant in order to provide a common background.

3.2 The Task

Basically, we asked to such subjects to provide a *resemblance value* between pairs of geometaphors composed in a 3D abstract environment and textual labels expressing topological relationships. Figure 2 represents the pairs of geometaphors and the visual compositions taken into account; each composition corresponds to a different valid Egenhofer's 9-intersection matrix [6].

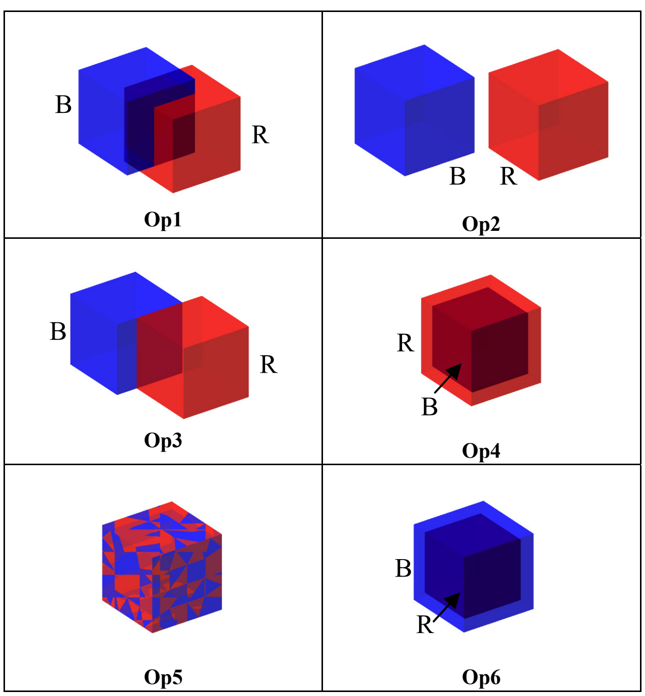

Figure 2. Visual compositions generated by the Egenhofer's 9-intersection matrix

As discussed in [8], the representation of 3D objects on a 2D plane benefits from the implementation of a number of pictorial cues (e.g., perspective, shadow, etc.) that diminish the ambiguity of the recognition by the user.
Accordingly to that research, we used a number of cues for easying the task of recognizing the spatial relations between the geometaphors pairs. The cues used included color, semitransparency and motion (i.e. the ability for the user to change point of view in order to address occlusion issues).
It is important to point out that the order the geometaphors were selected and put into the scene was meaningful for the answer and that the test participants were enabled to distinguish the first selection from the latter. For the sake of the reader in Figure 2 the first selection is identified by the red color and labeled as *R* while the latter selection is identified by the blue color and labeled as *B*.
The topological relationships are defined according the OpenGIS standard [6] that represents one of the most widely used specifications and includes: *Equals*, *Disjoint*, *Touches*, *Within*, *Overlaps*, *Contains*, *Crosses* and *Intersects*.
The scale for the resemblance parameter was set from 0 to 10, where 0 was associated to the value *it does not correspond to the relationship* and 10 was associated to the value *it fully corresponds to the relationship*.

The survey results are described in the following subsection. Each visual composition is associated to a pie chart (see Figures 3-8) displaying the resemblance percentages resulting from the answers. Percentages are calculated by summing, for each relationship, the resemblance values submitted by all the subjects; the sum is then normalized, assigning 100% to the overall sum of all the resemblance values assigned by the subjects for all the labels.

3.3 The Survey Results

Concerning the *Op1* visual composition (Figure 3), three relationships, namely *Overlaps*, *Crosses* and *Intersects,* were considered the most meaningful by having respectively a *resemblance* value of 18%, 25% and 30%.

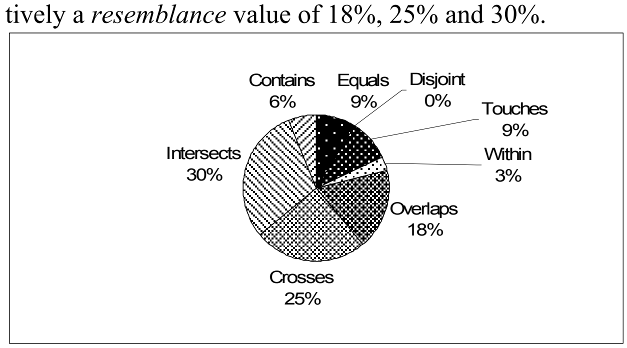

Figure 3. Subjects' interpretation of the visual composition *Op1*

The result implies that the subjects' mental model does not univocally associate the *Op1* operation with a specific relationship. An additional filter is needed in order to select a single interpretation from the resulting set. For obtaining such result we introduce three rules that reduce the most part of the ambiguity:

– *Rule 1*: the order the geographical objects have been selected is relevant (e.g., for the *Op4* composition only one of the following relations is true: *A Contains B* or *B Contains A*).
– *Rule 2*: the *Intersects* relationship has a lower priority in relation to the other relationships; *Intersects* is a relaxed relationship that can be defined also as *Not Disjoint*; in other words it can be associated to all those situations where all the other relationships defined above (with the exception of *Disjoint*) exist; in this work, when ambiguity situations exist, the higher priority relationship is applied.
– *Rule 3*: some topological relations make sense only for specific categories of objects (e.g., the Point-Point geometry pair accepts only the *Disjoint*, *Equals*, *Intersects* and *Overlaps* relations).

Applying such rules to the *Op1* visual composition we obtain a reduction of the ambiguity deriving from the subjects' answers.

In the case of the Point-Point (P-P) and Region-Region (R-R) geometry pairs then only the *Overlaps* and *Intersects* relationships belong both the Egenhofer's set and to the resemblance set (*Overlaps*, *Crosses* and *Intersects*). The *Overlaps* relationship has a priority greater than *Intersects*; therefore, applying Rule 2, the *Overlaps* relationship is selected.

In the case of the Line-Region (L-R), Point-Region (P-R) and Point-Line (P-L) pairs, only *Crosses* and *Intersects* belong both to the Egenhofer's set and to the resemblance set. According to Rule 2, the *Crosses* relationship is representative of *Op1* for such geometry pairs.

A more difficult case happens when the geometaphors represent two lines (L-L). In such situation both *Crosses* and *Overlaps* are admissible; the users, interacting with a system implementing our algorithm, will need to select the proper relationship at run-time, according to the specific situation.

As for the remaining geometry pairs, according to Rule 3, the *Intersects* relationship is the only choice that may be applied. All the results related to *Op1* are summarized in Table 2.

Figure 4 shows the resemblance result obtained for the *Op2* operation. The most significant percentage is represented by the *Disjoint* relationship (88%); a much smaller value (12%) is associated to the textual label identifying the *Equals* relationship.

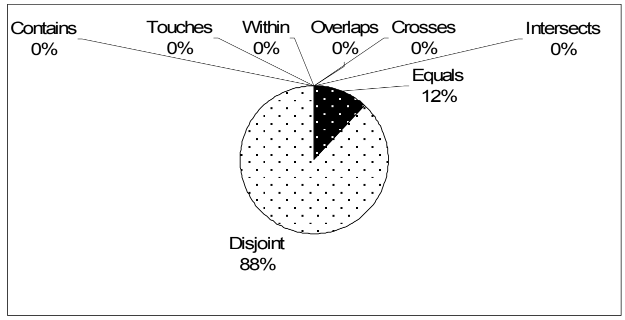

Figure 4. Subjects' interpretation of the visual composition *Op2*

Therefore the *Op2* operation has been associated to the *Disjoint* relationship for any pair built with the geometry types Point, Line and Region.

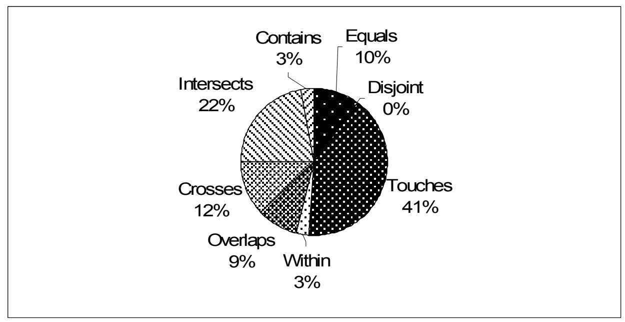

Figure 5. Subjects' interpretation of the visual composition *Op3*

The results for the *Op3* visual composition are summarized in Figure 5. Two relationships are particularly important: *Touches*, which gains the 41% of the sample, and *Intersects* which is represented by the 22% of the sample. According to Rule 2, we have associated the *Touches* relationship to any pair of geometries, with the exception of the Point-Point (P-P) pair; given that *Touches* is not defined for such category of objects (i.e. points), according to Rule 3 we have decided to apply the *Intersects* relationship.

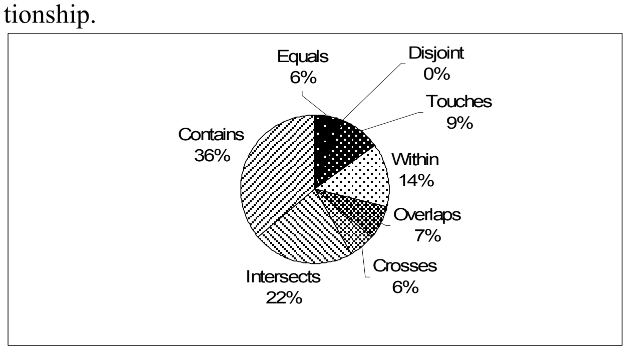

Figure 6. Subjects' interpretation of the visual composition *Op4*

As for the *Op4* visual composition (Figure 6), the most important relationship is *Contains*, but significant results were obtained also for *Intersects* and *Within*. According to Rule 2, we have associated the *Contains* relationship for any pair of geometries that permits this relationship (i.e. all pairs where the first geometry has a greater dimension than the second one: (R-R), (R-L), (R-P), (L-L) and (L-P)). In the other cases we have applied the *Intersects* relationship that represents the second subjects' choice. According to Rule 1, the *Within* relationship has not been considered; such relation seems to be related to a wrong interpretation by the subjects of the geometaphors' selection order.

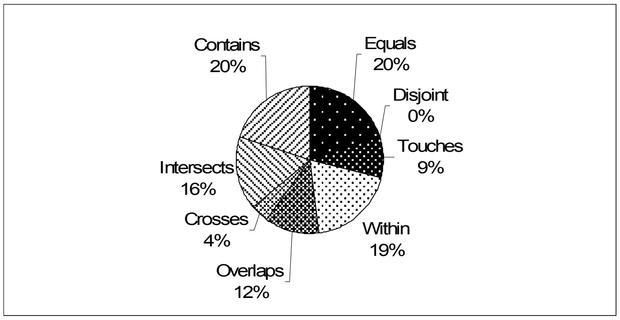

Figure 7. Subjects' interpretation of the visual composition *Op5*

Figure 7 shows the results for the *Op5* operation: the *Equals*, *Within* and *Contains* relationships result as admissible hypotheses for the interpretation (i.e. their resemblance value varies from 19% to 20%). The interpretative model discriminates the proper relation on the basis of the geometry dimension (Rule 3). In particular:

- if both the geometries have the same dimension (e.g., Point-Point) the model returns an *Equals* relationship;
- if the dimension of the first geometry is strictly bigger than the second one the model returns a *Contains* relationship;
- if the dimension of the first geometry is strictly than the second one the model returns a *Within* relationship.

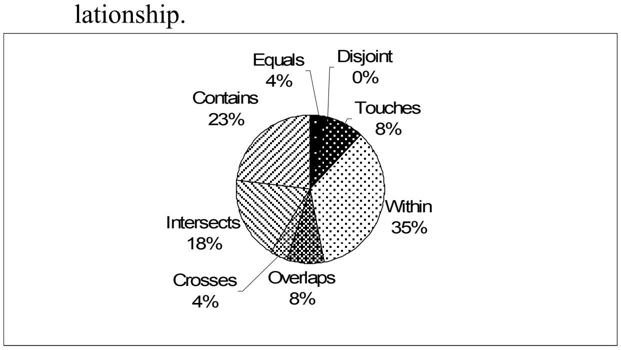

Figure 8. Subjects' interpretation of the visual composition *Op6*

The last visual composition considered is *Op6* (Figure 8). Such visual composition is very similar to *Op4*; the only difference is related to the selection order of the operands. The consequence is that the results obtained represent a mirror of those one obtained for *Op6*. In fact, we note a significant predominance of the *Within* relationship, followed by *Contains* and *Intersects*.

According to Rule 2, the *Within* relationship is applied when the first geometry has an equal or smaller dimension than the second one. There is an exception to this rule when both the geometries belong to the type Points; in such situation *Intersects* is applied. Besides, *Intersects* is applied when the first geometry has a greater dimension than the second one.

According to Rule 1, the *Contains* relationship has not been considered because it seems related to a wrong interpretation by the subjects of the geometaphors' selection order.

In conclusion, Table 2 summarizes the bindings among the different geometry pairs, visual compositions and labels describing spatial relationships.

Table 2. Summarization of the bindings resulting from the survey

	Op1	**Op2**	**Op3**	**Op4**	**Op5**	**Op6**
R/R	**Overlaps**	**Disjoint**	**Touches**	**Contains**	**Equals**	**Within**
R/L	**Intersects**	**Disjoint**	**Touches**	**Contains**	**Contains**	**Intersects**
R/P	**Intersects**	**Disjoint**	**Touches**	**Contains**	**Contains**	**Intersects**
L/R	**Crosses**	**Disjoint**	**Touches**	**Intersects**	**Within**	**Within**
L/L	**Overlaps/ Crosses**	**Disjoint**	**Touches**	**Contains**	**Equals**	**Within**
L/P	**Intersects**	**Disjoint**	**Touches**	**Contains**	**Contains**	**Intersects**
P/R	**Crosses**	**Disjoint**	**Touches**	**Intersects**	**Within**	**Within**
P/L	**Crosses**	**Disjoint**	**Touches**	**Intersects**	**Within**	**Within**
P/P	**Overlaps**	**Disjoint**	**Intersects**	**Intersects**	**Equals**	**Intersects**

3.4 Using Different Shapes for Representing Geometry Types

Some participants told us that further information about geometries (e.g., using different shapes for each geometry type) would have been useful in order to get more precise bindings between visual compositions and topological relationships. Because of that, we organized a new test where geometries were represented by three different shapes, as shown in Figure 9.

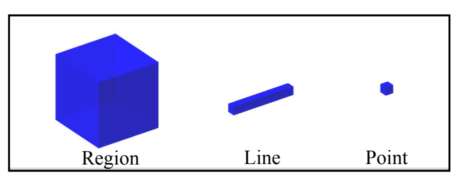

Figure 9. An alternative approach for representing different geometries

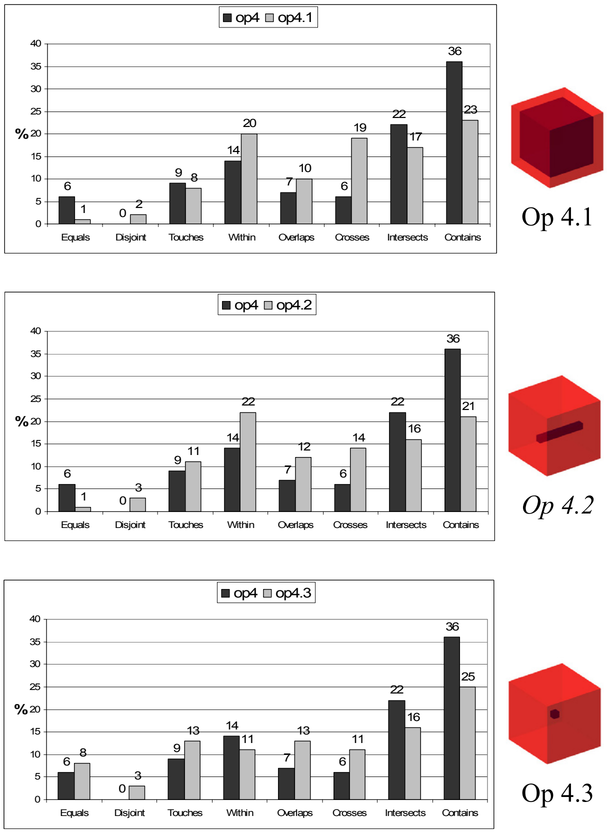

Figure 10. Comparison of the subjects' intepretation for the visual compositions *Op4*, *Op4.1*, *Op4.2* and *Op4.3*

Results derived from the new test don't highlight significant improvements. In fact, the resulting resemblance diagrams are similar to the previous ones deriving from the unified representation. In some cases, the new results have shown a wider dispersion of data. Figure 10 shows three different visual compositions (*Op 4.1*, *Op 4.2* and *Op 4.3*) depicting a shape (the blue object) representing either a Region, a Line or a Point; such geometry is disposed within another geometry (the red object) representing a Region. The different representations were shown in parallel to the subjects, asking them to associate the visual compositions to the textual labels. The results show that the choice of increasing the number of representations augments the confusion of the subjects. In all the situations, compared with *Op4* (see Figure 10), there is a higher number of labels that have been associated to significant values, but with a lower variance among them. We may infer from such results that a unified representation doesn't vary significantly the subjects' interpretation of a certain visual composition and in some cases may lead to better results in terms of convergence towards a unique association between representation and labels.

4. Conclusion

Concluding, this work has considered from a user centered perspective the association between visual representations and a complete set of topological relationships compliant with the OpenGIS standard. The results obtained represent a significant contribution for the implementation of visual query systems taking into account as a primary requisite the users' mental model, in order to augment the overall usability of the systems themselves.

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Visual Access to City's Websites

Robert Laurini

Abstract. At the inception of the Internet, the websites were only textual. Now, with the graphic possibilities, more and more websites integrate visual aspects, essentially to access and to visualize information. The goal of this paper is to examine the use of visual techniques in city's websites. More particularly, we will examine the metaphor of virtual cities, hypermaps and geography-based accesses, news magazines, etc. In the conclusion, we try to examine the trends in this domain.

Key-words: Visual Access, Websites, Cities, Metaphors

I. Introduction

Nowadays, practically all cities have a website. The objective of this paper is not to make a detailed study about their contents, but to examine their organization from a visual point of view. By visual, we mean to examine the quality of graphics, the metaphors used and their efficiency. First, let us give the following definitions:

- a home-page is the first page of a website (the URL),
- a sitemap is the entry structure to access all pages lying into a website,
- whereas a portal allows the accessing to pages, which are considered as the more important for the administrators (highlights).

Usually, the portal is located into the home-page. However, in multiple language websites, or in user profiles-oriented sites, the home-page often acts as a profile selector so giving access to different sub-websites.

Concerning the use of metaphors for website design (Van Duyne et al. (2003)), let us first of all mention that the two words portal and sitemap evoke metaphors: portal meaning the entrance gate and sitemap the cartography of the website. We can summarize the situation as follows:

	Portals	Sitemaps
Existence	Always	Not always
Contents	Salient items	Exhaustive or quasi exhaustive table of contents
Use of metaphors	Possible	Possible

Tab 1. Portals and sitemaps

All Internet examples were taken in January 2006.

In this paper we will examine the various types of visual accesses in city websites, and more precisely the geography-based accesses. But before, we will very rapidly study text-only websites.

II. Main metaphors for cities

The first aspect to mention is that some sites use neither metaphor nor visual tools: their presentation is only made with words. In this category, we can distinguish text-only portals and textual portals with some pictorial decorations.

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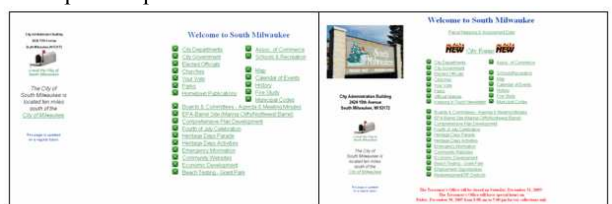
A. *Text-only portals, or with light pictorial decorations*

Text-only portals presently are very rare, although there were the majority in the 90'ies. Take for instance the site of the city of South Milwaukee, WI (See http://www.ci.south-milwaukee.wi.us/). Several years ago, the portal was practical text-only, with a unique icon for the letterbox. Few years after, the style is quite similar, and only a picture of the city entry sign was added, emphasizing the idea of a portal. See Figures 1 for an example.

Anyhow, even it those portals were common in the past, they were very functional, and were a sort of preliminary step to reach present portals.



(a) As in June 2002 | (b) As in January 2006

Fig. 1. Example of a text-only website and its evolution http://www.ci.south-milwaukee.wi.us/.

Another aspect is the diversity of users. In order to target more precisely information to deliver, some cities have organized their websites by user profiles. An example is taken from the city of Richmond, Virginia (Figure 2a), offering different information according to the following text-only six profiles, businessmen, newcomer, resident, senior, visitor and young people in a text-only list. The Italian city of Salerno offers a dozen of profiles (http://www .comune.salerno.it); for instance profiles are added such as handicapped, immigrant, sportive and student.

B. *Visual menu*

Verbal menus are more and more replaced by visual menus. Figure 2b gives the example of a homepage including several icons for Edinburgh, Scotland as it was in 2002. Now the portal is replaced by a new one, but we can still see the same icons, illustrating a sort of historical continuity.

(a) Richmond, Virginia, USA | (b) Edinburgh, Scotland, in 2002

Fig. 2. Various kinds of portals. (a) A profile-oriented portal from the city of Richmond, Virginia, http://www.ci.richmond.va.us (b) An extract of the Edinburgh visual portal in 2002, http://www.edinburgh.gov.uk.

C. *Virtual city*

In another direction, there exist portals based on a sort of virtual city. An example is coming from Trenton, New

Jersey as illustrated in Figure 3a. The more famous example is the homepage of Bologna, Italy (See Figure 3b as it was several years ago). As pictograms such as trains or theatres are meaningful, the interpretation of some buildings can be misleading. To correct this drawback, some words are added such as "ristorante", "shop" or "lex" (it is interesting to notice that in order to be understood by anyone, some "international words were selected", one of them is in Italian (ristorante), a second in English (shop) and the last in Latin (lex)). However, we were intrigued by the spherical building located in the middle: it is the entry point for religious information; indeed a church pictogram should lead to Christian information, not valid for other religions: so the search for a very generic icon promotes the creation of pictograms the meaning of which is not clear. To conclude this paragraph, let us say that this approach is very interesting from a visual point of view, but presents some difficulties of interpretation.

Fig. 3. Examples of virtual cities. (a) Trenton, New Jersey http://www.ci.trenton.nj.us/. (b) Bologna http://www.comune.bologna.it as it was in 2002.

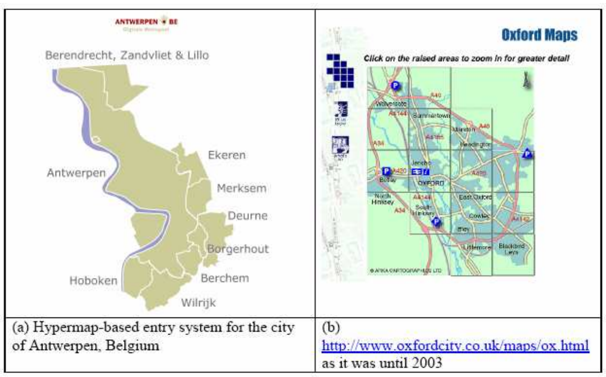


Fig. 4. Example of hypermap-based city portals. (a) Antwerp, Belgium http://www.antwerpen.be/MIDA/. (b) Oxford, UK http://www.oxfordcity.co.uk/maps/ox.html.

But this metaphor is not only used for cities, it can be used for any kind of organization. In the fourth section, we will examine some other examples of the metaphor.

D. Hypermaps and geographic-based access

A very interesting way of organizing geographic information is to use hypermaps (Laurini-Milleret-Raffort, 1990), also called clickable maps. Figure 4a is a good example from the city of Antwerpen, Belgium. Another example is given Figure 4b for a gridded map of Oxford,UK.

In Venice, Italy, an original entry system is provided through aerial photos (Figure 5a), whereas some accesses to symbolized shopping streets (Figure 5b) are also possible through French Yellow Pages. See also Figure 6 in Paris, France, giving another interesting access based on the approximate location of very important streets, with the Seine river as a reference map.

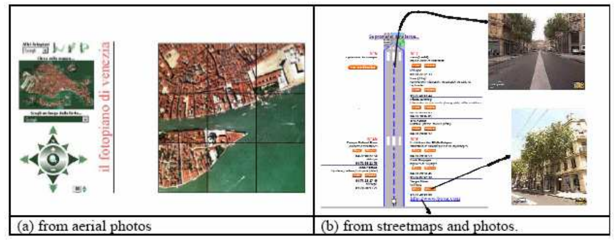


Fig. 5. Some portals based on geographic locations. (a) Portal of Venice, Italy based on aerial photos http://www.comune.venezia.it. (b) Excerpt of “shopping streets” from the Visiocity systems http://www.mappyvisiocity.com/ for the French Yellow Pages.

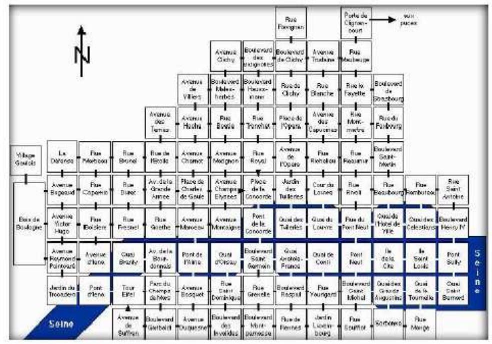


Fig. 6. Another interesting example to access to Paris information from streets http://www.umsl.edu/~moosproj/carte.html.

E. News magazines

Some cities organize their website as a news magazine: the home-page is looking as a cover giving a nice picture of the city (Figure 7). It is overall interesting that there is now a sort of convergence between the presentation of those two media, namely news magazine cover and website portal, applying same corporate design and graphic semiology.

Fig. 7. Examples of home-pages looking like news magazine covers in January 2006. (a) Lynchburg, VA, http://www.ci.lynchburg.va.us. (b) Miami, FL http://www.ci.miami.fl.us

F. Visual portals for visual portals

In some places, there exist portals of portals. By this expression, we mean that, instead of giving a textual list, or a set of icons, an interesting idea is directly to include a thumbnail of the portal the user desires to go.

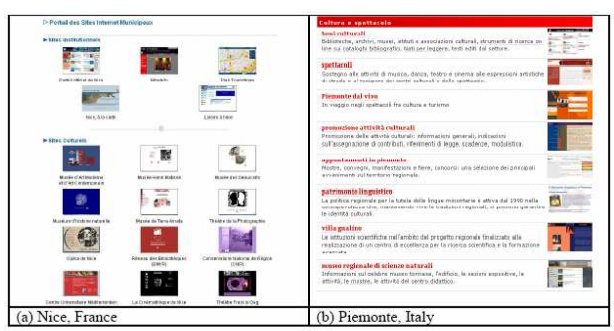


Fig. 8. Examples of portals for portals made of thumbnails. (a) Nice, France http://www.nice.fr/mairie_nice_1489.html. (b) Piemonte Region, Italy http://www.regione.piemonte.it/sez_tem/cult_spett/cult_spett.htm.

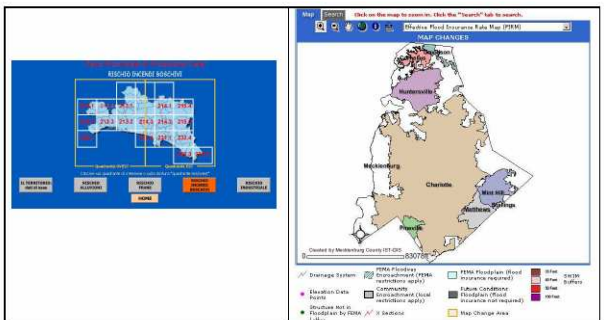
See two examples in Figure 8, the first from the French city of Nice, the second of Region Piemonte in Italy.

III. CARTOGRAPHY FOR CITIZENS

Internet mapping for the residents is something common. Numerous cities allow the city-dwellers some mapping capabilities: indeed some kind of GIS is provided. In this section, we will examine only two aspects, risk mapping and planning consultation.

A. *Risk mapping*

For instance, let us examine two examples. In the Italian city of Genoa (Figure 9a), the inhabitants must first give the zone, and then, they will get detailed information: in other words location → type of risks. Whereas in Charlotte (Figure 10b), NC, this is the contrary, the inhabitants must give first the type of risk, and then they will get a map, i.e. Type of risk → location.



(a) Genua, Italy | (b) Charlotte, NC, USA

Fig. 9. Examples of cartography through Internet. (a) Genoa, Italy http://cartogis.provincia.genova.it/cartogis/ppc/rischincbos.htm. (b) Charlotte, NC, USA, http://maps.co.mecklenburg.nc.us/website/floodzone/map.aspx.

B. *Planning consultation*

Another interesting aspect is the participation of citizens for urban planning. Regarding land use plans or development plans, in all countries, there is some phase of public participation. In other words, the planning officers, together with elected politicians ask the city-dwellers their opinions regarding the future of their city. For that, usually some planning maps are proposed through Internet. But the main problem is how to organize the participation? Several trials (Craig et al. (2002) were made under the name of PPGIS (Public Participation GIS). One of the important aspects is to allow people giving their opinion about the projects. For that a solution could be using argumaps. Proposed by Rinner 1999, those argument maps are made to help the users to position arguments on a map. Figure 10 gives examples, for instance by using markers such as pins, flags or smileys. Typically three types of markers are interested to position pro-opinions, against-opinions and official arguments. Imagine that the city's officers want to construct a new bridge over a river; official arguments will explain the necessity of building such a bridge; the citizens agreeing this project can give or explain a positive opinion (pro-opinion), whereas the opponents can detail a negative opinion (against-opinion). At the end of the consultation, hotspots can be easily detected, and an easy synthesis can be made, based on location.

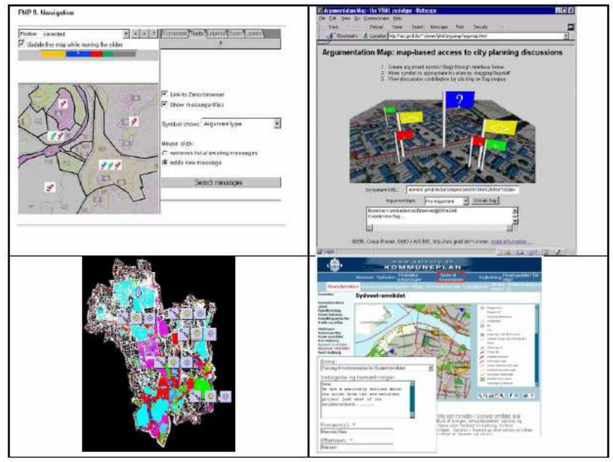
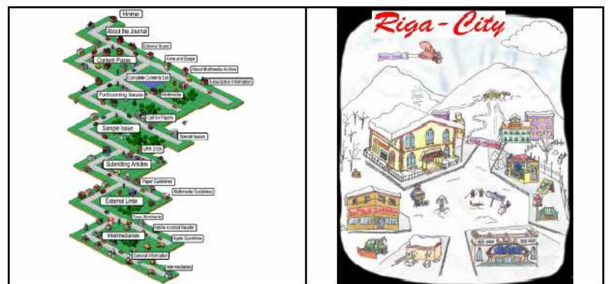


Fig. 10. Cartography of arguments, examples of graphic semiology (pins, flags, smileys) and an application in a Danish city http://www.detaktiveaalborgkort.dk. The argumaps based on pins and flags are issued from Rinner 1999, the third based on smileys is from Laurini (2001).



(a) A virtual land development map as a transition between a map, a graph layout and a virtual city. | (b) The Rigatoni band using the city metaphor to present its activities (as in 2002).

Fig. 11. Virtual cities. (a) A virtual land development map as a transition between a map, a graph layout and a virtual city http://www.ijrr.org/images/sitemap.gif. (b) The Rigatoni band using the city metaphor to present its activities (as in 2002) http://www.rigatoni.ch/

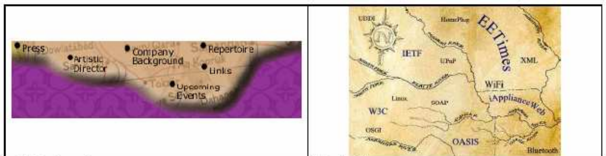
IV. VIRTUAL CITY AS A METAPHOR FOR WEBSITE DESIGN

In another direction, the metaphor of a virtual city can also be used to structure websites not only for cities, but also for other organizations (Dieberger A., et al. (1998)). Let us show two examples. In the first one (Figure 11a), a scientific journal uses this metaphor to present its sitemap, whereas in the second (Figure 11b) a Swiss band named Rigatoni uses again this metaphor for its portal. Figure 12 illustrates another interesting case of a virtual city (http://www.tipus.uniroma3.it/Master/lezioni/AID/VirT.jpg). Here the virtual city acts as a fake reference map to access services.

Fig. 12. A city map acting as a virtual town to organize services. http://www.tipus.uniroma3.it/Master/lezioni/AID/VirT.jpg

A. *Map metaphor (tendermaps)*

The map metaphor was created in 1654 by Madame de Scudéry with her tendermap (carte du tendre) in which she published an allegorical map of love and desire. Figure 13 depicts two examples of website using this metaphor. The first one (Figure 13a) presents a small map with some "cities" corresponding to entry points into a website for a dancing company. The second (Figure 13b) reuses an existing map, in which some "locations" are superimposed. Let us call the first one as a real tendermap, and the second a fake tendermap.



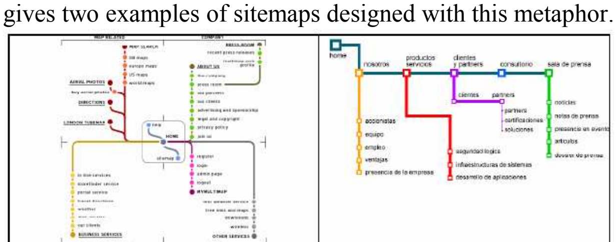
(a) Real tendermap | (b) A fake tendermap

Fig. 13. Some tendermaps, that is maps in which locations depict accesses to information or services. (a) A dancing company http://www.silkroaddance.com/. (b) A fake tendermap, reusing a real existing map http://www.netcentriccommunity.com/iAppliance/WebMap.jpg.

B. *Metro-line metaphor*

Another interesting metaphor is the metro-line metaphor which was created by Sandvad et al. (2001). Starting from the maps for metro-lines, they use this metaphor for representing several paths for visiting websites.

Indeed, in some cases, instead of proposing the access to isolated pages, it looks more important to propose structured routes to access information: the metro-line map metaphor can be a good metaphor in the context where pages are organized along paths: the site administrators propose several walk-through tours in lieu of sitemap. Figure 14 gives two examples of sitemaps designed with this metaphor.



(a) Sitemap of a mapping company (Multimap). | (b) Sitemap of a Spanish software house.

Fig. 14. Sitemaps designed with the metro line metaphor. (a) http://www.multimap.com /images/ps/misc/sitemap.gif, (b) http://www.germinus.com /mapa.htm.

V. CONCLUSIONS

Designing visual access to website has become a research domain per se in which some metaphors seem to structure the websites. In this paper, the structuring and the visual accessing to local authorities' websites have unveiled several tendencies.

Geography-based metaphors are also a source of inspiration for designing portals and sitemaps. The tendermaps are one of them, but the big difficulty is to update them regularly, i.e. adding or removing automatically some elements into the map, still keeping high aesthetic quality levels.

The Bologna-type virtual city experience of a totally visual access has shown the difficulty of understanding some icons. Now, it appears that a mixture of icons and letters seem to be a nice compromise. The use of photos instead of icons appears also as an interesting research direction. Apparently, the dominant metaphor in cities seems to be the news magazine metaphor. It is also interesting to see that now, in some news magazines the website metaphor is also in use: in other words those metaphors influence each other, and some cross-fertilization will certainly appear.

The metro-line map metaphor is interesting essentially when different paths can be defining into the website. The selection of "lines" and "stops" is still difficult, and a methodology must be defined based on decision rules: for instance in user-oriented portals with the metro-line metaphor, each line can correspond to a user type. Back in cities, a line can be defined for residents, a line for businessmen, a line for home-seekers, a line for handicapped people, and so on.

In local authorities, some other visual accesses can be defined. Examples in informative cartography for instance for risks, are good illustrations. For interactive cartography, visual techniques such as Rinner's argumaps are an interesting way for structuring public participation in urban planning.

To conclude this paper, let me say in the nearby future, some innovation will still continue to appear in designing visual access to websites, essentially because of the necessity to attract more people. Local authorities seem an interesting domain to study, not only because they are numerous, but also each of them tries to emphasize its own characteristics and culture: differently said, each of them shows or tries to show its own personality.

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Reactive and adaptive approaches in Learning Management Systems

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Abstract

This work derives from a series of considerations shared by the authors of this paper, which have risen about two different experiences at the University of Bologna and at the University of Trento. What pools the two experiences is the convergence of opinions regarding the development of e-learning in real-world academic settings. In particular, cooperative tools may result in more specialized learning environments responding to the effective user needs.

1. Introduction

In this paper we are going to describe cooperation aspects inherent to two different systems:
a) a Web-based Learning Management System based on the idea of learning community;
b) a multi-agent Web-based hybrid recommender system based on a collaborative bookmark management system approach using semantic capabilities.

The shared hypothesis is considering academic learning processes such as systemic and cooperative processes so that, our systems represent two different ways to provide cooperative learning. In the first case, cooperation is achieved by using both an architectural approach and communication reactive tools. In the second case, cooperation is realized through adaptive approaches. Both reactive and adaptive approaches can be useful and complementary in real-world learning environments.

In our opinion, the quality of an academic institution is strongly related to the quality of its educational processes which are based, in their turn, on the complex relationship between professional competencies of researchers/teachers and used teaching methods. In good and evil, the actual processes occurring in an academic institution are based on the quality of this relationship. Studying in a high-quality educational institution means learning from an intellectual environment where knowledge transfer (education) and creation (research) are interwoven, perceptible and "internalizable" by students. In marketing terminology, this could be considered as the "brand" of an academic institution.

It is easy to observe how the systemic intrinsic nature of these processes requires its own governance. The core of these rules is the direct relation between researchers/teachers and their students. Such an interpersonal relation enforces the vocation for universities to be places intrinsically opened to discussion and circulation of ideas and opinions. Indeed, freedom in research and teaching activities are two ethical pillars of these institutions. E-learning applications in academic environments introduce into the system a set of changes that could undermine this relation.

The creation of e-learning systems, or specialized components of these systems, we are going to present in the following pages have the same architectural structuring, though they are coming from different experiences.

This common-background architecture is based on a number of general assumptions.

1) User-centered design. The systems are built with and around users' requirements, applying agile and evolutionary prototyping software techniques. The software developing cycle and its architectural implications are derived from the needs of the actors involved in the process. We spent many hours and many resources in going around teachers' rooms and students' classes, in order to look at people needs and real system usage. Such a system, therefore, was not a software architect's conception; it has been substantially driven by users' suggestions.
2) Teaching methods vary depending on the disciplinary domain of the courses and on the specific user's preferences. In our opinion, a software system should not overwhelm the way people act by simplifying a complex relationship like the training process.
3) The usage of a LMS should not be mandatory. In a real situation, there are people not attracted by e-learning technologies, and they will therefore avoid using the system. These subjects could not be labeled as "bad teachers".
4) Every constraint on the nature/type of learning objects inside the system is needlessly restrictive and counter-productive. This does not mean that learning objects which are built using standards (like SCORM) are not usable in the system, but we cannot imagine that this is a necessary condition.

Imposing such a condition means to move users away.

5) There must be no filters between a teacher and his/her students. A teacher should not need for an "intermediary" in order to interact with his/her students through ICTs.
6) Modern Web-based learning environments must be able to dynamically respond to the different and personal students' learning styles, goals, knowledge backgrounds and abilities, in order to facilitate a student-based approach to the provided educational material. In getting to this task, tools for personalized distribution of educational resources have emerged as an important technology to *adapt* and personalize e-learning system on the basis of the effective user needs and modifiable user behaviour and interests [1].

The remain part of the paper describes in more detail our two experiences. In particular, we will introduce the making-of an e-learning platform based on the "virtual communities" metaphor and the necessity to extend our approach by providing adaptive services in academic frameworks. Some final considerations will conclude the paper.

2. E_learning in academic frameworks

The rapidly increasing expansion of e-learning systems has brought, in some cases, towards undervaluation of system effects on learning processes.
The problem derives from the fact that, in order to experiment innovative solutions, researchers/teachers knowledge transformation into some electronic artefacts (Learning objects) must be provided. Consequence of such a requirement, should be, for some authors, the redefinition of the relation with students, through an intermediation made by some professional role (multimedia developer, learning objects designer, content producer, tutor, etc.).
Though some situations exist where it is necessary to rely on professionals in order to innovate the educational process, it is quite easy to claim that this model, whenever it is spplied on an entire academic institution, is:

- A losing process: the transfer of knowledge from the teacher to the professional could have many disadvantages, last but not least the material is produced by a person that is expert with technologies and (perhaps) educational processes, but it is not necessarily expert about the specific topic he is helping producing the learning objects, and therefore a loss of quality is almost inevitable.
- Economically unsustainable and/or humanly unfeasible: it is not possible taking advantages by professional multimedia developers that are simply typists, in order to achieve quality in the learning objects. Producing electronic learning objects at a high quality level, imlies that we should have an expert for every teacher, available also when topics and courses change, or we should have a "super-expert" able to transform in learning objects (where students learn), topics coming from different fields or teachers. There is no enough time and money to pay such a huge number of experts that help all the teachers in a University, and it is not possible to find people so prepared to be able to help teachers in domains that range from fuzzy logic to labour psychology, from telecommunication to economic geography. It is impossible to find an expert in the field of the teacher able to comprehend and transmit the topic like the teacher him/herself.
- Demotivating: every teacher is able to teach with her own method, and will probably have problems in recognizing him/herself about something produced by others.

Based on this assumption, the software should behave like an amplifier of the communication space between teachers, students, tutors, and assistants. It will happen for sure that some colleagues will use the system under its capabilities, but this is largely better than nothing. The intermediation of professionals should be, in our opinion, limited to technical consultancy and the production of learning objects should be a process strongly coordinated and managed by the teacher. Whenever it's applied, this process is mostly perceived like a way of transferring a boring activity from the teacher to a typist.
In our opinion, some LMSs demonstrate limitations and contradictions, assigning fixed roles to subjects participating to educational processes. These roles are normally included in a vision of the training process that we could define as a "transfer model": the teacher (and to a lesser extend, the tutor) owns the knowledge which is transferred to students via a sequence of lectures. The student learns from references or books while guided by the teacher's lecture.
This model, once reified in the software, represents a crystallization of the original model, only apparently more participatory (students have to do some actions in the virtual), but it substantially enforces the power of one side (teachers, in fact, can use the software with higher privileges than students). Consequently, many non-traditional learning and teaching approaches (like Problem based learning, Learning by doing, Collaborative learning, Learning by projects, etc.), are obstructed by the software itself, instead of being facilitated. Moreover, if we consider technical courses, where more practical skills must be acquired and demonstrated, students have very often to develop a project. It could be an individual work, but it is more frequently a joint effort among students of a group. It would be more productive letting students work together also by using collaborative tools that allow them to interact among themselves and with teachers / tutors, but this kind of freedom (with all the administrative problems behind the scenes) is very often extraneous to a typical e-learning system.
The academic teaching has peculiar features: we don't aim to the mere transfer of notions, but to changing process that motivates the students critical point of view. Moreover the academic system life is organised

so that a consistent part of the work is done in a collective way.

Then, the metaphor of virtual communities becomes a natural way to extend what is often meant to be a real community to the electronic communication universe.

Providing cooperative virtual spaces (Virtual Communities) as a tool improving teaching/learning processes through communication improvement among actors of didactical processes, falls on work organisation, in particular:

a) most of electronic communication is written and it takes a longer period than traditional lectures-model activities

b) teacher-to-students relation cardinality is 1-to-n on the lectures model, while it is about n2 within cooperative ones, where n is the numbers of participants. Once again such models have an higher cost.

a) and b) points could be trade off by introducing automatic procedures like software agents so as They can make more efficacious and effective communication processes. In other words, it's suitable that a software system, potentially capable of being adapted to users needs and, can be used in case of e-learning applications applied within a university context.

There is a wide literature about the possibility to provide the software systems with adaptive mechanisms which allow the systems themselves to personalize their behavior, according to the users needs [7]. An initial classification of these systems is made by the distinction between properly said user-adaptive systems (the adaptive mechanisms are completely automatic) and user-adaptable systems (the adaptive mechanisms are derived by user choices) [16]. In this first kind, the system must have a data structure for every user who interacts with the system and in this structure the history of the interaction must be condensed in a shape (behavioral model) useful to the system to implement its strategies. This data structures are known in literature as User Models (UM) [10]. A UM is a data structure which gathers information on system-user interactions. Typically, the UMs are obtained on the basis of the knowledge about: interests and aims of the user [11], competences about the use or the contents of the system, history of the interaction of the user with the system. In [16] is reported a list of about sixteen classes of data sources about the user, generally exploited in UMs building. The unprocessed datum itself can not be immediately used in the adaptive processes of a system. The interpretation o such data is necessary in order to change them in an input source for the adaptation processes of the system. It is to say that the variability is abstracted through formal processes of generalizations known as stereotypes [15]. Formally a stereotype is a structure of generalization which describes different characteristics of an hypothetic user. Any characteristic is associated to a trigger. The unprocessed data of a user, abstracted through this interpretation, builds the UM of the user for the system.

The literature indicates three basic steps to prepare the development of an adaptive system: the first refers to the methodology used to obtain the UM; the second step, consequently to the chosen methodology, is about the type of data which have to be classified and stored [5]. Finally, the third step regards the personalized presentation for the information, which is depending on the goal of the system. The personalization occurs with different paths in texts, images, lexicon and in the User Interface as a whole. It can also occur by following rules of ubiquitary adaptivity for the presentation on different platforms and hardware systems.

On the next section we are going to describe the making-of an e-learning platform based on the "Virtual Communities" metaphor. In such a system many several services, provided to the users in order to support teaching/learning processes are exclusively reactive.

Through the experience with such a system as well as with a previous one, based, in its turn, on the "Course" metaphor, we have been convinced about the necessity to extend our approach by providing adaptive services (as it will be detailed in Section 4).

3. Online Community as a metaphor of learning space

In the history of the sociological thought, the label "*community*" has been used in several ways, in order to point out a variety of social phenomenons. Nevertheless, right in the difficulty found for the definition of the concept of "community", we find the first aspect that unifies the "*real*" and the "virtual" concepts . Usually, in the sociological literature, the concept of *community* is considered in as opposed to the concept of *society*, and the separation line of the two social structures is marked by the degrees of freedom of the individuals. In fact, in a *community* it is possible to observe a greater quantity of ties (both in intensity and extension) than in a society. In return, individuals get cohesion, safety and solidarity. *Virtual communities* [4,8,9,12,13,14,17] are something else in comparison with the concept of community as it's meant in the classics. Their use in a formative environment is further different. For example, the absence of anonymity, a typical aspect of these communication spaces, produces substantial effects on the dynamics of virtual relations. These aspects will not be further discussed, but it's important for us to stress that the software was built in order to virtualize real processes that happen in real communities.

As we already anticipated, traditional LMSs centred their architecture on the "course", conceived as a virtual meeting space between teacher and student. So doing, these systems isolate the moment notions are delivered in the environment, including technological settings where the contents are delivered. In order to eliminate this problem, we can proceed in two ways. First, we can imagine a LMS as a component of the whole information system of the academic institution. Second, we can adopt a more general metaphor than "*course*", which is able to supply communication tools to the various collective discussion ways that characterize the academic world. This unifying metaphor is represented by the *virtual community*, that could be subsequently specialized in *learning communities*, i.e., courses.

In Fig. 1 we quickly sketch the central part of the schema adopted for the realization of "Online Communities". Actually, the system is based on more than 300 classes, but all the main concepts are managed around People, Role, Community, Right, Duty and Permissions classes [6].

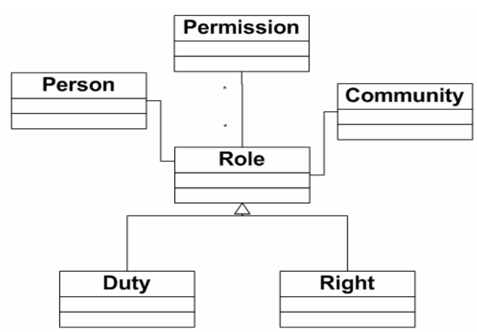

Figure 1. Core classes of "Online Communities"

Online Communities is exited from the experimentation phase in September 2005, after a long test phase (February - August 2005). Now it is used in extensive way at the Faculty of Economics and in the other six faculties of the University of Trento. In Figure 2 we show online accesses during the last year (an average of about 960 unique accesses per day).

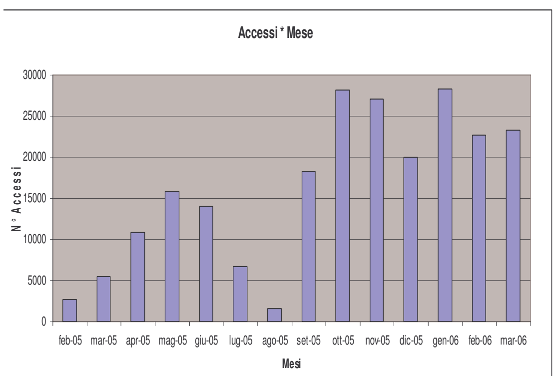

Figure 2. Online Communities accesses (from 2005-02-15 to 2006-03-23)

Table 1 shows the Online Communities we are using, while Table 2 reports roles of Online Community members.

Community	**N°**
Faculties	7
Other organizations	8
Departments	1
Laurea Degrees	71
Students	3
Work groups	51
Reserach groups	18
Courses	395
Total	**554**

Table 1. Online communities

Role	**N°**
Students	3920
Teachers	173
Tutors	18
Phd students	38
Guest	71
Staff	17
Total	**4237**

Table 2. Online community members

4. The InLinx (Intelligent Links) system

The research on e-learning and Web-based educational systems traditionally combines research interests and efforts from various fields, in order to tailor the growing amount of information, to the needs, goals, and tasks of the specific individual users. Semantic Web technologies may achieve improved adaptation and flexibility for users and new methods and types of courseware compliant with the Semantic Web vision. From another point of view, multi-agent systems working cooperatively over space and time are an important paradigm for building complex educational systems, dealing with open and dynamic environments. In this paragraph we describe both the collaboration and personalization aspects of InLinx, a multi-agent Web-based hybrid recommender system based on a collaborative bookmark management system approach using semantic capabilities. InLinx combines content analysis and the development of virtual clusters of users and of information sources that provides facilities to use the huge amount of digital information according to the student's personal requirements and interests. InLinx intends to gather different agent-based modules helping the user to classify domain specific information found in the Web and saved as bookmarks, to recommend these documents to other users with similar interests and to periodically notify new documents potentially interesting. The resources are processed to extract concepts (not just words) from the documents. Then, the classification, recommendation and sharing phases take advantage of the word senses to classify, retrieve and suggest documents with high semantic relevance with respect to the student and resource models [3].

Thanks to its bookmark sharing and recommendation facility, InLinx contributes to human collaborative works: it supports group collaboration among people involved in a work process, independently from time and space distance, and learns from positive and negative experience in group practice.

In its first version, InLinx has been designed as a tool to be used within a group of people sharing common interests or working domain. In origin, it was thought for a researcher group: researchers increasingly choose the Web as primary source where finding resources inherenting their research context. Typically, researchers need to be updated about publications of new papers in their field of interest (see InLinx paper recommendation tool) and they also need to share the most interesting resources with other individuals of the group who are interested in the same domain (see InLinx recommendation tool).

But InLinx can find application in any other context in which the group collaboration is a requisite, like a Web-based learning system [2]. Currently, we are working in order to improve the flexibility of InLinx adopting solutions for user modeling capable of capturing not only structural but also semantics information so that the system could be suitable for an open environment composed by heterogeneous users with miscellaneous interests.

On the system facet, InLinx responds to the request of widely accessible information services, available both to developers and users, and to the ubiquitous computing and communication challenge. In fact, traditional browser bookmarks lack of immediate portability and visibility from different user locations. InLinx allows to access to personal bookmark's repository from anywhere in every moment, without any software installation. You only need an Internet access point, being a PC as well a mobile device. So, access to your personal and shared data becomes independently of the platform on which the system is executing.

Moreover, InLinx deals with the issue of heterogeneity by combining a content-based and a collaborative approach. If by one hand a content-based approach allows to define and maintain an accurate user profile, on the other hand it has the limitation of dealing only with textual resources. Differently, in a collaborative approach, resources are recommended based on the rating of other users of the system with similar interests. As there is no analysis of the item content, collaborative filtering systems can deal with any kind of item, not only with textual content, and users can receive items with dissimilar content respect of those seen in the past.

5. Conclusion

This paper describes how academic institutions need integrated systems and technologies to guarantee the development of proficient e-learning in real-world academic settings. We argue a series of considerations derived from different experiences in two different frameworks and present their common characteristics. In particular:

- cooperative information systems,
- advanced technological tools that allow to manage educational institutions' policies,
- personalized services,

may result in a more specialized learning environment responding to the effective user needs and modifiable user behaviour and interests.

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Evaluating an E-learning Process

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Abstract

Today it is very important to adapt the formative method of the distance learning to the various situations of courses distribution and to your virtual class, so the e-learning platforms should have "easy–customizable" formative methods. Unfortunately nowadays many e-learning platforms don't have modifiable formative methods. The results is you have to use that process modifying your formative method approach.
So, in order to choice an e-learning platform you must have tools can help you to evaluate the formative method and understand if it is compatible with your approaches, and also to evaluate its flexibility. This paper defines a methodology and it describes a tool useful to compare e-learning platform from the point of view of the quantization of a formative method. This methodology is originally named GQM for e-learning platform and it is already adopted by the labs of the University "Federico II" in Naples and the "Politecnico di Torino".

1. Introduction

The tools that make you able to create the e-learning process should concur the personalization of the learning process for each virtual class. Building these processes involves often not only the choice of the materials to distribute (lessons, homework, test, etc) but the role and the participation of the actors involved (students, lurker tutors, secretarial, formation managers, etc), and the technological instruments useful to reach your objectives (computer network, PC clients and servers, platform).
For ages e-learning world believed that to define a formative method was sufficient to choose an e-learning platform, even with a good-looking interface and user-friendly for the students.
This has been demonstrated it is not only misleading but definitely wrong from the didactical point of view.
The most important thing is define a formative method for a virtual class, and be able to change it when necessary.
Many platforms nowadays are single-process and you must adapt yourself to it.
Absolutely this is not our target, in fact often you must adapt dynamically the formative method for the specific virtual courses.
In this environment you must use platform with a very customizable, and possibly reusable formative method, in fact if you find a good process you must be able to reuse it in another instance of the virtual course or in another course.
The main problem right now is to evaluate the formative method of an e-learning platform.
In this paper therefore we will face with the problem to select a methodology and a tool useful to evaluate and to compare the quality and the customizability of different formative methods of different platforms.
The methodology is already proposed in [1,2] and it apply the well-known GQM paradigm proposed by Vic Basili [3,4] to the e-learning platforms.
In the paper is structured as follows: in next section we will present the methodology, in section 3 is showed as is build a GQM instance to gather the information about the formative method. In section 4 the tool and the data analisis are proposed, and finally in the last section we state the conclusions and the on-going projects

2. The GQM paradigm

The Goal/Question/Metric (GQM) Paradigm is a mechanism that provides a framework for developing a metrics program [5,6,7]. It was developed at the University of Maryland as a mechanism for formalizing the tasks of characterization, planning, construction, analysis, learning and feedback. The GQM paradigm was developed for all types of studies, particularly

studies concerned with improvement issues. The paradigm does not provide specific goals but rather a framework for stating goals and refining them into questions to provide a specification for the data needed to help achieve the goals.
The GQM paradigm consists of three steps:

1. Generate a set of goals
2. Derive a set of questions
3. Develop a set of metrics

1 - Generate a set of goals based upon the needs of the evaluators - Determine what it is you want to evaluate.
2 - Derive a set of questions - The purpose of the questions is to quantify the goals as completely as possible.
3 - Develop a set of metrics and distributions that provide the information needed to answer the questions

3. The GQM for the formative process

In [8] we proposed the GQM methodology to evaluate some e-learning platforms. In [2,9] we defined methodology to compare open source e-learning platforms. The methodology is very flexible and it can be applied simply in order to get the point of strength and the points of weakness of a platform.
With the "clusters of goals" (macro-goals) [2] you can select a characteristic of a platform and compare it with the same characteristic of another platform.
One of these characteristics is the learning process, even if it is the most difficult to quantize.
To get this you have to select in the GQM for e-learning platforms the goals and the cluster about the formative method. In fact the GQM is a tree

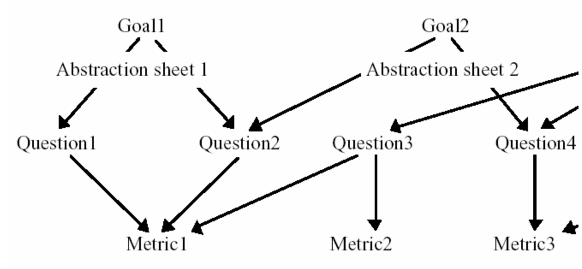


Figure 1 – The GQM Tree

in which the roots are the goals (or the clusters), and obviously if you select the clusters about the formative method you get a GQM about the formative method. This GQM can be improved including others goals about this argument taken from others clusters.

Using these criteria we considered only goals and clusters we developed in the GQM Plan [8]

4. Measuring the formative process using GQM: GQM_PF_Tool

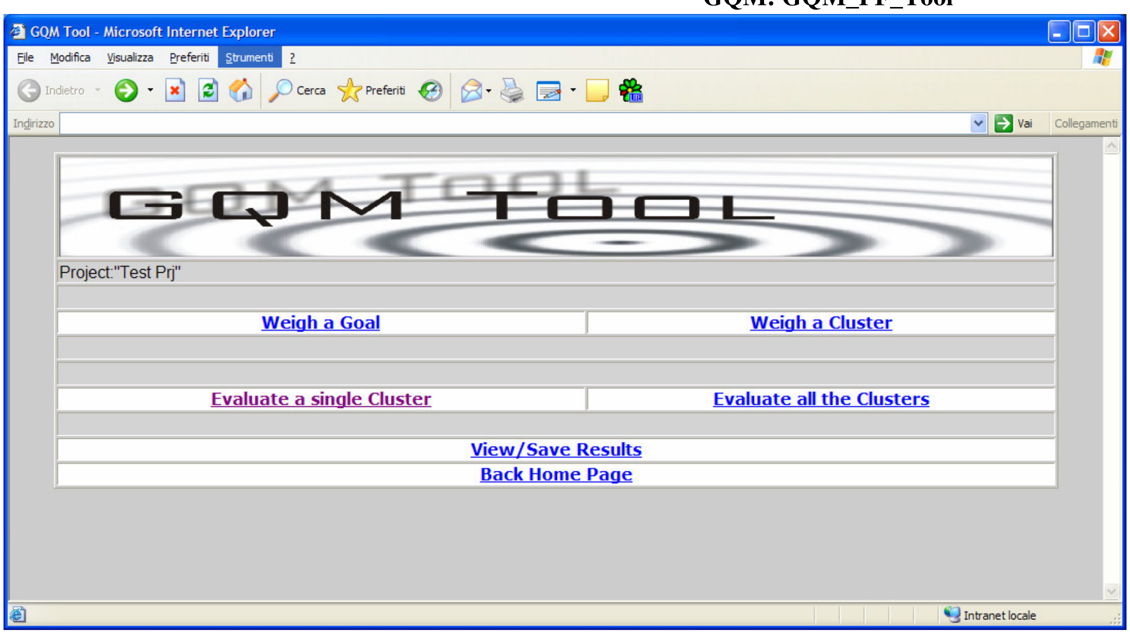


Figure 2 – The GQM Tool

In this section will be described the tool we

developed to perform our platform comparison.
Others tool was developed in the past [10] but no one had as target measuring and assess formative processes. Our tool is developed in PHP, so it is works in a client/server environment and it is reachable from internet with any web-browser.
It uses a MySQL DataBase, in wich are stored the data gathered during the evaluations and all the GQM structure (Cluster, Goals, QFs,…)
When you decide to create a new project or to modify an existing project the system permit to weight one or more cluster or to weight one or more single goals.
Weight a cluster, or a goal means give it's a value, a number (from 0 to 10). This number will be multiplied for the score got by that cluster, or that goal during the evaluation
In fact it is important to consider not all the chapters (cluster) of our evaluation have the same weight for the platform users, for example the SCORM capability can be vital if you will use courses made with this standard, but if you will use legacy courses this cluster will have less importance in the global score got by the platform.
After the process of weight the object useful for the evaluation you can perform the real evalution: the questions, organized in Goals and quality focuses [1] are proposed to the evaluator, that can choose the right metric from a list.
Having done the clusters evaluation you can view the results directly on the screen in a printable structure, in which are presented the clusters, the goals, the quality focuses and the questions with all the metrics associated with its weight; in fact every metric (possible answer) has a weight that is part of the score got in that goal or cluster.
In figure 3 you can see an example of the results of an evaluation.

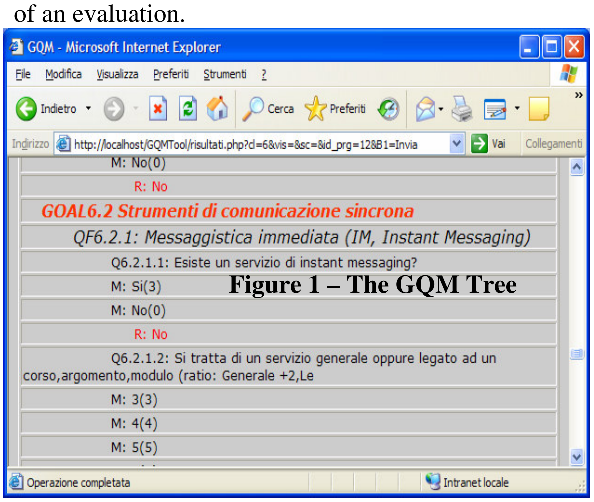
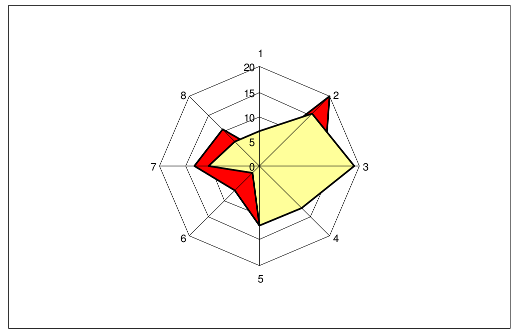


Figure 1 – The GQM Tree

Figure 3 – The results

Obviously it is possible to view all the GQM or just some selected cluster.
It is also possible to export the results in MS Excel format: in the spread text are proposed all the scores got in all the clusters and goals and also all the answers given previously with the weight associated to the chosen metric.
In figure 4 it is proposed an example of data analysis got with our tool.



5. Comparing open source e-learning platforms

In this section a platform comparison, from the formative method point of view, will be performed.
The platform under test for this evaluation are three well-known open source e-learning products: Dokeos, Moodle and A-Tutor.
To analyze these products, from the formative method point of view, we answered questions about the kind of importable materials into the platform, about the organization lessons and courses, overall from the point of view of their interaction, the about the capability to create learning paths linking courses and lessons.
From this point of view we considered important the capability to have more than one instance of the same course.
Then we considered some auxiliary didactical instruments useful for the learning of the students, by the others: communication instruments between students and tutors, the grading and auto-grading tools, and the shared boards, wiki, etc.
The first platform under test was A-Tutor, an open source e-learning platform distributed with GPL licence, developed by the University of Toronto, Canada.
From the content management point of view, the platform is quite poor event if it supports the SCORM standard.

In fact the concept of formative method was not developed. Therefore in this platform doesn't exist the learning path concept; the lessons can only be organized in a course without any capability to modify the sequence the lessons, neither the concept of pre-requirement was developed. Therefore in this platform the concept of instance is the same of the concept of course, so you can't modify it.
Then, about the auxiliary didactical tools, neither in this topic the platform is very interesting, in fact there are only the forums, a system of internal messaging and a chat. Others tools for the cooperative work are not present.
Lastly it is possible to create test, even if these are not mandatory for the following of the course (there isn't the learning path concept), therefore this tool it is not very customizable
The second platform analyzed was Moodle, one of the most popular e-learning platform in the open source world.
About the content management and the features the potentiality are big, even if the standards used are often owned and not very used in the e-learning context. It is important to consider that this platform give you the capability of import many multimedia content in a lesson.
It is also possible to create a learning path and to modify it dynamically in function of the student.
As said previously the lesson creator tool is very powerful and customizable from the graphic layout point of view.
Unfortunately also in this product doesn't exist the separation between course and its instance. Even if the capability of creating dynamic learning path replace this lack.
About the didactical tool this platform is surely the most complete; in fact it has a lot of communication tools and it supply all the tool for the cooperative work, such as the sharing of resource, the shared boards, the diaries and the wiki tool, etc.
Finally a consideration about the tests creator tool, that is fully embedded into the learning paths and it is compliant with many tools of this type.
The last open source platform analyzed was Dokeos.
This product has a great SCORM support that replace some lacks in the course management, in fact even if it is possible to import a lot of types of media contents and even if exists the concept of learning path this is just sequential and it can't be modified dynamically. Instead it is very interesting the tools used to reuse the lessons.
The communication tools are not so numerous but are useful and powerful, as the cooperative work tools.
There is a tool to create the tests quite incisive even if it is less powerful than the Moodle's one.
At the end of this section a graph, got with our GQM tool, is presented. In this graph are summarized the concepts expressed previously.

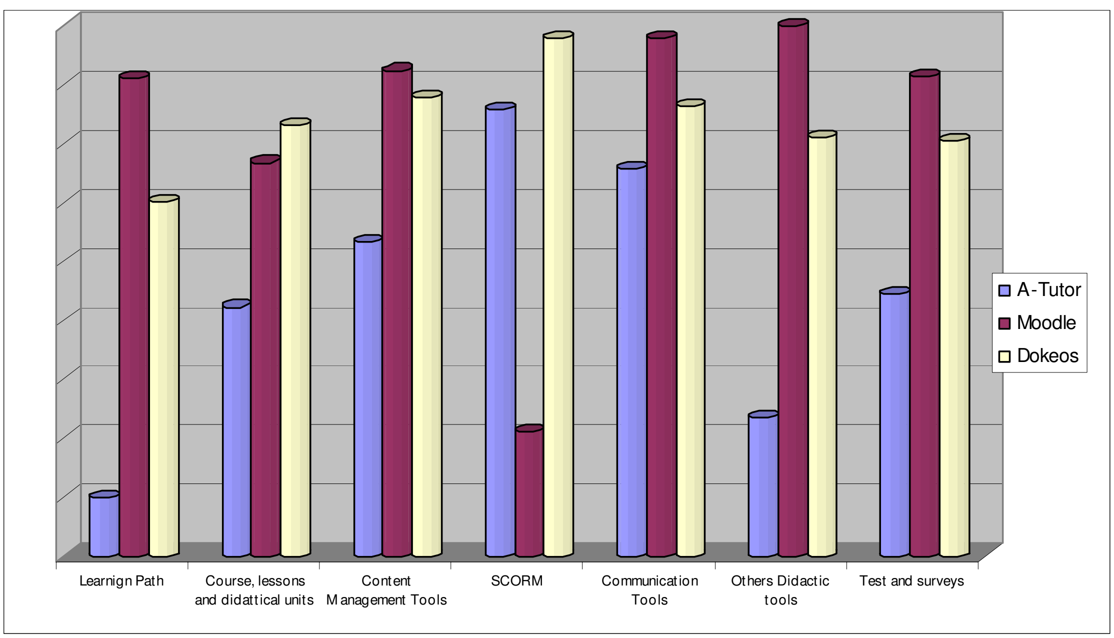


Figure 6 – The platfroms' results

It is evident the best platform from the formative method point of view is Moodle, followed by Dokeos.

6. Conclusions

In this paper a comparision of several open source platform fro the process formation point of vie has been done.

As you can see in the previous picture, Moodle is a very good platform from the formative method point of view, but the SCORM capabilities was poor.

A-Tutor doesn't give you the capability of create learning path, and, not negligible feature: it doesn't supply auxiliary didactical tools.

Dokeos, instead, even if in some macro goals seems be less powerful than Moodle, it gets a good total score in the learning processes management.

This feature, added to the good management of SCORM content, makes of it the best choice for e-learning in open source environment.

In the futures we plan to consider also the ECLIPSE tools and its plug-ins dedicated to didactical objectives, to complete the overview on open-source products.

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Integrated Management of Courses in a Distance Learning Environment

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Abstract: *In this paper we present a set of tools to be used together with a Learning Management System (LMS) for the integrated management of adaptive educational paths. For the sake of the modularity and reusability of components, both the LMS and the tools are stand-alone applications; on the other hand they are designed and developed such that they provide users and programmers with integration capabilities and a high degree of mutual interoperability. The proposed tools cover the life-cycle of the learning process; starting from the definition of the contents and their organic structure, passing through the authoring of the teaching materials and the packaging in standard learning objects as well as the definition of metadata for easy information retrieval and categorization over the web, until the delivery of courses to the students and their final assessment. The whole activity and life-cycle are profitably supported by the EifFE-L environment, an open source platform aimed to promoting distance learning techniques by providing easy to use web interfaces and friendly tools to an audience as wider as possible.*

Keywords: distance learning, user profiling, learning management system, conceptual maps, authoring tools

1. Introduction

In the framework of distance learning, the areas in which effort is requested to the teachers have substantially changed during the last few years, moving the focus of attention on the design and implementation of specific learning paths and related teaching materials as well as in the evaluation and assessment. Learning outcome is evaluated against the ability acquired by students at the end of a course as well as against the satisfaction of students. The degree of satisfaction for students can depend on many factors: the good result achieved as well as the perceived quality of the teaching or the amount of time requested for completion of a course. The possibility of making available targeted courses for students tends to minimize time-wasting activity while maximizing the results in terms of notions acquired and level of knowledge at the end of the course.

Driven by these considerations, a set of tools for the integrated management of courses is presented. Such tools cover the whole life-cycle of the production and management of distance teaching activity (design of educational paths, delivery of courses, management of virtual classrooms, evaluation, and assessment).

In this respect, in the last years, within the framework of a targeted action (the CampusOne Project, funded by CRUI – Conference of Rectors of Italian Universities [1]) much work has been done for encouraging the use of technology and for introducing innovative aspects in the learning/teaching process. One key action of the above project has led to the realization of the EifFE-L (**E**nv**i**ronment **f**or **F**reedom in **E-L**earning) e-learning platform, an open source, full-featured e-learning framework based on the concepts outlined [2]. The EifFE-L platform is mainly composed by a Learning Management System (LMS) together with a set of side tools aimed to improve the productivity in the learning process. The proposed tools are the following: Subject Matter Sequencing (SMS), SCO wizard, Virtual Class Register (VCR), and Test Maker. All together they go forming what we are going to call the EifFE-L system. SMS is a Subject Matter Sequencing tool with an easy to use web inter-face and with a database architecture underlying. SCOWizard is a graphical tool for the packaging of pedagogical resources into standardized Learning Objects [3]. VCR is an XML-based "Class Register" for monitoring and evaluating all of the participants to a virtual class. Test Maker is an XML-based tool for the generation of questionnaires (both tests and quizzes, running on server-side) for students' self-assessment and teachers' monitoring and evaluation.

The orchestrated use of the proposed tools enables authors to define teaching materials and educational contents in terms of a planned and well structured information flow. The use of these teaching materials in the proposed framework enables teachers to cover a complete learning process for their students. The whole system provides users with the technological means for the integrated management of the learning process and of the educational path which can be defined in terms of a work flow.

The paper is organized as follows. A methodology for the design and definition of educational path is presented in Section 1. In sections 2 and 3 considerations follow about adaptive educational path tailored to users' needs. The components of the system are described in section 4 and some conclusions are reported in the last section.

2. Definition of the Educational Path

Thinking of the concepts to be expressed, looking forward to the objective to be achieved, an educational path (i.e. learning path) has to be designed. The information flow within the process of definition of such a path is as follows:

1. Authors define and depict a set of learning modules in terms of their contents and requested effort. Authors also outline a general structure of the course.

2. Authors assign to each part of the course the relevant resources and teaching materials.

3. Authors make the course available over the Internet. Since now on, authors will also be teachers.

4. Teachers collect all of the information related to the activity carried on during the course.

5. Teachers check the effectiveness of their courses by evaluating the learning outcome of the students.

These five steps can be recursively repeated and they fully define the information flow of a complete educational path. Also, from a functional point of view, these five steps can be matched with actions to be taken with the specific tools offered by the EifFE-L system.

During step 1, authors define and depict a set of learning modules in terms of their contents and requested effort. Authors also outline a general structure of the course by means of the SMS tool. Outcome of the SMS is a record containing a summary (table of contents and index) of the considered learning module whose structure can be linear, hierarchical, or tree-shaped. In this record dependencies too are clearly expressed in terms of prerequisites, requested skills, and acquired skills as well as requirements and achievements. It can be easily represented through a graph with nodes and arcs. From a programmers' point of view, it is just an XML file.

During step 2 authors associate to each node of the graph (the SMS record) the relevant teaching materials. It can be easily done by authors themselves just browsing their knowledge base systems then choosing a suited Learning Object as well as by creating new ones by means of the SCOwizard. The Learning Objects (LOs) created by SCOwizard are guaranteed to be XHTML 1.0 strict and SCORM 1.2 compliant [4]. It is a good practice that, while creating LOs, authors pay attention to the correct definition of the metadata as well as of the prerequisites, requested skills, learning outcomes, and acquired skills at the end of the module.

During step 3 teachers can easily make their teaching materials available over the Internet by means of the EifFE-L e-learning platform. The outcome of the SMS is the index of the course to be published for the remote virtual class, and the SCOwizard LOs are the teaching materials stored in the database. Moreover users (students) can profitably exploit community functionality offered by the platform according to the use of a constructivist approach [5].

During step 4 teachers can easily collect all the information related to the activity carried out during the course. Such information is collected into an XML file containing a rich log of the system. Data are made available to the users through the LMS and they can be re-organized by means of the VCR so that users can collect information, perform statistical analysis and performance evaluations, and many other activities.

During step 5 teachers can easily check the effectiveness of their courses by evaluating the learning outcome of the students. This can be done by means of the Test Maker tool. Pages with "Questions and Answers" sessions can be created and tests are proposed to the students. Assessment and self-assessment results are transmitted both to the LMS and to VCR. Such data can even be exploited in order to create personalized learning paths with the aim of optimizing the information flow individually for each student so that results are maximized as well as completion time can be minimized.

3. Adaptive Learning Paths

User-modeling techniques allow defining models of users (based on preferences, interests, conceptual understanding, etc) and exploit such models to build systems that tailor their behavior to individuals and groups. Information is collected on the basis of the usage of the LMS by users who can easily be profiled and categorized. Within the EifFE-L framework each user is associated a user-profile. First of all personal data are collected (from external LDAP directory systems too if any available) so that users are duly registered into the LMS. According to one's preferences, each user can customize her/his own user interface and is asked to add personal information (e.g., passport photo, hobbies, other activities, title). The LMS administrator can add further information on the role of the user in the system: five different roles are possible namely administrator, faculty administrator, teacher, student, visiting student. The LMS collects data on the users as they attend courses (completed or not completed, assessment results) so that the user profile is dynamically evolving depending on the activity carried on within the LMS. Each user is mapped into a user space according to the definition of suited filters for having a view on some characteristics rather then other ones. According to different points of view, the user profiles can be focused on different performance indicators. For example, the description of the attitude (i.e., skills) in using the user interface and the tools (e.g., the users download files or they read documents while online? how many clicks of the mouse?) or the definition of the level of domain specific knowledge to be used for the creation of the learning path of the students (Custom Learning Path). The definition of the domain specific knowledge can be done by means of tests or check list created with Test Maker.

In this work the focus is on the definition of an individual educational path (Custom learning Path) for each user. This can be done by varying (enrichment with additional information or shortening by skipping known concepts) the sequence of Learning Objects in any individual teaching program. Sequencing is possible with the ADL-SCORM 2004 model [4]. According to the SCORM sequencing and navigation technology, the proposed system can be thought as follows:

- Activity tree
- Learning activities
- Sequencing rules
- Navigation
- Navigation data model

Moreover, in the proposed approach further functionality is proposed that is the capability of adapting the sequence to the user according to a personalized model of the student and of one's a priori knowledge and skills on the subject matter. Given the general structure of a course, a variety of algorithms and techniques can be used for optimization purposes. One objective can be the minimization of the completion time and effort as well as the maximization of the results. Once the course materials and its structure are defined, the (standard) learning path can be customized for each student depending on personal ability and depending on the results achieved while attending the course, thus creating a custom learning path. A dynamic data structure is created for each student and it is updated according to the results registered within the LMS and through the evaluation and self-evaluation tools and reporting system (see figure 1).

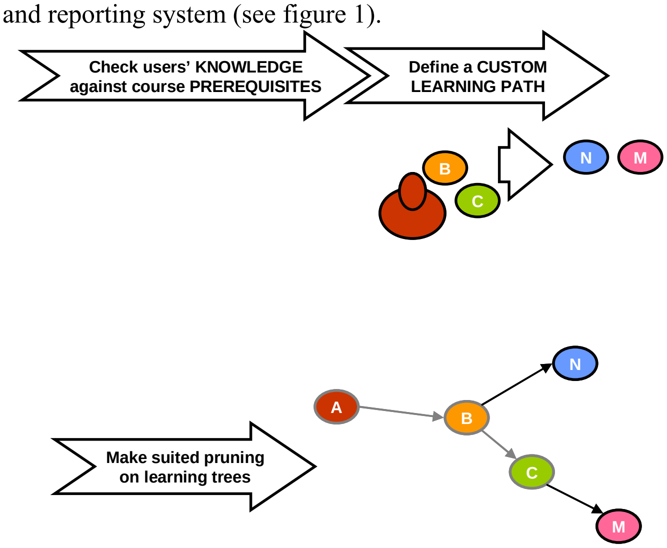

Figure 1 - Customizing learning path to user's profile

Generally speaking one can define a concept in terms of knowledge that is, a set of information related to it. Given a domain of knowledge *K*, acquiring more and more concepts (i.e., learning) we increase such domain of knowledge transforming it in a new domain *K'*. Knowledge can be thought as a set of information; concepts can be defined as functions mapping one domain of knowledge in a wider domain of knowledge. We can therefore define a set of concepts as:

$$Ci: Ki \rightarrow K' \quad \text{with } K' \subset K.$$

Ki is the requirement (Prerequisite) for the user to understand what is expressed into concepts *Ci* he is going to learn; *K'* is the new domain of the knowledge the user is in after attending that specific part of a course; $K' \cap K$ represents the learning outcome.

The process of definition of a standard learning path can be described in the following steps (see figure 3):

- Collect ideas together
- Arrange ideas in concepts
- Join concepts in learning paths

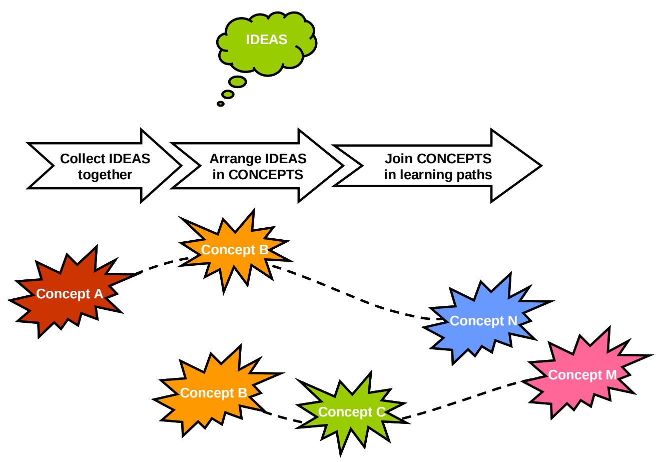

Figure 2 - Defining learning paths starting from concepts

Ideas, information, references, images, … are collected and clustered to define a concept Ci. For each concept prerequisites have to be investigated as well as learning outcome, so that learning paths can be matched with individual students' ability.

Once identified feasible educational paths, they can be aggregated in more complex learning units given by the combination of concepts and their organization in learning trees. On the root of a learning tree we have the general prerequisite for the underlying subject matter, the a priori knowledge needed and sufficient to start profitably a learning path tailored on a learning tree.

In its general form a learning tree is an oriented graph where arrows entering a node represent prerequisites and exiting ones represent learning outcome; concepts without entering arrows represent concepts whose prerequisites are the a priory knowledge necessary for that subject matter.

4. Components of the System

The system enabling teachers to the integrated management of the activities as described above is composed by a Learning Management System and by a set of specific tools. The proposed tools are the following: Subject Matter Sequencing (SMS), SCO wizard, Virtual Class Register (VCR), and Test Maker. A short description follows for each component of the system.

4.1 LMS

The University of Genoa, within the CampusOne Project has activated in 2001 a three-years action finalized to the introduction of e-learning facilities ad-hoc for the *athenaeum genuense*. At the end of the project, in 2004, one of the results consisted in the realization of a full featured SCORM compliant e-learning management system (LMS) with an XHTML 1.0 Strict WCAG Priority 3 compliant interface – called EiFFE-L - entirely integrated with UniGE Information System. Despite the large number of e-learning commercial products available, the University of Genoa decided to realize a novel – open source - LMS/LCMS, inspired to the best solutions and innovative frameworks (e.g., OKI [6]), in order to ensure that the University has total control and ownership of the implemented source code. This choice was made to prevent possible modifications and updates of the licence giving policies of a possible commercial product. EiFFE-L has been published as open source in SourceForge repository [2], under GNU-GPL License.

The main characteristics of such platform are: portability, accessibility, open source, multi-language front-end, and conformance to e-learning standards.

4.2 Subject Matter Sequencing

The Subject Matter Sequencing (SMS) tool allows users to create a course starting from independent modules or single topics so that depicting standard learning path can be made easier. Arranging lessons together in a specific sequence gives raise to a specific course.

The SMS offers such capabilities:

- ✓ Definition of a concept *Ci* in terms of "assets", atomic components who cannot be partitioned (sub-divided).
- ✓ Definition of a graph of concept dependencies by means of definition of logical relationships among pairs of concept *Ci* and *Cj*. For different kind of relationships are possible:

  $Ci > Cj$ *Ci* is a prerequisite of *Cj*;

  $Ci < Cj$ *Cj* is a prerequisite of *Ci*;

  $Ci \equiv Cj$ *Ci* and *Cj* are in some way correlated but they have a relationship of indifference;

  $Ci \varnothing Cj$ Ci and Cj are concepts completely disjointed;

  from a pedagogical point of view, in case of $\equiv$ and $\varnothing$ relationships there is no difference in composing a learning path where *Ci* before *Cj* or vice versa. The difference between the two relationships is that during the generation of a learning path, in a sequence of concepts, in order to guarantee the constraints imposed by the defined relationships, the distance Δ between two concepts *Ci* and *Cj* (i.e., the number of concepts *Ck* between *Ci* and *Cj*) should be greater than zero; in the case of "indifference" relationships the system minimizes Δ.
- ✓ Generation of an optimal learning path following the constraints imposed by the logical relationships among concepts (see below).
- ✓ Partitioning of the learning path in sub learning path according to the user inputs.
- ✓ Possibility of editing of the generated learning path to change the order of concepts in case of possible alternatives.
- ✓ Creation of an XML file output of the sequence.

If we think to a lecture, or a whole course (i.e., set of lectures) in terms of a sequence of ordered concepts, in our model that is the index of topics of a Learning Object (SingleSCO) or a sequence of Learning Objects (MultipleSCO, SingleCourse). Such sequence will be generated starting from the graph of the concepts dependencies.

At the very top of this graph one can find the didactic objectives (the concepts that represent the objectives). At the bottom of the graph one can find basic skills required, also called Primary Notion. All the notions that need some prerequisites are called Secondary Notion.

The graph must be analyzed starting from the primary notions and back-stepping towards the secondary notions up to the top where objectives are listed to represent learning outcomes. The graph itself is a graphic representation of the definition of a hierarchy of objectives. Nodes and arcs match with concepts and relationships among concepts.

By navigating the graph described above, one can find a series of elements priors one to each other and identify a specific path in it. This has been done on the basis of the Davies Matrix [7].

According to this theoretical approach the sequence outcome of the Subject Matter Sequence tool is free of redundancies; concepts in the graph appear once hence it is considered just once in the learning path. On the other hand, redundancies can be sometimes useful, from a student point of view, for refreshing basic notions acquired a long time ago. For this reason and many others the tool is not fully automatic, and allows human intervention to make modifications to the structure of the learning path, leaving some degree of freedom to the user (the author of the course) who can enrich the results of the mere algorithm with one's personal experience in teaching. On the other hand the teacher is forced to respect a rigid, formal structure while designing the courses.

4.3 SCO Wizard

The SCOWizard tool has been designed for the implementation of Learning Objects ADL-SCORM compliant, based on specific XHTML templates defined for EifFE-L. The main objective has been to create a simple off-line tool that supplied the possibility to realize SCOs (Shareable Content Objects) through the insertion of contents, without having to use HTML editors nor having to work into the templates code, nor having to study the SCORM rules in order to package standardized learning objects. The philosophy underlying SCOWizard has been to tailor the packaging procedure around the typical EifFE-L authors, realizing ad-hoc sequenced forms for each selected SCO template. The pages generated are XHTML 1.0 strict.

The SCOWizard has been designed taking into account the structure of learning material for a typical university lesson, defining a template asset with all the relevant components. The sequence of concepts generated with SMS can be used as input for the SCOWizard. The result of this analysis has been the realization of an XHTML base for learning objects - and several different CSS templates - with the following structure:

- Header and footer, where information about the author and the contents are defined, also in terms of metadata about the structure of the lesson (module), used in case of SCORM standardized learning object as "organization" of the resources that compose the lesson, i.e. IMS manifest structure [8].
- The number of sections (units) that compose the lesson (the number is dynamically modifiable during the authoring phase). If SCOWizard inherits a sequence of concepts from SMS, such sequence is the index and structure of the sections composing a lesson.
- The contents of each unit subdivided in paragraphs, which can be realized in several ways (typed paragraphs): only text, text with comments and notes, text with image (left/center/right), etc.

The aim of such learning object organization is that assets should satisfy accessibility and usability, being conformant to SCO packaging rules. At the end of contents' authoring phase, SCOWizard let the author choose a CSS layout among the list of templates available, creating a valid SCORM manifest (imsmanifest.xml) and packaging all the assets into a zipped container.

The indexing phase (metadata related to IEEE P.1484 LOM standard) is given by a separate tool, Metamaker, integrated with SCOWizard, which is under development at a beta stage.

SCOWizard has been realized as a Java application, with a SWING based GUI; the current release is 1.0, and the current work is devoted to reduce the rigidity of the learning object structure by having in input a "lesson semantic description" in RDF format, as well as to reduce the complexity of authoring phase without transforming the wizard into a WYSIWYG editor.

4.4 Virtual Class Registry

VCR is an XML-based "Class Register" for monitoring and evaluating the participants to a virtual class, finalized to the electronic accounting of the qualitative and quantitative appraisal of the participation of the students enrolled into an EiFFE-L course.

VCR is an open-source tool, integrated within the platform, which uses the users data (statistics, tracked assignments, evaluated posts on forums, etc. in a flat XML structured file) generated within the teacher's functionalities. Once generated the XML file can be transferred on a local computer, where the VCR is installed.

The VCR import XML data into an internal database, allowing the teacher to complete data and to add his own appraisals. The new data and grades are introduced "visually" (using different colors and icons, e.g. red color to characterize data to be filled), using a series of panels and forms resembling a traditional paper-based class register, with a cover that encloses six different pages. The cover and the successive pages are accessible through the home page of the tool. In synthesis the main functionalities of the pages are the following.

- ✓ Cover: the cover of virtual class register contains a summary of the course;
- ✓ Definition of concepts in terms of "assets", atomic components who cannot be partitioned (sub-divided);
- ✓ Participation: the page of the class register devoted to the evaluation of participation/attendance of each enrolled student;
- ✓ Activity: the page of the class register which collects all the information useful to assign one total estimated grade on the activities carried out from each student;
- ✓ Test: the page of the class register which collects all the information useful to assign one grade on the tests carried out during the course;
- ✓ Exercises: the page of the class register which collects all the information useful to assign one grades to each exercise carried out during the course;
- ✓ Individual Projects: the page of the class register, which collects all the information useful to assign an appraisal on the individual assignments;

- ✓ Workgroup: the page of the class register, which collects all the information useful to assign one global evaluation to the tasks collaboratively done within a group of students.

4.5 Test Maker

TestMaker is an open source tool specifically designed for the EifFE-L platform, for creating tests. TestMaker offers advanced editing capabilities for creating tests that will be published within the EifFE-L framework in order to evaluate and check skills, capabilities, and knowledge of the students at different times during the learning path:

- before starting a course (prerequisites),
- after the completion of a course (acquired skills),
- at the end of a course for self-evaluation (self-improvement),
- at the end of a course for the final evaluation and score (final results).

Test authors can create three different types of test:

A) Evaluation test with free answers: questions are listed and answers have to be given by writing free text inside a text area. Answers are forwarded to the author of the course according to the EifFE-L database definition. Final evaluation can not be automated; it is up to the teacher reading, evaluating, and scoring given answers as well as communicate the final results to the students by using collaborative tools provided with the EifFE-L platform;

B) Evaluation test with pre-defined answers: questions are listed and answers are requested and collected. The system can calculate a score of the test according to a pre-defined score table. The teacher receives both the test and the relevant result;

C) Self-evaluation test: questions are listed and answers are requested. The system suddenly replies with a right or wrong message so that students can improve their knowledge. Tests are not forwarded to the teachers who are only informed about the making of the self-evaluation test.

Moreover each test can also be timed. Questions and answers can be proposed by following different models:

- o Multiple choices: only one is the right one! (can be with radio buttons, drop-down list, numerical evaluation);
- o Multiple answers: one or more can be the right ones! With check boxes;
- o True/false: only one is true! With two radio buttons;
- o Free answer – students have to write their own answers, maybe correct or not!
- o Missing words: students have to complete text or sentences without any suggestions.

Authors of tests are also required to give explanation on the reason why answers are right or wrong so that students are also told and they can learn from their mistakes too.

5. Conclusions

This work discussed some of the result of a project, CampusOne, funded by CRUI - Conference of the Rectors of Italian Universities whose goal has been to create an e-learning open source portal which would respond to the most recent an binding provisions of law concerning the delivery of on-line education and to activate a process of cultural growth for both teachers and students concerning the use of ICT for didactic purposes. In particular, some specific aspects of the EifFE-L (**E**nv**i**ronment **f**or **F**reedom in **E-L**earning) e-learning platform and related tools have been illustrated, aimed to improve the productivity in the learning process.

The discussed system enables teachers to the integrated management of courses in a distance learning environment, making available tools to support the authoring, teaching, and evaluation activity.

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The Digital Instructional Design Abilities Cultivation of Teachers- A Case Study of the Health and Physical Education Domain

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Abstract—The grade 1-9 Curriculum focuses on instructional innovations. Teachers need to have instructional design abilities. An instructional system and supporting frameworks is needed to help teachers. The researchers participated in the setting process of the Health Learning website and developed a "Health and Physical Education Domain Instructional Design Model" for the related teachers. In the first phase, an instructional design workshop was held for the seed-school teachers from eight schools. The teachers followed the design model to develop, discuss and revise instructional designs. Then they went back to their own schools to teach a one-hour class and record the whole teaching process. According to the field notes, the feedbacks from their students and teachers, the "Teacher's self-evaluation sheet of instruction", and the "Teacher's peer evaluation sheet of instruction", the teachers discussed and revised their teaching plans and teaching design. In the process the researchers designed a comprehensive questionnaire and retrospectively studied how to improve teachers' digital instructional design abilities and how to renew the teaching results with the Model. This study also expects to see that, with than Internet platform for posting and sharing instructional design process and results, teachers can benefit in discussing, observing and teaching.

Keywords: Digital instructional design, Digital instructional material, Health and Physical Education

I. PREFACE

The grade 1-9 Curriculum has modified the curriculum standards to be more flexible. Thus teachers must modify the textbooks or create their own teaching materials. Since the beginning of this education reform, to meet the change, many training workshops have been held by the government or local assistance groups to establish Health and Physical Education Domain Instructional Design Model to help teachers acquire the abilities of creating teaching materials and teaching activities. This research, completed in 2004, is to use this model in four phases to train and help teacher groups in the seed-schools in Health Learning website to reach the following three purposes. First, it is to upgrade the teachers' abilities in instructional design to improve the students' learning. Second, there' re opportunities for discussions to improve teachers' teaching ability to ben. Third, it uses the internet platform for teachers to learn from others.

There are two groups of "seed-school teacher groups" in this research: one is from the schools invited by Health Learning website; the other is from the information seed-schools, junior high or elementary schools, under the Ministry of Education(MOE), willing to develop the content in the Health Learning website when they apply to be seed-schools. Teachers from these form their teacher groups called "seed-school teacher groups" in this research.

II. TEACHERS UNDER EDUCATIONAL REFORM

A. With the changes of textbooks, teachers should have the ability to do instructional designs

School-based curriculum is the core concept of the grade 1-9 Curriculum. It develops teaching courses mainly by taking the school's education ideas and the students' needs as its core, the school's personnel as its main body, and the school's facilities and resources as its basis, to adopt measures according to specific circumstances, schools, or students. It emphasizes on giving the students suitable, living and instant learning (Chang, 2003). To reach the goal, besides selecting adequate textbooks, some ways are taken, such as transforming textbook content or activities to meet local features, re-organizing the lessons of textbooks according to one's over-all course plan, or re-editing the textbook content according to the students' needs (Chang, 2003).Besides methods mentioned above, we focus more on the teachers' ability to re-construct the teaching materials.

The idea of "A teacher is a researcher" is constantly advocated (Ou, 1999). A scholar mentioned that to develop courses and improve teaching quality, a teacher should have the attitude of learning and adjusting by doing in the developing courses. Using action researches to improve course development and teaching will benefit both a teacher's teaching and students' learning. An action research which teachers learn and adjust by doing to solve course and teaching problems will be one of the core strategies in running the grade 1-9 Curriculum. (Chang, 2003).

According to the idea of "the school as the center", each school can create its own teaching materials to lessen its dependence on textbooks (Chen,2002).But some scholars questioned the teachers' ability to create instructional designs. So in using textbooks, teachers should have the ability to re-create, re-edit, or re-transform the teaching materials（Chin,1999.2003）.

Based on the above ideas, in the grade 1-9 Curriculum, Health domain and Physical Education domain were combined as one(Lin & Chua, 2003). With many years of experiences in researching and developing experimental teaching materials in the domain of Ethics and Health, the researchers developed materials used in several experimental schools, modified and then sent to National Institute for Compilation and Translation to be examined.

To help teachers acquire the ability of instructional design, we held several meetings with experienced school principals, directors, and excellent teachers to draft a flow chart of instructional design which was later used by many different users and many workshops held by the Ministry of Education. They came up with many productive instructional designs and ideas for further modifications. Later, to meet the needs of local workshops, we discussed and exchanged views with teachers in all over the island, such as Taipei City, Taipei County, etc to find ideas for modifications. We later developed the "Health and Physical Education Domain Instructional Design Model" (Fig.1.), a systematic (Lin, 2001) and its four assistant instructional design charts. The users can do an instructional design smoothly by following the guide of the systematic chart and the assistant charts.

The instructional design chart starts with the teacher's ideas. After that, the theme has to be decided. After drawing the instructional design structure chart, with the content for instructional design in mind, a teacher may write down the related sub-guidelines of the basic guidelines, the supplementary explanations(including related domains and major issues), and the corresponding teaching objectives. He or

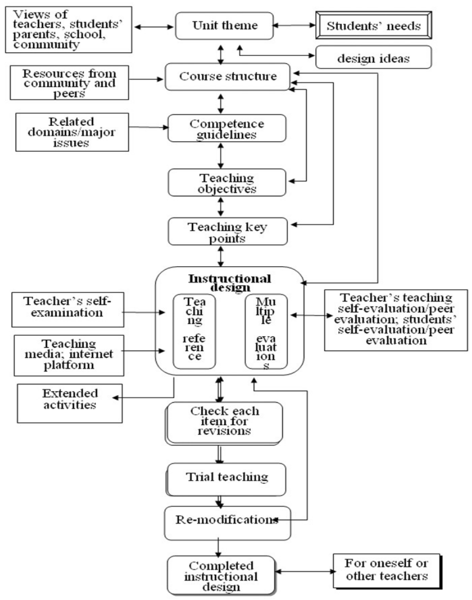

Fig.1: Health and Physical Education Domain Instructional Design Model

she may first write down the teaching objectives and look for suitable sub-guidelines. Then, the required class hours and the key teaching points are decided. With the key teaching points, following the instructional design chart, a teacher may design each period which should be interesting, living and suitable for the students. Time control and substitute activities should also be considered. Notes and self-examination points are listed out as well. Finally, the question "how do you know the students have learned what you teach?" is brought up. That is, what are the means you may use to evaluate the students' learning? Basically this step finishes the paper work process which will be carried out in trial teaching and further modifications if necessary. The teachers, in the process of personal participation, will gradually finish the instructional design according to the needs of his won students, build the ability to design and establish the confidence (Lin & Tzen, 2001)

B. The learning of digital teaching materials for teachers

In recent years, the Ministry of Education has gradually promotes digital instructional materials and internet uses (Lin, 2004) and has established a website (http://content1.edu.tw), an area for sharing teaching resources and experiences. The learning websites for six categories were also finished, including Life Learning website, Nature Learning website, Science Learning website, Health Learning website, History and Culture Learning website, and Arts Learning website (MOE, 2004). These platforms can provide teachers access to sharing their instructional designs, exchanging experiences or search for materials. We are now working on the Health Learning website (http://health.edu.tw) to empower the teachers' ability for instructional design. Therefore, learning how to transform teaching materials into digital, how to use them, and how to share the resources by using digital platforms will be crucial for modern teachers.

III. THE MEASURES TO DEVELOP TEACHERS' DIGITAL INSTRUCTIONAL DESIGN

The purpose of this research is to help develop teachers' ability to do instructional designs. The time of was from January to December, 2004. The targeted participants were the eight seed-school teacher groups of Health Learning website set up by the MOE.

Four phases in the research: the first phase is to build up the know-how basis for teachers. The second phase is to have trial teachings in the classroom according to instructional designs and record the process. The third phase is to go through evaluation by utilizing the "Teacher's Self-evaluation sheet of instruction" and "Teachers' peer evaluation sheet of instruction" to comment on the instructional designs and teaching and fill in Feedback questionnaires. The final phase is to finish the instructional designs and make them digital to be shared.

Methods of the research: analyze documents and papers; target group meetings and group discussions; group hands-on practice; trial teaching recorded; virtual teaching evaluation and questionnaire feedbacks etc. They are described as follows:

A. Analyze documents and papers

Related documents were reviewed to form the theory basis of this research. The systematic "Health and Physical Education Domain Instructional Design Model" and its four assistant instructional design charts were utilized. So are the The "Teacher's Self-evaluation sheet of instruction" and "Teachers' peer evaluation sheet of instruction."

***B.** Target group meetings and group discussions:*

The teachers joining the research were from the seed-school teacher groups. In workshops of the first and third phases, target group meetings and discussions were held to share experiences to enhance their expertise.

C. Group hands-on practice

To put the theory into practice, traditional lectures (one-way) were not taken. Besides making good use of group cooperative learning method, participants were put into groups to run through the whole process of "think, design, teach, modify, finish, and share" in the first and third phases. Thus, their design ability can be advanced in hands-on practices and instant feedbacks can be received.

D. Record trial teaching

The seed-school teacher groups combining "theory and reality", having trial teachings recorded in the second phase, they may document them for future discussions and use them for instructional design evaluations in the third phase.

E. Virtual teaching evaluations

The seed-schools are in different locations. So the trial teachings are recorded and will be watched by other teachers to have virtual teaching evaluations.

F. Questionnaire feedbacks

After the end of the third phase, “Instructional Design workshop feedback questionnaires” should be given out and filled in. Five items in the questionnaires which are related to this research and there are five degrees for each item. (5-excellent, 4-good, 3-fair, 2-not well, 1-to be improved) There are also some open questions for comments. The questionnaires were collected to find out if the targeted objectives are met and understand major problems therein to be noticed in future researches. All the thirty-three questionnaires were retrieved. The explanations for codes in this research are described as following :

Table 1：code description

Category	School	Serial numbers	Member	Partition	Date
Target group discussions & feedbacks: A Internal group discussions & feedbacks: B questionnaires *: C posted instructional designs: D	Junior high: J Primary : P	The serial numbers for junior high and primary schools in each area are arranged according to the writing strokes of the first Chinese character in their school name(from least to most) and listed with numbers from small to big.	Specialist:S Senior teachers: T1,T2,T3 Teachers in teacher groups: M1,M2,M3, M4	A **dash,--,** is used for partitio**n**	Western dates, month and day being 2 numbers

*questionnaires were done without signature and were assigned with numbers starting 01,02,03,---,32,33.

IV. RESULTS AND DISCUSSIONS

This research has four phases. The results are as follows:

A. First phase: build up the know-how basis. Eight seed-school teacher groups attended the workshop.

1. Every teacher in each teacher group finishes an instructional design. There were totally eight instructional designs from each group. The content covers topics like growth, man and food, mental health, safe living (including Chinese herbs), and public health.
2. Course specialists and senior teachers joined the discussions. Different teacher groups exchanged views, gave suggestions for modifications, refreshed reminders, or helped figure out some hidden problems to help each teacher group finish their design. After each group’s presentation of their instructional designs, course specialists and senior teachers responded with comments and feedbacks.
3. Course specialists refreshed reminders timely, for example, the importance of time control in their design.
4. During small group discussion, course specialists joined them and offered their suggestions. This worked out best for instructional design.
5. While working on the designs, teachers should notice teaching evaluation.
6. After each group went through the process of thinking, designing, discussing, modifying, presenting and modifying, course specialists again gave them instructions and suggestions. Then the instructional design was finalized and prepared for trial teaching.
7. Digitalizing the content of instructional designs by using basic computer skills like WORD or PowerPoint. 8. Making instructional designs digital also made things effective for presentation, interactions among teachers, course specialists’ suggestions from teachers during presentation and small group discussions. Each process could be completed within very short time.

From the above, the seed-school teacher groups, after following Health and Physical Education Instructional Design Model and its assistant charts in doing hands-on instructional design practices, they finished their basic instructional design. After they received instructions or suggestions, they could modify them immediately, showing the obvious benefit of making instructional designs digital.

B. The second phase: do trial teachings according to instructional designs and record the process. This had to be done by each school’s teacher group.

With one-period instructional design completed, teachers returned to school to have trial teachings to be recorded. After that, discussion meetings were immediately held, where the involved teachers talked about what they had learned, the differences between instructional design and trial teaching, points to improved etc. Other teachers also gave suggestions and encouragement. Finally course specialists commented.

1. Before trial, teachers prepared it with assistance.
2. Right after trial teaching, discussion meetings were held. Involved teachers talked about what they had learned.
3. To find out how well the students learned, pre-test was given before teaching and post-test after teaching.
4. Among teacher group members, in trial teaching teacher or instructional design designers, both thought that rechecking design flow chart and process and exchanging opinions constantly would positively help narrow down the differences.
5. Instructional designs should be modified after trial.
6. Recorded trial teaching provides virtual classroom environment for evaluation basis in the third phase.
7. Completed digital instructional designs increased convenience after being modified according to the problems occurred in trial teaching.

Teacher group members, after sharing what they learned and the differences between design and operational curriculum can check and improve them. Besides, through communications, discussions, and instructional design ability was enhanced. Recoding technology, applied to teaching, provides A-V information and may help teaching. Recently it is used for evaluating teaching and teaching quality(Chang, 1999). Thus, recording offers a virtual classroom environment for teachers’ teaching evaluation. Besides, camera technology has become digital as well. Therefore, it’s much easier to present the pictures through PC and edit them. The recording CDs of this research will be an important source for teaching discussions in the next phase.

C. The third phase : instructional design evaluations, feedbacks, and modifications

The teacher groups joined workshops again to fill out evaluations and questionnaires. Teaching recordings were used providing virtual settings. Everyone watched the recording and started the evaluation. After it, they used the

"Teacher's Self-evaluation sheet of instruction" and the "Teachers' peer evaluation sheet of instruction" for modifications to improve their designs. Finally questionnaires were finished to show their evaluation. Following is the description of evaluation and the questionnaires:

1. Instructional Design valuation:

Recordings provide virtual classroom setting to recheck their own instructional designs and others' and find out the differences between instructional design and trial teaching so they could make adjustments. The advantages of the trial teaching would be pointed out and given feedbacks. Teaching objectives should be clear and meet the related teaching guidelines and the amendments. The content of instructional designs should match the objectives. Activities should be integrated, interesting. Student evaluation measures should be multiple. Media equipment should be used if necessary. Besides, course specialists should instruct the teachers how to use the "Teacher's Self-evaluation sheet of instruction" and the "Teachers' peer evaluation sheet of instruction." Finally, according to the above results, they checked their own designs and teaching recordings for further adjustments.

The results indicate that digital teaching recordings offer virtual classroom environment for checking teaching and evaluating, a good way to enhance teacher's design ability. From watching recordings and discussions, teachers learned to link and combine instructional design evaluations, learning guidelines, the ten basic learning skills, teaching content, teaching activities, and students' evaluation and attention to making teaching interesting.

2. The feedbacks in the questionnaires for instructional design workshops

A. results in quantity:

Teachers checked five-degree questionnaires. (5 to 1) It showed that the teachers' satisfactory response regarding four of the five items, i.e. course arrangement, learning evaluation, instructors' performance, and workshop quality, all reached 97% satisfaction rate. The teaching process reached 84.8%. Obviously the workshops were helpful to improve their ability for instructional design.

B. quality description:

From the questionnaires, the teachers participated were considerably advanced in instructional design. In this workshop, the teachers learned the know-how knowledge of instructional design step by step through interactions with professors, senior teachers, and colleagues.

The information in the third phase indicated that it's helpful for the teachers to join the workshop and improve their ability for doing designs. Digital instructional design flow chart helped beginners and experienced ones to recheck their work. Digital teaching activities offered opportunities for discussions, sharing, modifications, and can be handed down for teachers in the future.

D. The fourth phase: completion of instructional designs and making them digital for sharing

Every group posts completed instructional design unto the Health Learning website and share these digital contents and interactive on a learning management system platform.

A complete instructional design model will help teachers improve their ability in designing. Digital technology to make instructional designs digital not only benefits oneself in keeping files, but has the advantages of portability.

V. Summary and Suggestions

A. Summary

1. The systematic instructional design flow chart of the Health and Physical Education Domain Instructional Design Model can help teacher groups finish their instructional designs and definitely enhance their ability in designs. Digitalizing each process digital can effectively assist teachers finish their instructional designs.
2. Confidence of teachers of doing instructional designs is strengthened. Teachers may gradually turn the students' needs into self-made teaching materials closely meeting the specific needs of each school-based curriculum.
3. Recording teaching process can offer teachers effective "virtual classroom." By watching the recordings, the content for evaluation can be proposed and teachers can learn how to evaluate an instructional design as well.
4. Teachers not only learned to design, but realized the importance of interaction with senior teachers and course specialists.
5. Digital files or content have advantages of portability, duplication, maintenance, and easy editing. Digital presenting and sharing in developing courses technology and materials can be crucial in demonstrating.

- Suggestions:

1. A school developing school-based curriculum can make good use of this model to shorten the required time.
2. During the research, the teachers involved also brought up problems of utilizing digital technology. Problems like these can possibly be solved by assigning technology work to professionals in this field. Teachers can focus on designing drafts based on their teaching expertise and passing the digital part of the work to digital professionals. Thus they can work in a team.

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A virtual tutor for a multimedial distance learning course

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Abstract

The use of new technologies is leading to great changes not only in the organization of educational programs but also in the skills required of learners. They have to take on a more active role in distance learning environments, becoming actors-producers of their own learning path. However, to be successful in this new role they need support. The present study describes a multimedial course offering support by a virtual tutor, created with the aid of Artificial Intelligence techniques.

1. Introduction

In our dynamic, fast-moving society, information has become a strategic resource that has a strong impact on the efficiency of social and economic, as well as cultural systems.

Telecommunications and especially the Internet are being increasingly adopted to create distance learning courses, that provide added value in the learning process. They ensure easy access by users to vast stores of data, greatly facilitating lifelong learning.

Because the World Wide Web is a highly flexible tool, it enables use of a variety of representation forms and different organizations of the teaching material, and allows open, unlimited interaction with the external, public environment. Users can access vast data stores, navigating freely as the mood takes them and so enriching their perception of the world.

This turns users into active movers in their learning process and so facilitates not only the acquisition of specific concepts but also the development of more general skills, such as data collecting and selection, the ability to make critical, personal interpretations, decision-making and gauging of the results, and learning to identify and modify interpretation models on the basis of stimuli deriving from the external environment.

All the same, it is not easy to become actor-directors of one's own learning process. It is essential to be conscious of what one has already learnt and what one still needs to learn in order to attain a given target. Not all users of distance learning environments are able to do this on their own, autonomously directing the process and making the most suitable choices. For this reason, the e-learning research community has paid particular attention to personalizing the content of distance learning processes. This involves deciding what important rules need to be set to allow the system to automatically define the best path for each individual user.

Another research area that is often interwoven with the previous one is that of creating virtual tutors in distance learning environments, that can emulate the behavior of the teacher in a traditional learning situation. On the basis of analysis of the data on the user-machine interactions, the virtual tutor must intervene and advise the user about the next action s/he should take, suggest material for further study, provide feedback about exercises already done, and so on.

The present work describes an interactive distance learning course equipped with a virtual agent that supports the learner throughout the learning process.

Before going on to describe the application in detail, some consideration of previous examples of virtual agents is made, focusing particularly on those adopted to date in distance learning situations.

2. From chatterbots to virtual agents

Although they are mostly unaware of it, users navigating the Internet make daily use of information software that guides the data search within the Web, in the form of search engines. Although these are very simple virtual agents, they are essential as filters of the huge quantity of data available, in order to show only those conforming most closely to the user's search criteria.

A more sophisticated virtual agent is the chatterbot, a software that can simulate man-machine dialog. The input is generally in the form of questions or sentences of all types, to which the software responds on the basis of its own vocabulary or reasoning process. The illusion of dialoguing with another human being is sustained thanks to the results of research in the field of Artificial Intelligence, that has always concentrated on how to simulate human cognitive skills. The earliest chatterbot, Elisa, (created in the '60s by Joseph Weizenbaum of the Massachusetts Institute of Technology) was intended to resemble a Rogerian psychologist. [5]. In recent years, thanks to developments in artificial intelligence techniques, more and more chatterbots have been developed and these are becoming more and more "human". A competition for these has been set up, awarded the *Loebner Prize* that is the first formal instantiation of a Turing Test sponsored by New York philanthropist Hugh Loebner. [4]. The latest winner was A.L.I.C.E. (Artificial Linguistic Internet Computer Entity) [1], developed by Richard Wallace, which was ranked the "most human computer" by the panel of judges.

Apart from chatterbots, other virtual agents integrated in software environments guide the user in the use of the software itself. The most sophisticated ones act as true personal assistants rather than just as tools, because they learn about the user on the basis of the interaction and can anticipate his/her needs according to previous experience.

For example, NOMI and INTERWERK-Agent are virtual characters that allow the user to navigate a site, and present the available products (e-Commerce).

With MM-Mail, an experimental service that was presented by Telecom Italia Lab at the SMAU 2002, the user is given the chance to send personalized and multimedial e-mails because the service incorporates a program that can transform text messages into actions by a virtual character. The text is read by a vocal synthesis system and the associated phonetic information is transformed into facial animation parameters by an animation motor.

This experience has also been applied to the field of distance learning. In fact, Artificial Intelligence can provide a very valuable contribution to distance learning: the use of agents to create online tutors supporting the learning process by giving advice and providing appropriate feedback is now very common.

3. The role of the human tutor

In distance learning situations, the user and the tutor will become more familiar as the learning process develops and they get to know each other better. In a traditional situation, the teacher is seen as the *knowledge repository,* whereas in a distance learning situation the teacher figure is replaced by the tutor figure, that has more of an advisory capacity, working to support and facilitate learners working more autonomously, especially in cooperative learning situations [6]

It is clear that in an online course the tutor has a fundamental role of supporting the teaching material and technological device, as well as fostering communication among the participants in the learning process.

The tutor's role is therefore particularly demanding in terms of time. This is the reason why, when setting up an online course, the decision to insert a virtual tutor does not only derive from the need to ensure software usability but also has the advantage of making a tutor figure permanently available to the students. To date, experiences with such a figure have ranged from a tutor that merely guides the navigation of the courseware, to more sophisticated tutors that can simulate a real teacher and provide explanations and appropriate feedback.

The complex nature of the tutor figure in distance learning contexts can be appreciated by distinguishing the different roles, as has been done in the classification below [2, 3]:

- *The tutor as counsellor*: has the task of ensuring that communication among the learners is both simple and productive.
- *The tutor as coordinator:* must provide indications to stimulate, maintain and revive discussions about how best to carry out and coordinate the various work phases.
- *The tutor as trainer:* must support the participants during training exercises. It is essential for the tutor to be continually available to students and to adopt an encouraging attitude to those needing further explanations.
- *The tutor as facilitator:* provides clear indications on how to carry out the activities.
- *Il tutor as moderator:* encourages all discussions proceeding along "parallel tracks" without ever converging, by pointing out the conceptual nodes of the subject, suggesting methods for approaching the problem or taking a position in discussions that are going nowhere.

- *The tutor as organizer:* is especially useful in cases of large groups of participants, where the collaborative activities require strong organizational cohesion and therefore someone who will take care of the collection, summary and review of the work done.

It is evident from the above classification that the tutor figure is particularly oriented toward the support of communication in collaborative and cooperative learning situations. But the classification is especially useful during design of a virtual tutor agent, and this was the starting point of the current work.

4. The virtual tutor

One of the major challenges in the e-learning field is the creation of a virtual tutor that can fully satisfy all the above roles. An analysis of the products currently available on the market has shown that in most of them only some of the characteristics listed above are addressed by the virtual tutor. For example:

1. Language courses on CD-Rom edited by Garzanti Linguistica. In these applications the tutor acts as a guide to the cd rom, offers support in interactive dictation and marks exercises, pointing out the mistakes made.
2. "Orienta tu" introduces the figure of the virtual Tutor, that assists the user to analyze and compare the various offers. "Thanks to the Tutor, the user no longer feels like a midget among giants".
3. On the site www.edufamily.it the tutor provides feedback on the exercises done by the users; assesses events and emits pre-recorded sounds varying according to whether the feedback is positive or negative.
4. On the site: www.smau.it/tecnorama/italiano/flash.html a tutor is provided that guides discovery of the new technologies adopted in the field of distance learning. Its functions are somewhat limited because it only presents the sections and lessons present in the site.

The functions of the above virtual agents are summarized and compared with those of the human tutor in the following scheme:

Table 1. The tutor role in the examples analyzed

	1	2	3	4
Counsellor				
Coordinator				
Trainer	X		X	
Moderator				
Facilitator	X	X	X	X
Organizer				

Without claiming to be useful as a generalization, Table 1 summarizes the results of the study conducted during the phases of analysis of our application. All the applications we studied feature tutors, that generally have the role of facilitator, guiding user navigation, but only rarely intervene during practical work on exercises. The aim of our work was to create a virtual tutor that could support the student during both navigation of the teaching materials and execution of the tests, advising on further study or revision of the topics when necessary. In the following section, the application specifics and the rules used for the tutor are analyzed.

5. The E-Fl@ash course

The "E-fl@sh" project is a multimedial course, available online, that aims to introduce users to the applicative package Macromedia Flash® 5. It is addressed to all users approaching the world of animation for the first time, allowing them to acquire the knowledge needed to start creating animation.

The application integrates an animated agent that can personalize the training path by tailoring presentation to the interaction occurring with the student. For this purpose, the agent keeps trace of the learner's interaction with the teaching content, and intervenes if specific events occur. The tutor figure is indiscreet, in the sense that it only intervenes to suggest actions if such specific events occur.

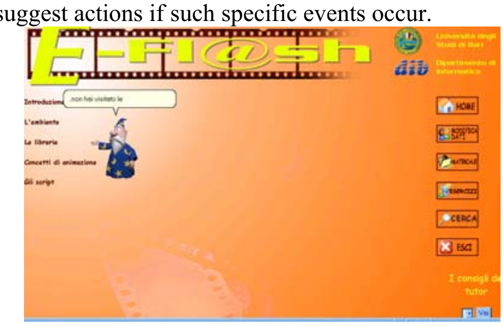

Figure 1. System screen shot

5.1. Users involved and their roles

The potential users of E-Fl@sh belong to two macrocategories: teacher and learner.

The teacher's task is to insert teaching contents in the course, in the form of tests and texts. A series of reports is also available, allowing trace to be kept of the learners' progress, and there is a messaging service available for communicating with the learners.

The learner can: access the course content from any internet point and use the material both on-line and off-line; search for a specific content using an internal search engine; check his/her learning progress with the on-line assessment tests.

The application also provides a virtual tutor that keeps trace of all his/her interactions with the learning content and, on the basis of events, advises the learner about what the next step should be.

Details on the virtual tutor are provided in the next section.

6. The virtual tutor in E-Fl@sh

As considered above, in any learning situation, be it on-line or traditional, the learner needs some support during the learning process. This need is clearly greater in distance learning environments, in which the student plays an active role in the process but is not always able to identify and undertake the right action at the right time, to achieve his/her learning goals.

In the design of E-Fl@sh, therefore, a "tutor" was incorporated to carry out tasks, defined in the light of the roles a human tutor will adopt in a traditional learning situation.

The techniques used to create the tutor in E-fl@sh are based on the problem solving methods used in the Artificial Intelligence field to create expert systems. The idea is to collect the knowledge of teaching strategies possessed by an ideal teacher and apply it at the crucial moments during man-machine interaction. This can be done thanks to the declarative form of knowledge representation used rather than the traditional procedural representation: i.e. to the description of the goal rather than how to achieve it.

In such a system, the teacher's description of all the teaching aims is an essential element, together with all the possible ways of attaining them. It is therefore necessary on the one hand to list the rules that will allow the system to react in a given manner when a given event occurs, and on the other, to install a means of interpreting these rules and recognizing what kind of situation has occurred and therefore what rule to apply.

We stress the fact that the teacher's knowledge of the domain has deliberately been kept separate from the teaching strategies. This permits a wide generalization of problem solving aspects, because by simply modifying the rules describing the knowledge, the tutor can modify the mode of interaction with the learners and adopt different teaching and tutorial strategies.

In the application E-Fl@sh, therefore, all possible intervention by the teacher has been translated into rules for the tutorial component.

Reading of a rule in natural language is of the type:

*"IF the condition occurs **then, perform** action"*

where this representation of the knowledge makes it possible to define: the conditions, as the state in which the student or system could be and the action, being the intervention to be made if the condition has occurred.

The rules defined are completely context-independent, but are closely dependent on the teaching structure: the content in E-fl@sh is organized so that each assessment test is linked to a given topic, a map and a set of exercises. For this reason, the rules are defined on the basis of the results obtained in the test, the number of pages on the topic visited and whether or not the map has been viewed. The conditions therefore have the following format:

Table 2. The format of rule conditions

Assessment test score (**ScoreTest**)	AND
How many pages on the topic have been visited (**VisitedPage**)	AND
Has the Map been viewed? (**Map**)	AND

Some of the rules used by the tutor are shown below:

Table 3. Some tutor rules

ScoreTest	VisitedPage	Map	Action
Low	Low	NO	More in-depth study of the topic advised
Low	None	NO	Viewing the topic before doing the test is advised
Low more than once	Low	NO	Shows the map and inhibits access to the test until the theory pages have been studied
Low more than once	High		Shows the map and in-depth study pages on the topic
High	None	NO	Poses another test to confirm mastering of the topic
None	High	NO	Shows the map and suggests doing an assessment test

None	M	YES	Shows the assessment test

7. Conclusions and future work

It has now been amply demonstrated and proven that distance learning supported by technology gives learners an active role in their learning process. Not only does this help them to master specific contents but it also fosters the development of self-regulation skills. It is also true, however, that not all learners are equally able to manage their learning process efficaciously. That is why a tutor figure is needed to supply suitable support and stimulation.

This work presents a first prototype of a virtual tutor embedded in a multimedial distance learning course. The idea of the tutor stemmed from shared reflection on our experience with Artificial Intelligence, virtual agents and distance learning systems.

We are currently designing experiments to be carried out to assess the efficacy both of the course content and above all of the embedded virtual tutor and relative tutorial rules.

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The ECDL Certification of ICT Usage Skills in the Italian Universities

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Abstract

We present the results of a monitoring exercise whose objectives were to analyze the experiences of the Italian Universities in the framework of the ECDL programme and to assess the impact of the ECDL certification in the Universities. Our investigation focused on the ECDL projects carried out by 50 Universities in the year 2004. The analysis has shown that the ECDL certification was used by the majority of the Universities to assess the basic computer skills of their students. On the contrary, the organizational and teaching profiles of the Universities varied as a function of their size.

1. Introduction

The Italian Government, following the EU Lisbon summit held in the year 2000 [1], started a program to increase among the citizens the ability of using information technologies. Special attention was devoted to the University students: the Italian Ministry of Education, Universities and Research made a specific choice, inserting in all University curricula credits devoted to acquire some specific knowledge of ICT technologies.

The development of basic ICT abilities in our Higher Education system is hindered by the high heterogeneity of practices and policies following from different educational priorities, professional goals and funding sources. Establishing a practical benchmark capable of defining a good nation-wide educational ICT profile is quite difficult. A practice that has worked well in one context, may not work at all in a different one. The wide diversity of educational systems employed in Italian Universities prevented the transfer of practices from one environment to another.

The Ministry then decided to endorse the standard of the European Computer Driving License (ECDL). This programme addresses the problem of establishing a benchmark of basic ICT skills, i.e., skills that everyone should possess [10].

The ECDL programme was initially introduced in Finland and then promoted at European level [3] by CEPIS (Council of European Professional Informatics Societies http://www.cepis.org). Currently, the governing body of the programme is the European Computer Driving Licence Foundation (ECDL-F http://www.ecdl.com). AICA, the Italian member of CEPIS, is the certification authority that manages the programme in our country.

The main features of the ECDL programme can be summarized as follows:

- *internationality*: 137 countries world-wide have adopted the programme; the certification exam, based on the so-called QTB (Question and Test Base), is available in 32 languages;
- *integration between academia and industry*: the programme is supported by the national professional societies that integrate professional and academic competences;
- *technological neutrality*: the programme defines ICT skills independently of hardware and software vendors; in particular, it is possible to obtain the certificate using only open source non proprietary technologies.

The ECDL certificate proves that its recipient possesses some basic skills in using a computer, such as editing a document with a word processor, preparing a table using a spreadsheet, querying a database, browsing the Web.

The ECDL syllabus consists of seven modules:

1. Basic concepts of information technology

2. Using the computer and managing files
3. Word processing
4. Spreadsheets
5. Database
6. Presentation
7. Information and communication.

The certification is released to whomever correctly performs a set of activities randomly extracted from the QTB, which is not public. The exam is fully automatic. There are two types of certificate: a START license (obtained after passing the exams of four out of seven ECDL modules) and a FULL license (obtained after passing the exams of all seven ECDL modules). Exams take place in Test Centers. In Italy, these Centers are specifically accredited for this purpose by AICA.

The ECDL programme is ten years old, and millions of people have already received an ECDL certificate all over the world. Some papers study its impact in Higher Education. In [5] the impact of the ECDL programme in Irish Universities is evaluated. The diffusion of the ECDL programme in the Italian Universities in the year 2003 is presented in [2]. In [4], the ECDL programme is used as a reference standard to define basic skills of nurses and nursing staff. The results of a project for forming University staff for ECDL via e-learning technologies are analyzed in [8]. In [9], authors describe how the programme can be adapted to special situations, like for instance those dealing with students with physical handicaps.

In this paper we present the results of a monitoring exercise aimed at analyzing the experiences of the Italian Universities in the framework of the ECDL programme in the year 2004. Our analysis focused on both the organizational and teaching aspects addressed by the Universities in the implementation of their ECDL projects. The results reported in this paper refer to 50 Universities that had ECDL projects active in the year 2004. As a similar investigation was carried out for the year 2003, in what follows, we also present a few comparisons between the outcomes of the two analyses.

The paper is organized as follows. Section 2 presents some quantitative results related to the performance of the ECDL programme. Section 3 focuses on the organization adopted by the Universities to teach the ECDL syllabus. The position of the Universities with respect to the credits awarded to the students is discussed in Section 4. The organizational and teaching profiles that characterize the Universities are presented in Section 5. Finally, a few conclusions are drawn in Section 6.

2. ECDL performance

As already pointed out, the results of our investigation refer to the ECDL activities performed by the Italian Universities in the year 2004. A first interesting result of our investigation concerns the level of diffusion of the ECDL programme in the Italian Universities. It is worth to underline that in the year 2004, it was active in the 92.6% of the Universities, that is, 50, that participated to our monitoring exercise.

Another important aspect of our investigation deals the number of students involved in the ECDL programme. For the year 2004, this number was equal to 50,755, and among these students, 25,263, that is, about 50%, were females. The number of students involved in the ECDL programme in the year 2003 was much higher, namely, equal to 101,635.

It is worth to underline that the reduction of this number is linked to both the decrease of number of students enrolled in the Universities and to increased diffusion of the ECDL programme in high schools.

A fundamental outcome of ECDL programme is represented by the number of exams, related to the single ECDL module, performed by the students. In the year 2004, the total number of exams performed by the students was equal to 144,649. The number of exams passed by the students was equal to 120,266, with a success rate equal to 83.14%. By comparing these results with the results of the year 2003, we notice an 18% increase of the success rate, that is, the students did much better in the year 2004.

The investigation has then examined the number of ECDL START and ECDL FULL certifications awarded to the students during the year 2004. The analysis has shown that 11,842 students received the ECDL START certification, whereas 8,612 students received the ECDL FULL certification. This means that about 40.3% of the students involved in the ECDL programme received a certification. In particular, 23.3% of the students received the ECDL START certification and 17% received the FULL certification.

Table 1 summarizes the performance of the ECDL programme in terms of number of exams and number of certifications awarded to the students in the years 2004 and 2003. The table also shows the relative difference between the two years.

Table 1 – Performance of the students in the years 2004 and 2003.

	Year 2004	Year 2003	Δ
Number of exams performed	144,649	124,159	+14%
Number of exams passed	120,266	98,849	+18%
Number of ECDL START certifications	11,842	10,759	+9%
Number of ECDL FULL certifications	8,612	8,029	+7%

As can be seen, in the year 2004, both the number of exams performed by the students and the number of exams passed increased by 14% and 18%, respectively. Moreover, even though the number of students involved in the ECDL programme in the year 2004 was much lower, the number of ECDL certifications awarded to the students was higher. This means that the ECDL programme had a much better performance in the year 2004.

3. Teaching organization

An important aspect of the ECDL programme deals with the organization chosen by the Universities to teach the ECDL syllabus. ECDL teaching can rely on different methods, namely, classroom teaching (with the co-presence of teacher and students), self-learning, and blended learning (that combines classroom and self-learning methods). Each University can typically adopt more than one method since teaching activities are typically customized to the background of the students and to the requirements of the individual curricula.

Our analysis has shown that 32 Universities, that is, 64% of the Universities that participated to our monitoring exercise, adopted some form of blended learning, whereas classroom teaching and self-learning have been chosen by 26 and 28 Universities, respectively.

By looking at the combinations of the various teaching methods, it is interesting to notice that the teaching activities of 26 Universities, that is, 52%, relied on more than one teaching method and among these Universities, 14 adopted all the three methods. The analysis has also shown that the majority of the Universities that chose only one teaching method, namely, 11 out of 20 Universities, relied on blended learning.

The organization of teaching activities was further analyzed by focusing on the number of hours taught for each ECDL module. On the average, the Universities organized courses whose duration ranged between 6.5 hours, corresponding to the "*Using the Computer and Managing Files*" module, and 9.3 hours, corresponding to the "*Database*" module.

To get better insights in the teaching organization chosen by the Universities, we analyzed the number of hours taught for each ECDL module. Figure 1 plots the corresponding distribution. Note that the distribution refers to the Universities that offered courses for the individual ECDL modules. Indeed, the teaching activities of a few Universities did not cover all seven ECDL modules mainly because these Universities focused on the ECDL START certification, that requires only four out of the seven ECDL modules. The figure shows that the choices operated by the Universities were rather uniform. In the majority of the Universities, the classroom teaching activities dedicated to each ECDL module did not exceed 8 hours, whereas the duration of very few courses exceeded 12 hours. Negligible was the number of Universities that offered courses whose duration exceeded 20 hours.

Another interesting result deals with the presence of tutors to support the teaching activities. The analysis has shown that 44% of the Universities employed tutors to help students with the laboratory experiences carried out during classroom teaching. Moreover, 50% of the Universities employed tutors as an aid for students during the whole ECDL learning process. This is particularly important because of the increasing presence of self-learning either used in isolation or in combination with classroom teaching.

Self-learning experiences have been investigated by analyzing the types of learning resources used to support these activities. On-line and off-line multimedia and printed material were typically used in combination. Even though there were a few Universities that

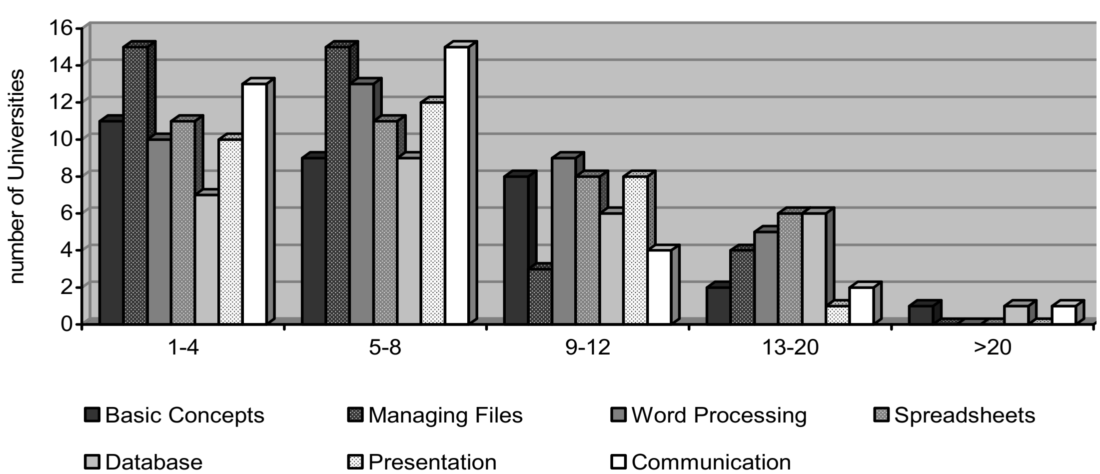

Figure 1 – Distribution of the number of hours taught by the Universities for each ECDL module.

developed their own learning resources, the majority of the Universities relied on material available on the market, with a preference towards off-line material.

4. Credits

In our investigation, we also focused on the importance granted to the ECDL certification inside the curricula of University students. For this purpose, we evaluated the number of credits associated to the ECDL certification by the Universities involved in our monitoring exercise.

As a consequence of the Bologna pan European agreement dated 1999 – aimed at improving and standardizing Higher Education for people all over Europe – the Italian University system introduced the credit (usually referred with the acronym *CFU*, deriving from the Italian definition of Credito Formativo Universitario) as the measurement unit to quantify the learning effort required for students to graduate. Following the recommendations of the ECTS (European Credit Transfer System) a full time Italian University student is expected to "earn" 60 *CFU*s per year, where each *CFU* corresponds on the average to 25 hours of global student effort (i.e., lectures, exercising, laboratories, and individual study).

Due to the autonomy of each University in defining the *CFU* distribution of its own curricula, no common specification of the number of *CFU*s corresponding to the ECDL certification has been given. As a result, the Italian Universities made very different choices, as shown by Figure 2, which presents the minimum and maximum number of *CFU*s associated with the ECDL certification. As can be seen, the number of *CFU*s awarded to the ECDL certification ranged from 0 to 10. This clearly shows the lack of any reference agreement among the Universities.

Actually, if we look at each single University, we definitely find a more regular behavior: as represented in Figure 3, most Universities adopt very limited ranges of *CFU*s (i.e., difference between the maximum and the minimum number of *CFU*s associated with the ECDL certification) for their own curricula.

However, to better comply with the aim of improving the student mobility across Universities, some reference values would be very beneficial. For this purpose, it is possible to notice that the distributions shown in Figure 2 are characterized by mean values equal to 2.89 and 5.31, respectively, and that the modes of these distributions are equal to 3 and 6. This range of values seems then a reasonable reference for the ECDL certification.

Different considerations deserve the Universities that assigned zero *CFU* to the ECDL certification: for these Universities, the ECDL certification was clearly considered as a pre-requisite for the corresponding academic programme. In perspective, this choice seems the most appropriate: the level of competence certified by the ECDL programme is actually very basic, and increasingly owned by high school students before entering the University.

5. Organizational and teaching profiles

A multivariate statistical analysis, based on both Correspondence Analysis (CA) and Principal Component Analysis (PCA) [6] [7], allowed the identification of some profiles characterizing the management of the ECDL programme in the Italian Universities. To this end we used also a supplementary variable, namely, the size of the Universities: large, medium or small size, "superlicei", polytechnic, and private. Both CA and PCA highlighted two main profiles characterized by a centralized versus a decentralized management model, where the first one is characterized by centralized decision-making processes and organization of ECDL activities. These profiles emerged, albeit at a different level, with respect to the three dimensions investigated, that is, the organizational, regulatory, and teaching issues. Similar profiles were found also in the previous investigation referring to the year 2003. In particular, a more decentralized

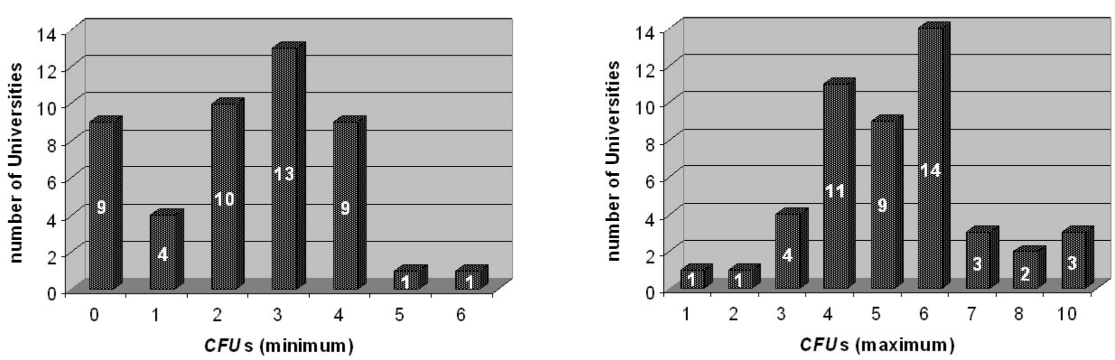

Figure 2 – Distribution of the minimum and maximum number of *CFU*s associated to the ECDL certification.

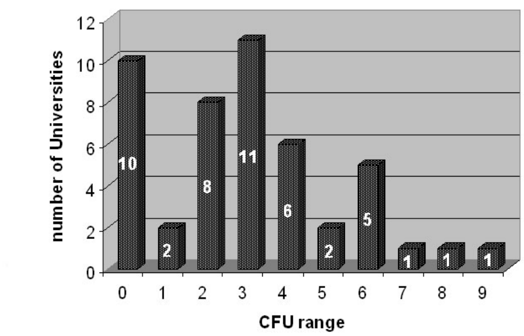

Figure 3 – Distribution of the *CFU*s range.

management structure was prevalent in large Universities, frequently spread over several campuses, with several entities organizing courses and exams, namely, Faculties, Degree Courses, external organizations; on the contrary, small and private Universities usually preferred a centralized approach, with a single teaching and Test Center serving all Faculties.

Focusing on the results for the organizational dimension (Figure 4), the first observation regards two contrasting areas that are separated by the vertical axis. On the right we find Universities with a centralized organization of the ECDL activities and on the left the Universities with mostly decentralized activities. More specifically, the Universities that activated courses at a centralized level nearly always organized in the same way both exams (93% of Universities) and training (86%). On the other hand, the rules regarding the ECDL certification were often defined at a decentralized level. In terms of financing of the teaching and testing activities, it is common across the board to make use of the funds provided by the CampusOne funding scheme but it also emerged that large and polytechnic Universities more frequently recur to direct forms of payment. "CampusOne" was a project (http://www.campusone.it) of the Conference of Rectors of Italian Universities (CRUI) that was launched in the year 2002 to promote the ECDL programme in the Italian Universities and has strongly contributed to the diffusion and the acceptance of the culture of the ICT certifications even beyond ECDL.

As regard to the regulatory dimension, it is worth noting that wherever the certification was obligatory, the ECDL START was required. Rules regarding the ECDL certification were often defined at a decentralized level. Moreover, the number of credits was higher in the Universities where the certification was obligatory.

6. Conclusions

Our monitoring exercise has shown that the majority of the Italian Universities adopted in the year 2004 the ECDL certification to assess the basic computer skills of their students. Moreover, the prevalence of the ECDL START certifications is a demonstration that the Universities considered this type of certification as a "reasonable" first-level approach towards the ICT education.

The teaching organization was characterized by a large variety of choices for what concerns the organization of the courses to teach the ECDL syllabus and the number of hours dedicated to each ECDL

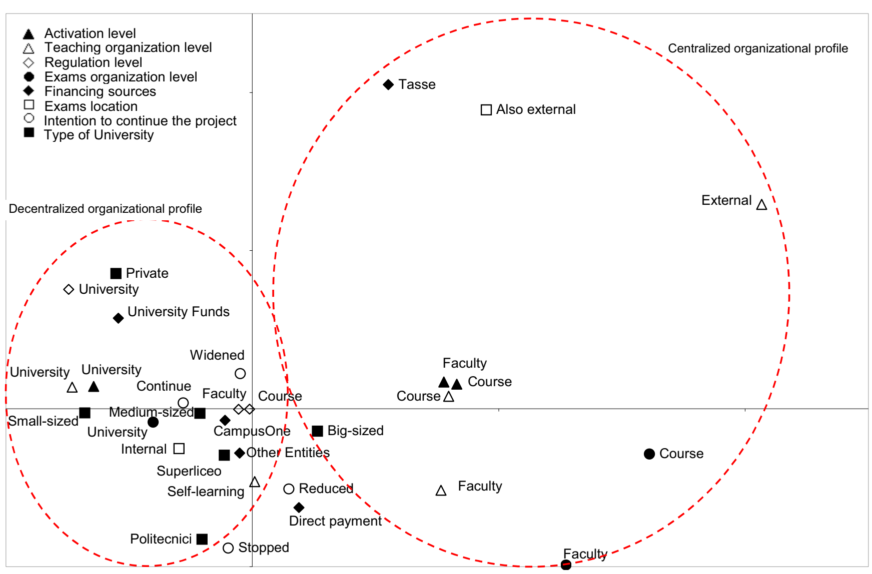

Figure 4 – Correspondence Analysis for characters related to the organization of the ECDL programme.

module. It is interesting to notice the presence in many Universities of tutors to support students during the overall ECDL learning process.

The analysis of the organizational and teaching profiles has shown that the choices operated by the Universities were typically influenced by their size.

Acknowledgements

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e-Learning of Traditional Medicine Course for Elementary and Middle School in Taiwan

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***Abstract*—Herbal medicines are very popular taken in dietary and tonic food by eastern country people. Since 5,000 years ago, eastern traditional medicine has been practical used in China for disease prevent and treatment. Most of the theory is acuminated from the experience and some of the enthnomedicine. Recently, the natural therapy is very commonly used by clinical doctors in the world. And the biotechnological research papers were published in LAN cent and many Medicinal Journals. The education and research are more important than the western medicine. For the western medicine has a systematic teaching course in medical school. Therefore, how to remind the people which should be comprehended according to traditional Chinese Medicine and avoid confusing and easy understanding courses were necessary works for today's education. E-learning course is a convenient, high speed spreading teaching to the whole world. In this study, we have created a new teaching platform of traditional medicine that can help people easily to learn traditional medicine in entire life. The references of traditional medicine were collected and edited into digital lesson plans, such as VCR, games, or flashed cartoons. The diversification of digital lesson plans can help people learning the traditional medicine easily. Moreover, the e-learning teaching method can let a lot of people to obtain the information by networks, and learn how correctly used the herbal medicine in daily foods. In this course, the contents of the e-learning were suitable for the elementary schools to undergraduate schools, and everyone who is interesting in traditional medicine. In summary, the digital lesson plans of traditional medicine offered a good method to teach and learn traditional medicine.**

Keywords: e-Learning ; Traditional Medicine Course

I. Introduction

Maintaining the health of oneself is all base, training and teaching learner's correct and useful health knowledge is very important. Chinese Medicine Prescription has been used in clinical for thousand years. And traditional medical science is countless intelligence that is worth application for maintaining human health. But Chinese medicine education curriculum isn't one part of the elementary school or high school courses in Taiwan. Therefore, how to remind the people which should be comprehended according to traditional Chinese Medicine and avoid confusing and easy understanding courses were necessary works for today's education.

Digital learning is very important gateway in 21st century that is a convenient, economy effective, high speed spreading teaching to the whole world. In this study, we have created a new teaching platform and interactive multimedia of traditional medicine content that is created for use on-line has to bring added value to the learner and support teachers in helping students to understand easily concepts of traditional medicine.

II. The framework of Chinese medicine learning classroom

The on-line courses designed for general people to learn health knowledge. The Chinese medicine section provides links to interesting on-line courses, learning about herbs materials and other e-learning solutions for Chinese medicine education as well as for general interest. The nine course sections the use of multimedia and learning interactions in e-learning and blended learning to improve health skills and knowledge.

This interactive multimedia was created, including (1) Special training area for learning of Chinese traditional medicine Concepts. For example, *Ying and Yang* theory, *Five elements* (wood, fire, earth, metal, water) theory, *Four property of food or drug (*warm, cold, hot, cool and neutral) theory, *Six excessive or untimeliness atmospheric influences* as exogenous pathogenic factor (wind, fire, summer heat, dryness, dampness, cold), *Eight therapeutic methods* (diaphoresis, emesis, purgation, mediation, invigoration, heat reduction, tonification, and resolution) and livelihood with four seasons and environment change.(2)Top shop of Chinese herb (knowledge of Chinese medicine herb).(3)Live in city (Chinese medicine herbs applied in live).(4)Keep in good health in hall (Traditional Chinese medicine).(5)Formosa tribal unit (folk medical herbs).(6)Super-cool game (teaching game). (7) Film city of time (Teaching activities videos or photos). (8) Network island. (9)Update news unit that we can update the knowledge about health and Chinese medicine, (Fig 1,2) that is very base and important for learning about Chinese medicine .

III. TYPES OF MULTIMEDIA

It is wonderful experience to discover and acquire knowledge by oneself. The pedagogical model of explore learn type was be adopted. And for enhance student's learning motivation and interest by adopting the activity of the game type.

The students were exposed to interesting computer learning environment that embodied the lesson of Chinese medicine guidelines set. By searching on-line, the students were able to find and learn about Chinese traditional medicine and take care himself.

Here are four key models for Project-Based learning, PBL: (1) Teaching video or photo model, (2) Flash 2D or 3D teaching animation model, (3) context model for learning the knowledge about Chinese medicine and (4) interactive game model for examine or review have learned knowledge of Chinese medicine.

IV. SUMMARY

Today it is true that the media, new and traditional, are being transformed to the digitalisation phenomenon. This has happened with the radio, television, cinema, press, etc. Because of the development of information science and technology, becoming a effective tool which can be used with conveniently of information on the network. How make the correct of network resource and how offer high-quality Chinese medicine multimedia resource to have message or function of efficiency even more network, it is this research expects to probe into.

The e-learning teaching method can let a lot of people to obtain the information by networks, and learn how correctly used the herbal medicine in daily foods. In fact many teachers need to acquire urgently health knowledge and teaching media of resources available and how to retrieve them and embed them successfully in their classroom practice. And since new Chinese medicine courses were established and executed, the Chinese medicine education curriculum is becoming interesting and economy effective, can applied by teacher to improve students' learning or support student learning Chinese medicine course by oneself just in time and on demand. It is important to edit successfully media for e-learning; you need to make it short (not longer 2 minutes) is required and content link will be convenient.

In conclusion, we would like to develop funny, impressive, engaging, and easy learning digital multimedia and courseware of Chinese medicine knowledge. This multimedia were created using 2D and 3D technology, complex animations, stunning graphics and charts, text, video for learners or visitors will understand and state the concepts of Chinese medicine by e-learning method, apply Chinese traditional medicine knowledge in maintaining actual healthy life daily that acquire from experiencing studying and web learning and learn it continuously.

In addition, successful programs or multimedia for Chinese medicine learning to enhance digital integration and professional intensification, closer co-operation between the educator, artist, computer designer, and Chinese medicine expert is urgently needed. We now can do it, and we should.

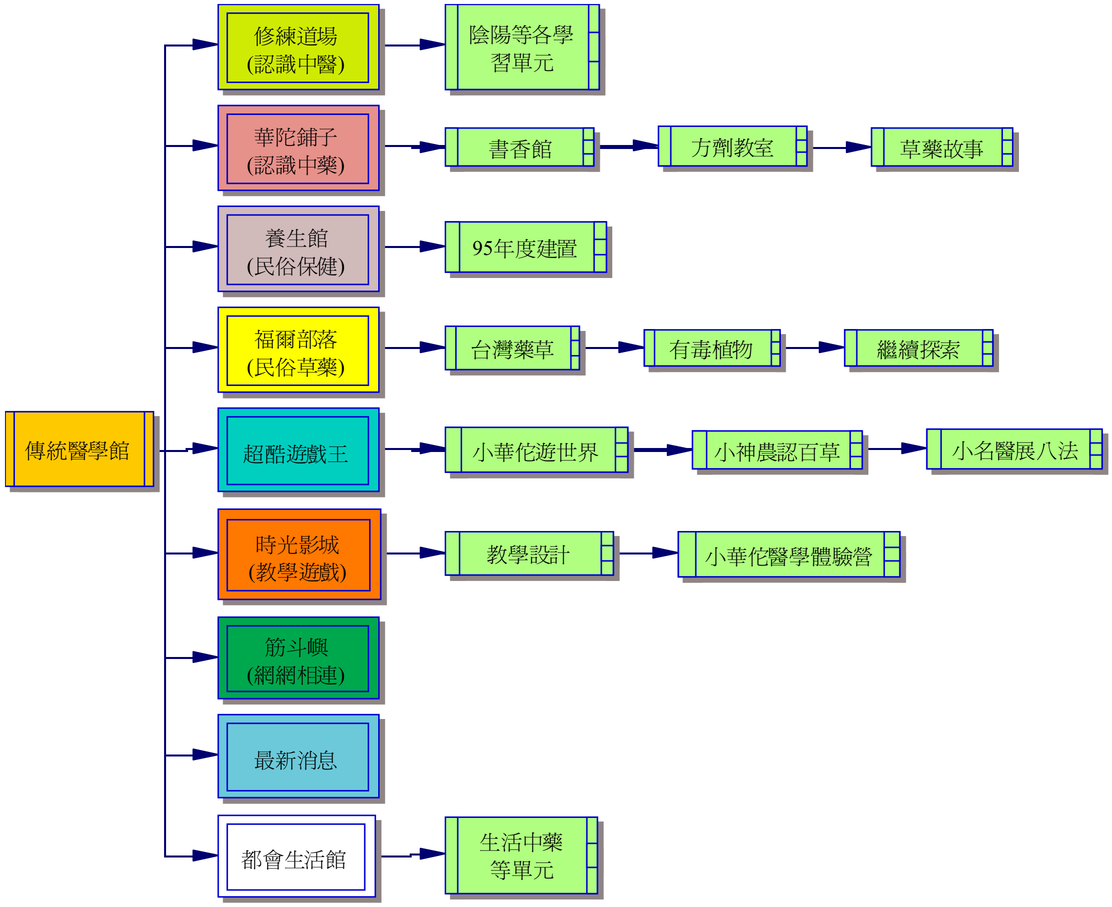

Fig. 1 The framework of Chinese medicine learning classroom

Fig. 2 The pattern of Chinese medicine learning classroom

The Design and Implementation of the Chronobot/Virtual Classroom (CVC) System

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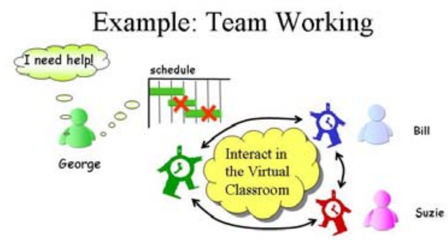
Abstract

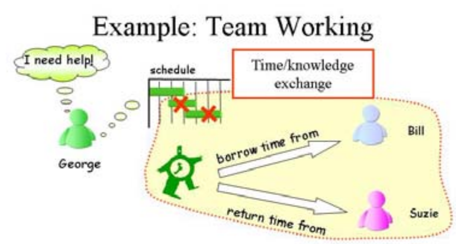
In this paper, we describe our approach to the design and implementation of the Chronobot/Virtual Classroom (CVC) system, which is a novel time/knowledge exchange platform. The system is based upon a flexible, component based architecture. The messages used by the distributed components are formulated in XML, and every component can be tested separately. The communication server is built on the basis of the Java Messaging Service (JMS) engine. Message archiving techniques are described to support unlimited message retrieving. Verified in practice, the system can provide an operational, robust platform for time/knowledge exchange in e-Learning and distance education.

1. Introduction

Chronobot/Virtual Classroom (CVC) [3] is a novel time knowledge exchange platform where any pair of users can exchange their time and knowledge. The chronobot is a time management tool for storing and borrowing time. Using Chronobot, one can borrow time from someone and return time to the same person or to someone else. The virtual classroom is a versatile communication tool that combines the functions of a web browser, chat room, white board, and multimedia display. The CVC system is an integration of the chronobot and virtual classroom that allows users to freely switch between these two applications and obtain maximum benefits from both.



(a)



(b)

Figure 1. Application of the CVC system:
(a) Communication in Virtual Classroom; (b) Time and knowledge exchange in Chronobot

For example, as illustrated in figure 1, George, Bill, and Suzie are all students who are doing a group project together in a graphics design course in which they use the CVC system to collaborate with each other. The whole project is divided into several tasks, each of which is mainly assigned to one person. George meets a problem in his task and cannot solve it by himself. So he interacts with Bill and Suzie in the virtual classroom, and eventually they help him out. However, in order to keep workload even among teammates, George has to put in efforts either in the past or in the future to help Bill and Suzie. The chronobot serves as a platform for them to do such time and knowledge exchanges which could have significant value for many applications. Many more interesting scenarios can be found in [3].

In this paper, we describe our approach to the design and implementation of the CVC system. Aiming at a large-size, reliable, and scalable communication system, we have designed a flexible, client/server based system architecture. The functionality of servers and clients are broken down and encapsulated into components. The messages exchanged among components are formulated in a platform-independent format (XML), and every component can be separately tested using a customized testing tool, (the remote control). The most important server – the communication server – is designed and implemented based on an open source Java Messaging Service (JMS) engine, ActiveMQ [1]. Additionally, a message archiving mechanism allows users to retrieve messages within any time range.

The rest of this paper is organized as follows: the overall architecture of the CVC system is described in Section 2. In Section 3, we discuss message formulation and testing of the distributed components in the system. The communication servers and client tools are described in detail in Section 4 and 5, respectively. Message archiving is discussed in Section 6, followed by a brief conclusion in Section 7.

2. System Architecture

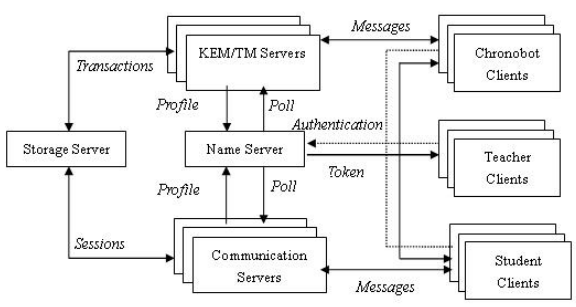


Figure 2 System Diagram

The CVC system is illustrated in Figure 2. Basically, the system follows the client/server architecture. The clients (e.g., chronobot, teacher, and student clients) provide user interfaces interacting with different kinds of users. The time/knowledge exchange and related functions are implemented by services from the different servers (e.g., name server, KEM/TM (Knowledge Exchange Management/ Time Management) server, communication server, and storage server). Following is a brief description of these servers and clients:

- Chronobot Client: a tool for chronobot users to exchange time and knowledge.
- Student Client: a tool for students to attend the classes in the virtual classroom.
- Teacher Client: a tool for teachers to attend classes in the virtual classroom. Besides the basic communication functions found in the student client, it is equipped with some administrative functions (e.g., permission manipulation and student grades management).
- Name Server: a server providing naming services for all clients and dynamically managing the working load of the communication servers and KEM/TM servers.
- Communication Server: a server providing communication services for virtual classroom clients (i.e., teacher and student clients). The messages for learning activities in the virtual classroom are all relayed by the communication server and are recorded as *learning sessions,* or simply *sessions*.
- KEM/TM Server: a server managing time and knowledge exchange for chronobot clients. The transactions on time/knowledge are all performed in the KEM/TM server, which are recorded as *time/knowledge exchange transactions*, or simply *transactions*. For more detail about the KEM/TM server, please refer to [2, 6].
- Storage Server: a server storing the *time/knowledge exchange transactions* from KEM/TM servers, and the *learning sessions* from communication servers.

In the entire system, there is only a single instance of the name server, which is required to be known by all clients and other servers. Multiple instances of the communication and KEM/TM servers can work at the same time. When these servers start up, they will register their profiles (address, capabilities, current work load, etc.) with the name server. The name server will dynamically assign tokens to the teacher, student and chronobot clients after the proper authentication. In order to balance the workloads among the servers, periodically the name server polls messages to the communication and KEM/TM servers to fetch their status.

3. Message Formulation and Component Testing

(a) (b)

Figure 3 Messages for Authentication Component in Name Server (a) Incoming message; (b) Outgoing message

The servers and clients in the CVC system are designed based on components, which are encapsulated software elements with specific functionalities [4]. For example, the name server is designed and implemented by three components, i.e., an authentication component, a profile retrieving component, and a workload balancing component. Every component has an interface designed to achieve maximum flexibility and reliability and may be configured by incoming and outgoing messages in XML. These XML messages are partially described in [5]. For example, the authentication component in the name server may be configured with the incoming and outgoing messages shown in Figure 3.

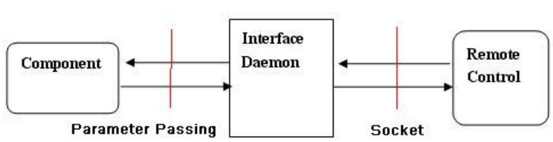


Figure 4 Testing a Component Using Remote Control

One of the most important advantages of component-based design is that the components can be tested separately without implementation of the whole system. For this purpose, a customized testing tool named *remote control* was designed and implemented. Shown in Figure 4, the remote control can simulate any incoming messages via a programming language-independent interface (i.e., Socket). At the same time, it can receive any outgoing message transmitted by the component.

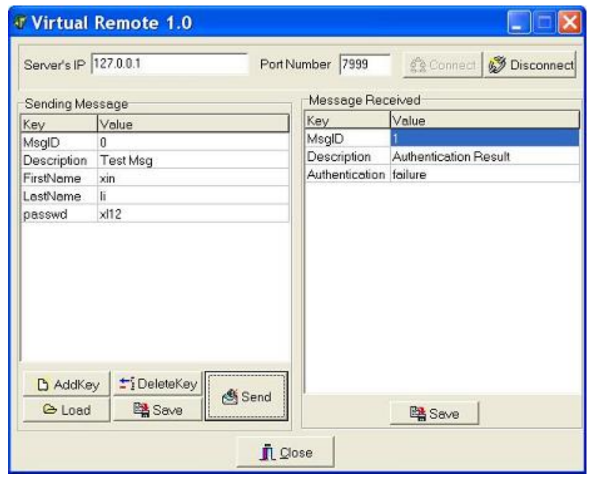


Figure 5 Remote Control (with Testing Results on Authentication Component)

Using the remote control, the functions of components can be easily verified before they are integrated into the real system. For example, Figure 5 shows the remote control with the testing results on the authentication component of the name server. A tester can send the authentication component messages containing different pairs of user names and passwords. From the server responses received by the remote control, it is very easy to check whether the component works as expected.

4. Communication Server

The communication server is one of the most important servers in the CVC system. It supports the message transmission (either broadcast or peer-to-peer) for the whole system. The communication medium used is HTTP based using an open source Java Messaging Service (JMS) engine called ActiveMQ [1]. Using HTTP protocol makes the communication stateless, and the ActiveMQ messaging allows for a persistent messaging protocol.

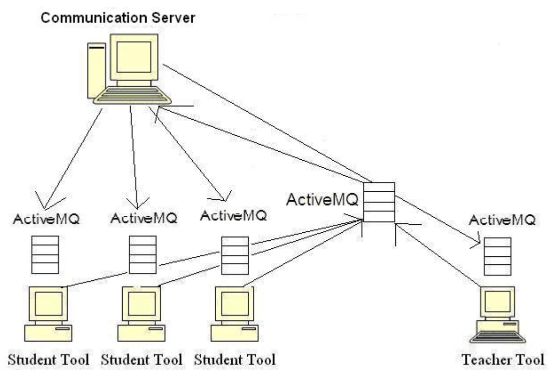


Figure 6 System Diagram of Communication Server

Figure 6 shows the system diagram of the communication server. Each student/teacher tool (i.e., client) writes to the same upload queue. The communication server reads all messages from this queue and reacts accordingly, writing all messages to the student/teacher tools to individual queues A java servlet is used to create an HTTP interface to a queue. This needs to be in place to take HTTP posts and HTTP gets from all ActiveMQ servers and clients. For more information about ActiveMQ refer to [1].

5. Client Tools

There are three client tools used in the CVC system: 1) the student client, 2) the teacher client, and 3) the chronobot client. Each is described in detail in the following sections:

5.1 Student Client

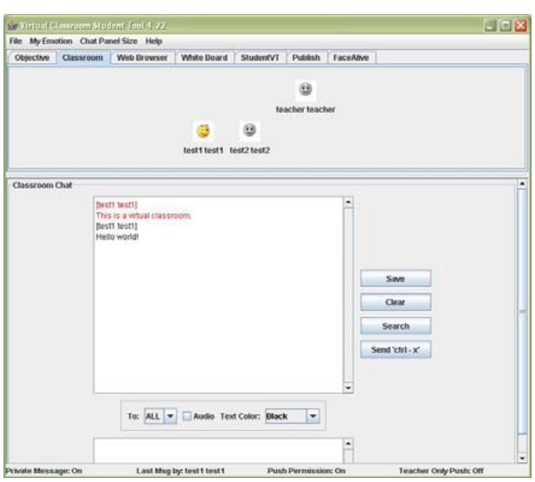


Figure 7 Student Client

The student client is designed for students in the virtual classroom and is illustrated in Figure 7. The students (represented by emotive icons) can join a virtual classroom and exchange information in the form of text messages, web pages, sketches, and audio/video clips. The emotive icons express the feelings of a user during a learning session.

5.2 Teacher Client

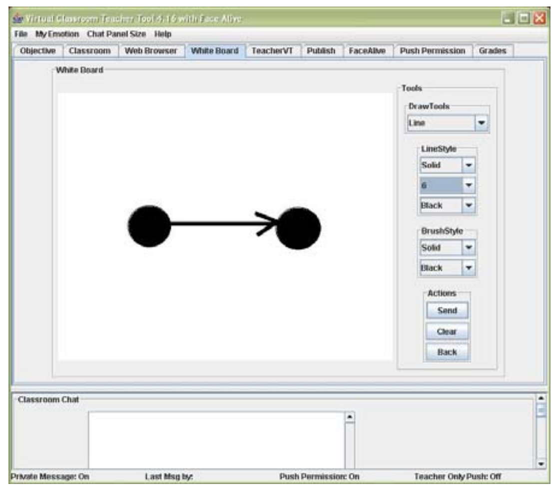
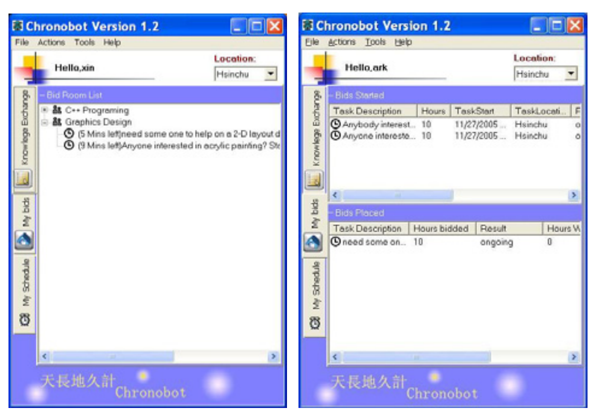


Figure 8 Teacher Client

The teacher client is designed for teachers in the virtual classroom and is illustrated in Figure 8. In addition to all the functions as available in the student client, the teacher client also includes certain administrative functions, including permission manipulation and student grade management.

5.3 Chronobot Client



(a) (b)

Figure 9. An example of chronobot, (a): bidding room for time knowledge exchange; (b): transaction records.

The chronobot client (illustrated in Figure 9) is designed for users in the chronobot system. Basically, the chronobot client is a tool to exchange time and knowledge though bidding processes. Users can start new bids in different bidding rooms (figure 9(a)). A simple example of such bidding is “I need someone to help me on a 2-D layout design for 5 hours”. Users can respond to these requests by placing their own bids. For example, a user can respond with “I can contribute 2 hours on it”. The details about these transactions are saved into each user’s record (figure 7(b)).

6. Message Archiving

The time/knowledge exchange transactions and learning sessions accumulated in the CVC system are the most valuable assets for further knowledge acquisition (e.g., user profiling and ontology construction). Following is a brief description of the techniques used to store and retrieve transactions and sessions.

6. 1 Message Storage

This is conceptually a very simple operation:

1. The server pulls messages from the main queue regularly;
2. The server stores the messages in a special table with the following basic (high-level) structure (Figure 10).

Course	From	To	Content	Time Stamp
		{ALL, <specific user ID>}	(set of fields)	

Figure 10 Message Structure

The timestamp field stores the date and time where the message was *received* by the server, not the client’s clock’s time since it can happen that the clocks are not synchronized. This serves to maintain consistency.

6. 2 Message Retrieval

The sequence of operations to retrieve messages from the storage is described below:

1. The user authenticates as usual, and after that, s/he selects the course s/he wants to retrieve messages from;
2. The user asks the system to show the retrieve message history dialog (Note that at this time, this option is only available after the user has enrolled a course);

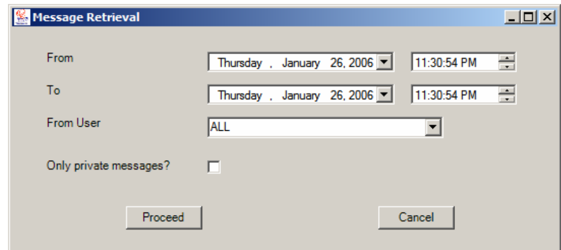


Figure 11 Message Retrieving Dialog

3. The user selects a range of dates, user IDs (of the course participants), and whether s/he wants to retrieve private messages only;
4. The client pushes a special message in the main queue that indicates that the server must perform a message retrieval;
5. Once the server receives the retrieval message, it queries the database using the criteria specified by the user;
6. All the messages found (if any) are posted in the specific queue of the user who requested the history;
7. If no message was found, a special “not found” message is posted in the client’s queue;
8. Once the client retrieves the search result from the user’s queue, it either shows the messages in the message panel, or, in the case that no message was found, the user is notified accordingly;

7. Conclusions

In this paper, we described our design and implementation of the CVC system, which is a novel time/knowledge exchange platform. A flexible, client/server based system architecture was described in which the clients and servers are all designed based on components that can be tested separately using our customized testing tool (remote control). The communication server is designed and implemented using ActiveMQ. The client tools for the users of the virtual classroom and the chronobot were described as well, as were the techniques to store and retrieve time/knowledge exchange transactions and learning sessions. Verified in practice, the system can provide an operational, robust platform for time/knowledge exchange in e-Learning and distance education.

8. Acknowledgements

This research is supported in part by the Industry Technology Research Institute (ITRI) and the Institute for Information Industry (III) of Taiwan. We would like to thank Christopher Santamaria for the design and implementation of virtual classroom Java clients, and too many others to name here for testing our CVC system.

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Evolution of IMA as a Tool for Accommodated Learning

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ABSTRACT

IMA is a tool that has been developed to assist learners in customizing their learning experiences. It functions in most browsers, and is currently developed to run in a local environment.

Students have several options in terms of creating a personalized accessible learning environment over the Internet. IMA serves as a tool for asynchronous, accommodated learning to a diverse global student body.

Feedback from testers of IMA has been incorporated into the application, so that IMA can evolve. The goal is to design and create a robust, standards-compliant, open source and cross-platform software system. By using developing and developed international standards rather than proprietary systems, users are free from operational limitations and long-term maintenance costs of proprietary systems. Open-source software will maximize the chances of developing robust and bug-free systems, because many programmers will scrutinize the code. Software that runs on all platforms ensures that the maximum number of end-users will be able to take advantage of IMA.

KEY WORDS
Education for Students with Special Requirements, Distance Education tools, methodologies

1. Introduction

The educational bandwagon has, over the course of time, carried many passengers. For many educators, 'hot' phrases like 'active learning,' 'peer instruction,' "collaborative learning' and 'web-based learning" have changed over time, as the focus shifted from students to process. While process is important, the student's learning should always be central. In zealousness to discover the ideal methodology, educators can lose sight of the people for whom they are working: a diverse population of learners with different needs and goals.

One of the barriers to finding a process that meets the needs of the students is that administrators get too immersed in process and evaluation. Samuel Mitchell, in *The Unfinished System of Education, [1]* refers to a creation myth wherein the dominant power (administration) constrains itself so tightly that it does not permit the development of new agents (individual students.) The education process should develop to meet the needs of the many, which outweigh the needs of the few, due to fiscal limitations. Surely, in the age of technology, educators can bypass that quandary.

This paper examines the evolution of a model of delivery which can be customized by the student, allowing access to information as the students would like to receive it, while still allowing for the critical personal interactions which can be lacking in some distance education models.

2. IMA's Inception

IMA began as a reaction to inaccessible web content. Frustrations as an end-user of an inaccessible (information not accessible for Deaf/hard of hearing students) pre-recorded video presentation related to an Information Technology Blended course offering. "Blended" courses are those that have an in-person and an on-line component. When thinking of Distance Education, accessibility components are not always fully considered. Working with deaf students and teaching both distance and "blended" courses at RIT has been useful for faculty. As a result of these experiences, we have been conducting ad hoc experiments with blending some emerging hardware and software technologies to better serve our students, deaf and hearing alike. RIT faculty researchers have begun developing some open source software resources aimed at educators, and in particular distance education practitioners. [2]

With the advcnt of the Internet, Distance Education removes the physical barrier of distance, but can implement other barriers for students in terms of interact-ability. But this 'distance education' concept pre-dates the Internet. Frances Cairncross, author of *The Death of Distance*, points out that distance education has occurred via radio and television networks for decades; long before the birth of the Internet. [3] As the expense of higher education escalates in America, educational institutes look to expand their student base and decrease costs. Distance Internet-based education has been viewed as one solution.

The concept of distance education is a fine one; allowing students to access education, "Anywhere, any time, for any one." True distance education should permit students to receive materials that can be modified to suit individual learning needs (accommodations) and styles. Ideally, educators must interact with the students, learn their respective backgrounds, examine how students receive and process information. Then an appropriate methodology can be implemented. Given the diversity in the virtual classroom, this is no easy task. Educative models have changed as the population changes; from Traditionalists to Baby-Boomers, Generation to the Millennial generation.

Diversity encompasses age, gender, culture, as well as physical and cognitive limitations of learners. Any of these can potentially become a barrier to receiving and processing information. Interactive Media Assistant's (IMA) evolution focuses on the barriers for students with disabilities, and allows ALL students to create an interface that supports the reception of the materials being presented, in a fashion that is pleasing to each individual. Upon development of IMA, it became clear that all students, for a variety of reasons, might prefer a system like IMA, which allows customization of content.

With the shrinking of the global community, more cultures are virtually meeting in the online educational classroom, and students are learning beyond the scope of the curriculum, which is how it should be. Sheila Tobias talks about 'stalking the second tier;' [4], which includes a variety of students who have 'different learning styles, different expectations, different degrees of discipline, different "kinds of minds" from students….' [5] How can one methodology accommodate all of these challenges? The customization of the IMA interface allows students to re-take some control over their respective learning processes.

True Access for All!

What are the true barriers to academic success? Throwing technology at a problem does not magically make the problem go away. Hembrooke and Gay discovered that utilization of technology in the classroom without clear guidelines for appropriate usage resulted in detrimental memory of lecture content. [6]

Distance Education certainly has potential to address issues related to accessibility in the physical classroom. But the use of uncaptioned content, and the lack of empowerment of students makes it more challenging to view Distance Education as a solution to accessibility woes. A Distance Education model is needed to support both asynchronous and customizable, accessible learning. With pod-casting increasing in popularity, and the ability to stream videos, the technology is enabling some students while clearly disabling others.

The Americans with Disabilities Act was implemented to ensure access for people with disabilities. While Distance Education may be textually based, many models of delivery still require phone chats, videotape viewing or other auditory components. Learning tools need to be proactive and be accommodative to the learner's needs.

Barriers to Learning

Captioning videos means that Deaf or hard of hearing students can now follow the dialogue, but for English as a Second Language students, captioning provides additional feedback which assists in both the learning and comprehension of the language. Within the classroom, virtual or physical, accommodations which permit customization of a learning experience can empower students to not only access the materials, but also to feel connected to the materials. Providing guidelines on usage of technology can enhance the learning experience.

Challenges in the classroom can include issues related to physical accessibility. Students with visual disabilities may be limited in visually rich environments. Students with auditory disabilities may be limited in auditory-rich environments, and students with learning disabilities may be challenged in both of the above environments, with respect to the attention spans required to view or hear information.

Another barrier not frequently considered is the issue of community. Some cultural groups feel uncomfortable leaving their home base to go and study at a school that does not have the same supports and 'comfort' of the home community. While some might argue that the 'real world' demands this personal growth, others would contend that it is perfectly acceptable to obtain an education and remain immersed in the culture or community in which one was raised. That is the foundation for mentoring and community development.

Asynchronous learning should be a priority for true Distance Education. While social interaction IS a huge part of the educational process, this interaction is certainly possible and meaningful as off-line discussions.

Accommodative learning would allow students in different time zones to view materials at their leisure, and interact with classmates via email, bulletin boards, wikis, weblogs or other modes that are not time-critical.

The Technology

How, then, does technology assist with these very different challenges? Empower the learner to make the experience reflect his or her needs. Distance models provide a vehicle to unite various audiences while lowering administrative costs. Distance models are not going away; if anything, the educational growth in this area has been staggering. [7]

For a successful distance experience, students must be able to interact with each other, with the faculty member, AND with the materials. There are a multitude of educational tools available which provide the former, such as BlackBoard, Breeze or Desire2Learn. There are, however, not many tools that allow students to directly interact with the materials, permitting customization for learning preferences.

Interactive Media Assistant (IMA) is a tool developed at the Rochester Institute of Technology, an institute that houses the National Technical Institute for the Deaf. RIT's student population of 15,200 includes a deaf/hard of hearing population of 1200 students. NTID is the world's first and largest technological college for Deaf and hard of hearing students. The tool allows customization of various windows that deliver educational content.

At this time, IMA is built to work in most of the major browsers (FireFox, Mozilla, Camino, Safari, Netscape, SeaMonkey, and Internet Explorer) to be delivered and run in a local environment. Each individual window generated by the application contains a video, scrolling text, or a space for students to create their own notes. All of these windows have the ability to be moved to where the user wants, resized to whatever size is necessary, or minimized if the content is unwanted or unnecessary.

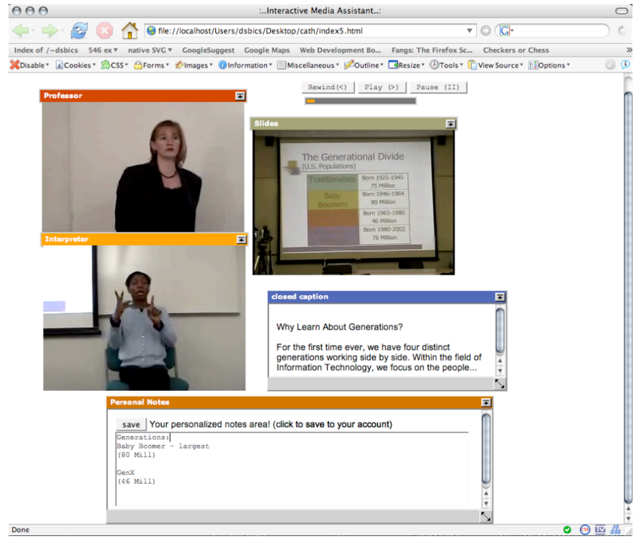

Figure 1: IMA with all tools visible

Figure 1 demonstrates IMA in full functionality. Students can pause, stop and restart the materials via IMA, receive feedback related to the length of the presentation, take their own notes within the tool, and choose how to receive their educational materials.

This ability to customize and pause materials would also be beneficial to students with learning or cognitive disabilities. Selecting the preferred visual windows (professor, whiteboard/PowerPoint, captioning, Interpreter or Notes) can focus the attention on the preferred modes of communication. Captioning can be laid on top of the content window, or can be placed beside the content window. Upon obtaining user feedback, a new interface was developed. This brought significant changes in how closed captioning was displayed with IMA.

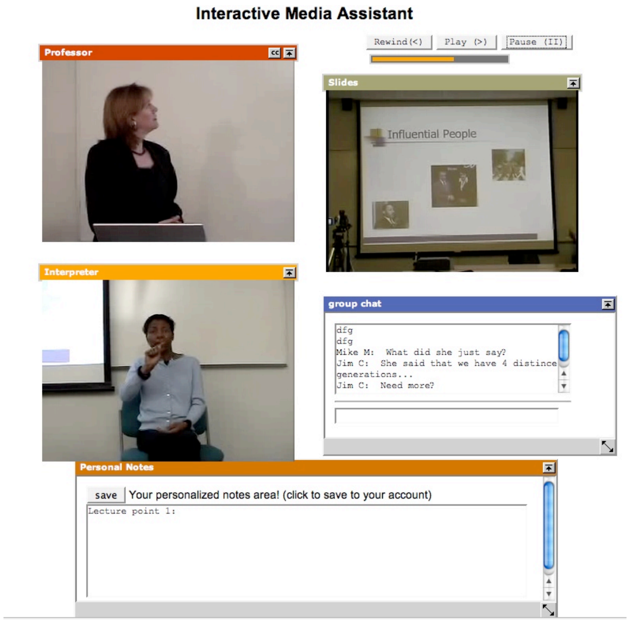

Figure 2: IMA with CC button and Group Chat

Figure 2 represents the removal of the captioning window, to allow for a group chat feature. A closed caption (cc) button has been placed in the Professor window, where it is more in keeping with a real-world familiarity for end users. The captioning can be turned on or off, depending on user preference. The captions overlay at the top of the video.

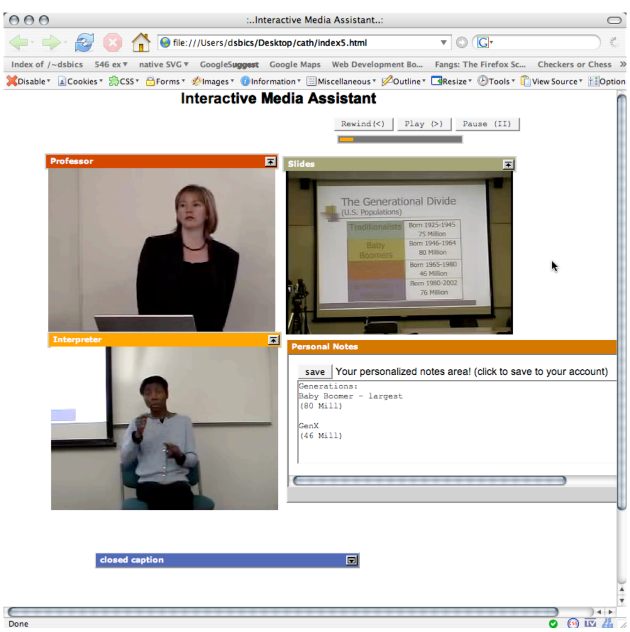

Figure 3: IMA with Interpreter Window

Figure 3 demonstrates the application as it would appear for students who are Deaf and use a sign language interpreter to receive information. The benefit of IMA becomes apparent: Deaf students can quickly glance between the interpreter and the professor, while also having the PowerPoint slides located closely. The eye movement distance is much smaller. Students can pause and rewind, changing their visual focus at any time.

The windows can be paused, rewound, fast-forwarded and played at the convenience of the user. For students who are Deaf or hard of hearing, or for English as a Second Language learner, this means that materials can be viewed and reviewed, with the student being able to take notes independently. Students may arrange to meet online and view materials together, utilizing the group chat feature to learn collaboratively.

The ability to pause and customize materials may also be beneficial to students with learning or cognitive disabilities. Selecting the preferred windows will cause the students to focus attention on a mode of communication that provides the most information.

The challenges facing developers are related to the combination and synchronization of the delivery of course content. The current project combines three video feeds: a professor speaking, a Sign Language Interpreter, and the related course power points or white board materials. This is combined with personal notes and a group chat, happening simultaneously, remaining synchronized.

The IMA solution is interesting technically because it works within an ordinary Web browser using HTML, CSS, Ajax and JavaScript. Web browsers and supportive software technologies have matured sufficiently and the promise of earlier attempts to make synchronized multimedia happen for distance education can be realized in a much more robust, standards-compliant, open source and cross-platform fashion than had been previously possible. It is the opinion of these IT department researchers that open source solutions make much more sense for educators and students than proprietary systems.

3. Conclusion

Interactive Media Assistant allows for customization of a variety of classroom content. The tool will enable students to customize the information they receive, and to maintain a learning pace with which they are comfortable. The students can replay the materials, and alter the focus on second or third viewing of the content, if they so choose.

The barriers to learning, as they relate to diverse students, can be reduced significantly by allowing students to interact with their materials when, where and how they choose, within one window. IMA provides a mechanism to accommodate these preferences.

Beginning implementation of this tool has been for local use. Future research will continue with IMA to transfer the distance model to an in-class system so that students can customize their real-time learning experience. The flexibility of IMA allows students to customize their learning experience. The utilization of a web browser means that students are not compelled to purchase or use proprietary software.

The dangers of transferring to an in-class experience have been considered. Providing students with a laptop or desktop computer and expecting them to only use IMA is not a realistic scenario. Students are frequently seduced by the lure of the internet. There are, however, ways to limit the ability of the students to use other applications while in the classroom. While faculty like to place responsibility on the students, Arthur Sterngold feels that students ARE accountable but not solely to blame. [9]

Faculty need to provide a clear framework of how technology should be used in the classroom. Some institutes feel that internet usage should be restricted for freshmen, with seniors having unfettered access; the implication being that with maturity comes wisdom. Other institutes empower individual faculty members to dictate what happens within the classroom.

Usage of a tool such as IMA would necessitate access to the internet. Therefore, guidelines would need to be given to the students on how to use the IMA, and faculty expectations of usage, in a live situation. For distance materials, the issue would not be relevant.

Further development of IMA will ensue, after additional user testing and implementation via the delivery of a complete Information Technology class. This class will be recorded and then offered as a blended or distance class. As the technology advances, testing will be done with IMA as a live tool.

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E-World: A Platform for Managing and Tracing Adaptive E-learning Processes

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Abstract

In this paper we propose E-World an e-learning platform, which is able to manage and trace adaptive didactic contents designed and created by a visual language based tool, named ASCLO-S (Adaptive Self consistent Learning Object SET) editor. We also propose a case study aimed at assessing the usability of the presented e-learning platform and students' performances on two teaching approaches. The usability was assessed through a questionnaire, while students' performances were analyzed using the information traced by E-World. Finally, we analyze and discuss the achieved results to identify dependences among usability, learning performances and students' welfare.

1. Introduction

The e-learning evolution proposes a good number of tools assisting instructional designer during the analysis, design, and delivery of instruction and on the other side provides powerful tools supporting students during the knowledge acquisition process. Nowadays, the traceability of learning process is becoming more and more appealing for both teachers and students. In particular, teachers use the achieved information to compare the expected target audience with the students who really attend the course. Moreover, information on learning performances and the explicitness of teaching materials can also be analyzed to assess the agreement with the teacher expectations. From the student point of view, traceability information is used to assess the acquired knowledge and plan the efforts in the knowledge augmentation process. In order to trace the learning processes several kinds of e-learning platforms have been proposed in the market, see e.g. [16][19]. Initially, different kinds of communication infrastructures between e-learning content objects and e-learning platforms were defined and used. On the other hand, in the last few years standards providing standardized data structures and communication protocols have been proposed. In particular, the ADL (Advanced Distributed Learning) [1] consortium produced the SCORM (Sharable Content Object Reference Model)[2] consequently the collaboration among government, industry and academia to enable interoperability, accessibility, and reusability of Web based didactic contents.

In this paper we present an e-learning platform, named E-World, which extends the software architecture proposed in [10] to trace and manage adaptive knowledge contents designed and created by a visual authoring tool, named ASCLO-S (Adaptive Self consistent Learning Object SET) editor [11]. We also propose a case study consisting of two experiments on two different teaching approaches, namely blended and pure. These experiments aimed at assessing students' performances and the E-World platform usability. The students' performances were assessed using information traced by the platform, while the E-World usability has been assessed by a questionnaire. We used the achieved results also to evaluate the dependences among usability problems, learning performances, and students' welfare.

The remainder of the paper is organized as follows: Section 2 describes the E-World platform and its architecture, while the case study is discussed in Section 3. Related work and final remarks conclude the paper.

2. E-World Platform

The ADL (Advanced Distributed Learning) [1] consortium produced the SCORM (Sharable Content Object Reference Model) [2] a de facto reference model, which was born consequently the collaboration among government, industry and academia. In particular, SCORM works with standards bodies to integrate their specifications into a cohesive, usable, holistic model.

To fill the gap between the early standardization stages and the widespread adoption the ADL [1] initiative proposes content examples, a conformance test suite, and a sample Run-Time Environment (RTE) [2]. Concerning the Run-Time Environment (RTE), the ADL proposes a realization of the API (Application Programmer's Interface) enabling the communication between didactic contents and e-learning platforms to implement the traceability, and the content sequencing and navigation. This implementation is based on a typical client/server Web architecture. The server component implements the RTE by J2EE technology, while the client component needs a Web browser supporting ECMA script and Java applets to enable the communication between didactic contents and an e-learning platform.

An alternative communication schema between didactic contents and the RTE as well as a software architecture based on Web Services [12] and on a Middleware [9] software component have been proposed in [10]. In this paper, we adopt the communication schema and extend the platform proposed by the authors to enable the traceability of adaptive didactic contents, and synchronous and asynchronous collaborative environments. The contents and the collaborative environments are designed and created by two visual authoring tools named ASCLO-S (Adaptive Self consistent Learning Object SET) editor [11] and SYCLE (SYnchronous Collaborative Learning Environment) editor [14], respectively. Figure 1 shows the relationship between the run-time components and the hardware nodes of the extended e-learning platform, named E-World. For space reasons and for the scant relevance, the component diagram in Figure 1 does not contain the software components implementing the user profiling and identification.

The software components of the *Middleware Machine* node allow the e-learning platform to properly communicate with the software components deployed on the other nodes. E-World can be extended with a new feature implementing a software component and invoking it by an entry in the Middleware Machine node. The software component implementing the new feature is successively deployed either in the Service Machine node or in a different hardware node.

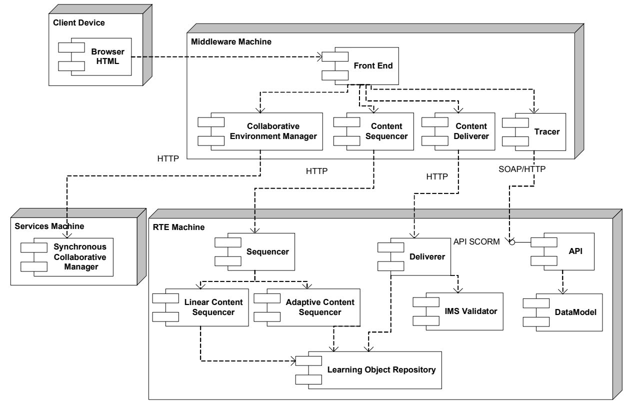

Figure 1. E-World architecture

The *Middleware Machine* node is composed of five software components. The *Front End* aims at presenting the appropriate features and contents to the students and teacher using the components on the *Middleware Machine* node. In particular, the *Front End* uses the *Content Sequencer* to show the suitable knowledge content to the students, while to trace the learning process the *Tracer* component is proposed. Differently, the *Content Deliverer* component allows the instructional designer to deploy single e-learning activities or whole courses. Finally, the *Collaborative Environment Manager* component is used to manage the cooperation among students and teachers.

The *RTE Machine* node contains the software components to manage and deploy linear and adaptive didactic contents as well as to trace learning processes. The *Sequencer* component is used by the *Content Sequencer* component to manage learning processes. Currently, E-World is able to manage linear content sequencing, as proposed in the standard SCORM, and adaptive content sequencing as suggested in [11]. It is worth noting that because of the flexible architecture, this platform can be easily extended to manage different adaptive models. The *API* software encapsulates a Run Time Environment (RTE) compliant with the SCORM standard and provides an interface to enable the traceability of didactic contents. The interface is the same as described by the ADL in the RTE book [2]. These *APIs* are used to establish a handshake between didactic contents and the RTE of the e-learning platform. The *API* software component is also used to store information on the student interaction with the presented didactic contents into the E-World database.

The deployment of a process based on synchronous and asynchronous activities [14] first requires the validation of its e-learning activities and then the updating of the system database. It is worth mentioning that the platform also enables the deployment of single e-learning activities. Concerning the e-learning activities two different validations are performed. In particular, didactic contents, adaptive learning processes, and tests are validated differently from the synchronous collaborative activities. In order to deploy linear and adaptive didactic contents in E-World their SCORM IMS Manifest have to be validated using a suitable parser. Differently, a QTI [17] parser is required to validate the manifest of a test.

The *Synchronous Collaborative Manager* component on the *Service Machine Node* provides means to handle and use synchronous and asynchronous collaborative environments. Collaborative environments can also be used and managed separately from E-World. The database for the learners' profiling is not considered when this component is integrated in the proposed platform.

E-World has been implemented using J2EE technologies. In particular, Apache [4] and Tomcat [5] were used as Web Server and Web container, respectively. Instead, the main technologies used to dynamically deliver contents are Java Server Pages (JSP) and servlet. Finally, to integrate the component to trace learning processes we used a Web Service implemented using AXIS SOAP Engine [3].

3. Case Study

In this section we report a cases study on the E-World platform. The case study is composed of two experiments, which were carried out by undergraduate final year students of the University of Salerno attending the Web Technologies course of the Bachelor program in Computer Science. Once the students enjoyed the adaptive didactic contents we asked to state their satisfaction and welfare by using a questionnaire. We used the results of the usability studies and the information concerning the traceability of the adaptive learning processes to evaluate dependences among usability problems, learning performances, and students' welfare.

3.1 Adaptive Didactic Contents

We used ASCLO-S editor to define adaptive contents for two relevant topics of the selected course: XML (eXtended Mark-up Language) and XSLT (eXtensible Stylesheet Language Transformations). The former has been used for the first experiment (blended), while for the second experiment (pure) the latter topic was chosen. We refer to the students that participated to the blended teaching experiment as blended group, while pure group is used for the students that participated to the pure teaching experiment. The blended group was composed of nine students that first attended a classroom lesson and after an online lesson on the same knowledge contents. The pure group was composed of six students that enjoyed only the online lesson on XSLT. The students of both the experiments had a homogenous know-how.

The experiments were carried out in a laboratory of the University of Salerno in two sessions. The experiment on XML was carried out first. The experiments started at 3 pm and were conducted in a many-to-many session. The experiment supervisors were four for both the experiment sessions. The students of the blended group did not participate to the other experiment.

The experiments were divided in four steps and were carried out without invoking any kind of tutor support and time limit. First an introductory course of ten minutes was presented to provide information about the experiment rather than to illustrate the E-World usage. After that we asked to explore the platform to familiarize with it. The third steps consisted of performing four tasks: creating an account to use E-World, selecting the course, enjoying the course, and accomplishing the test to assess the acquired knowledge. Finally, both the students' group filled in a questionnaire (Table 1) aimed at assessing the usability of both the platform and the didactic contents.

To avoid frustration and disappointment during the knowledge content fruition, the students were not informed of the traceability of the learning process. For privacy reasons, the students were informed after the accomplishment of the experiment.

The students freely used the platform after the introductory course. They did not manifest any kind of problem and became familiar with E-World in a very short time. After that the students performed all the assigned tasks of the third experiment step. Only for space reasons the traced information as well as the test scores are not reported.

3.2 Usability and Welfare

The usability tests were carried out without invoking any kind of support and time limit. Moreover, it was kindly required the testing participants to annotate any type of problem they found during the use of the platform. As a result, the students were motivated to carry out the experiment and to discover usability problems. To assess the perceived usability of the E-World platform from the students' point of view we asked the students of the experiments to fill in a questionnaire. This questionnaire aimed at assessing the usability of both the proposed platform and the enjoyed didactic contents.

The usability reports for both the usability experiments were achieved analyzing both objective and subjective findings. Objective findings include the subjects' response times for the relevant aspects of the usability testing, as well as the data gathered through the testing by the supervisors. Findings from the questionnaires constitute the subjective findings. The questionnaire was divided in the following categories: *Student Background (A)*, *General Reaction (B), Page Structure (C)*, *Terminology (D)*, *Platform Learning (E)*, *Platform Capability (F)*, *Multimedia Object Management (G)*, and *Student Satisfaction (H)*.

A category was composed of three questions to assess the homogeneity of the statistic sample. The general reaction of the students in terms of satisfaction degree has been evaluated by the questions belonging to the *B* category. The questions of the *C* category aimed at assessing layout and structure of the pages, as well as their contents. The satisfaction degree of the students about the terminology that the platform used was evaluated by the *D* category. The *E* and *F* categories aimed at investigating the satisfaction degree of the system learning simplicity and its performances, respectively. Finally, the satisfaction degree on the used multimedia objects and the enjoyed knowledge contents was evaluated by the questions of the *G* and *H* categories, respectively. The questions composing the usability questionnaire, except those of the *A* category, are shown in Table 1.

The answer for each question ranges between 1 and 9. For example, the value 1 for the question *2.1* represents the worst judgment (*horrible*) that the tester can express on the platform user interface, while the best judgment (*wonderful*) is expressed by the value 9.

The students of the blended group expressed a good general judgment on the platform. The students' suggestions revealed that on one side the platform did not produce any kind of disorientation or problem and on the other side that students considered this platform not rousing. The second group of students, namely pure group, had a different reaction. In particular, the questionnaire answers revealed that the students were divided in two groups. 50% of the students expressed a sufficient satisfaction degree, while a mediocre judgment was expressed by the other students. As expected, students who first attended a traditional classroom lesson reached a greater satisfaction degree than the students enjoying only digital contents.

Better results were achieved by the answers of the questions of the *C* category. Indeed, the students of both the groups expressed a satisfaction degree on the page graphical layout in terms of characters, images colours, and navigation. Despite the positive reaction of the students, some of them suggested improving both the page platform navigability and the fruition of the knowledge contents by a larger central frame.

The analysis of the *D* category revealed that on the average the satisfaction degree of both the group of students is sufficient. In particular, three groups of students having the same size and belonging to the pure group expressed a general judgment between mediocre and fairly good. On the other hand, 20%, 50%, and 30% of the students of the blended group expressed a mediocre, sufficient, and fairly good judgment, respectively. Once again the platform was more appreciate from students who first attended a traditional classroom lesson.

Id	Question
B	Cross one of the numbers that better reflect your judgment of the E-World Platform. (*General Reaction*)
B.1	From *horrible* to *wonderful*
B.2	From *frustrating* to *satisfying*
B.3	From *difficult* to *easy*
B.4	From *boring* to *exciting*
B.5	From *incomprehensible* to *understandable*
C	Judgment of the E-World pages (*Page Structure*)
C.1	Reading the characters in the pages is (from *simple* to *difficult*)
C.2	The characters appear (from *fuzzy* to *clean cut*)
C.3	The chosen fonts are (from *incomprehensible* to *understandable*)
C.4	The character colours are (from *appropriate* to *inappropriate*)
C.5	The character size is (from *appropriate* to *inappropriate*)
C.6	The contrast between the text and the background lets you distinguish the page content (from *not well* to *well*)
C.7	During the navigation the page structure supports you (from *never* to *always*)
C.8	The amount of the information that can be visualized in a page is (from *inappropriate* to *appropriate*)
C.9	The way the page contents are arranged is (from *illogical* to *logical*)
C.10	The sequence of the pages is (from *unclear* to *clear*)
C.11	The page navigation is (from *unpredictable* to *predictable*)
C.12	Coming back to the previous page is (from *difficult* to *simple*)
C.13	Coming back to the home page is possible (from *never* to *always*)
C.14	The orientation while you navigate is (from *difficult* to *simple*)
C.15	The graphical layout of the pages is coherent (from *never* to *always*)
D	Used terminology and provided information (*Terminology*)
D.1	The use of nomenclatures and terminologies of the platform is (from *inconsistent* to *consistent*)
D.2	The nomenclatures and the terminologies are difficult to understand (from *often* to *never*)
D.3	The terminologies is appropriated with the performed actions (from *often* to *never*)
D.4	Technical terminologies is used (from *often* to *never*)
D.5	Links, names, and titles of the pages are (from *confusing* to *appropriate*)
D.6	E-World advised you during the contents fruition (from *never* to *always*)
D.7	The action accomplishment leads to predictable result (*from* never to *always*)
D.8	The page contents are introduced by the page title (from *never* to *always*)
E	Judgment on the learning of E-World (*Platform Learning*)
E.1	Learn to use E-World is (from *difficult* to *simple*)
E.2	How long does it take to master the platform? (from *much* to *little*)
E.3	Finding the sensible maps is (from *difficult* to *simple*)
E.4	Remembering the names and using the platform commands is (from *difficult* to *simple*)
E.5	The steps to accomplish an operation are (from *much* to *little*)
F	Performance and simplicity of the E-World platform (*Platform Capability*)
F.1	The platform is (from *slow* to *fast*)
F.2	The pages are downloaded (fro *slowly* to *quickly*)
F.3	Your expertise level conditioned the E-World usage (from *yes* to *no*)
G	The quality of the multimedia objects (*Multimedia Object Management*)
G.1	The image quality is (from *bad* to *good*)
G.2	The images are (from *fuzzy* to *clean cut*)
H	Satisfaction degree of the presented knowledge objects (*Student Satisfaction*)
H.1	The presented knowledge contents integrate the classroom lesson (from *no* to *yes*)
H.2	The knowledge contents are clear and well organized (from *no* to *yes*)
H.3	Unclear knowledge contents could be enjoyed more than once (from *never* to *always*)

Table 1. Questions of the usability questionnaire

Concerning the *E* category, 40% and 60% of the students of the blended group found the platform fairly good and good to learn, respectively. Similarly, 83% of the students generally expressed a fairly good judgement, while the remaining students expressed a mediocre judgment. They expressed a worse satisfaction degree for the number of steps to accomplish an operation. Concerning the *F* category the students of both the groups expressed almost the same positive judgment.

Unlike the students of the blended group, the students of the pure group expressed a scant satisfaction about the multimedia objects. They found the images fuzzy and of a poor quality. However, both the groups provided a sufficient judgment, in general.

The assessment of the subjective findings was concluded analysing the answers provided for the questions of the *H* category. A mediocre judgment on the average was expressed from the pure group, while the blended group expressed a more positive judgment.

The evaluation of the objective findings was concluded by analyzing the information gathered by the experiment supervisors and E-World platform. The achieved information was used to identify further problems on platform usability and delivered knowledge contents. For instance, on the self-assessment test presented at the end of the lesson, a meaningful usability problem was revealed. The traceability information showed that most of the recruited students confused the meaning of two buttons, namely next and submit. The next button should be intended for skipping the question, while to answer to a question the latter button had to be used.

3.3 Discussion

The experiments provided relevant information in order to comprehend the students' satisfaction degree and their performances, as well as the usability effect of both the didactic contents and e-learning platform on the students' welfare.

As expected, concerning the time to enjoy didactic contents the students of the pure group spent more time than the blended group. In particular, the mean time spent was about half an hour for the blended group and more than one hour for the pure group. This gap was due to the fact that the pure testers had to spend more time to enjoy the presented didactic contents, not having ever studied them before. We also observed that on the same experiment the mean times spent by the students to consume didactic contents of the same size were very different. As a result, the time spent to carry out e-learning processes and traced by the platform is not generally adequate to estimate the students' difficulties. Hence, further considerations on didactic contents should be performed in order to better understand the difficulties that students could encounter during the knowledge augmentation process.

The usability study and the information traced by the platform also revealed that students' welfare is also influenced from the perceived usability of both e-learning platform and didactic contents. This assertion is confirmed first by the subjective findings and then by objective findings. The subjective findings revealed that the satisfaction degree does not exclusively depend on the knowledge complexity, but is also influenced by the knowledge that the students had before taking a course up. The students' knowledge was assessed by a multiple choice test, whose score was traced by the e-learning platform. We observed that on the average the students of the pure group from one side achieved the best results and from the other side carried out the test in less time. Best learning performances were probably due to the awareness of their formative lack.

Concerning the results of the proposed case study we observed that the traced information should be analyzed considering the learning context, the used teaching paradigm, and the usability of both the platform and didactic contents. Hence, instructional designers should consider all these aspects whether the reengineering of a learning process is required to improve student's performance and welfare.

4. Conclusions

In the literature there are many different proposals [6][15][18] based on Web Services [13] to integrate e-learning software components. Xiaofei *et al.* [15] propose a functional architecture based on Web Services for building standard-driven distributed and interoperable learning systems. The functional architecture defines components that make up an e-learning system and the objects that must be moved among these components. A proposal for a Middleware component was suggested by Apostolopoulos and Kefala [6] with the aim to bridge the lack of a consistent management scheme in the integration of e-learning services. They implemented the e-learning components as agents, which are maintained in a local Management Information Base, and can communicate with the agent manager through the SNMP protocol. Chang *et al.* [13] suggested the use of SOAP to implement API Adapter and transport parameter part in LMS. The LMS Web Services are implemented in .Net, while to enjoy knowledge contents the client needs specific software components. The components include a SOAP engine to allow the communication between LMS and client machine.

Concerning the identification of usability attributes, Ardito *et al.* [7] capture the peculiar features of e-learning platforms and knowledge contents reporting a preliminary study on a group of users. The student interaction with an e-learning framework in a real teaching context was observed. Differently, in [8] the author proposed a preliminary set of guidelines and criteria to be exploited for designing usable e-learning applications. In particular, they adapted the SUE (Systematic Usability Evaluation) inspection, which was originally developed for hypermedia evaluation.

In this paper we extend the e-learning platform presented in [10] to enable the management of adaptive e-learning process. A case study was also carried out and presented in order to assess the usability of the presented platform as well as the performance and satisfaction of students enjoying adaptive didactic contents both in pure and blended teaching scenarios. Dependences between usability problems, and students' satisfaction degree and performances were evaluated and discussed.

Future work will be devoted to further assess the proposed e-learning platform on several education contexts. We also plane to replicate the study on a larger and heterogeneous statistical sample. Finally, we are going to perform empirical studies to estimate the effort to create and to enjoy adaptive contents.

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Establishing a National Health e-Learning Portal in Taiwan

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ABSTRACT- *Taiwan introduced a new Grade 1-9 Integrated Curriculum (G1-9 IC) in 2001. New curriculum standards provide only guidelines of major contents in 7 learning areas and focus on reminding teachers the basic abilities students should have and not providing standardized and detail textbooks. The national Health e-Learning Network (HeN) is one of six education networks funded by the Ministry of Education (MOE) to support G1-9 IC. After one year planning, the construction of the website (http://health.edu.tw) launched in 2003. The development team recruited more than 100 experts. About 40 elementary and secondary partner schools all over the country are collaborated to promote the website and digital learning contents. According to the three stages principle of preventive medicine and seven major contents of health and physical education learning area of G1-9 IC.. Through the implementation of information and network technology, many multimedia e-learning units(MeU) were developed. School teachers, students and parents can access these contents freely and share their experience interactively on the user community platform linked on the website. In the future, HEN will further coordinate the resources from public and private sectors to establish a health e-learning portal and provide life long health education. The family physician-based community integrated delivery system in conjunction with health information management and referral system will be integrated to provide a comprehensive and continuous holistic health care to reach the goal of health for all.*

Keywords*: health education, e-learning, integrated curriculum, elementary education, secondary education*

INTRODUCTION

In Taiwan, the implementation of the 9-year compulsory general education system started in 1957. Since 1993 the Curriculum standards for primary and junior high schools have undergone the first revision. Coming with the 21st century to meet the national development needs and public expectations the government started to engage in educational reform in order to foster national competitiveness and the overall quality of citizens lives. The development of a new curriculum was divided into three stages including the integration of Grade 1-9 Curriculum, guidelines of seven learning areas, and reviewing process.

The development adopts the following four principles: (1) to involve all aspects of daily life that correspond to the students' mental and physical development; (2) to encourage the development of individuality and the exploration of one's potentials; (3) to foster democratic literacy and respect for different cultures; (4) to develop scientific understanding and competences, in order to meet the demands of modern life.

The goals of curriculum are to achieve the following abilities:

1. To enhance self-understanding and explore individual potential;
2. To develop creativity and the ability to appreciate beauty and present one's own talents;
3. To promote abilities related to career planning and lifelong learning;
4. To cultivate knowledge and skills related to expression, communication, and sharing.
5. To learn to respect others, care for the community, and facilitate team work;
6. To further cultural learning and international understanding;
7. To strengthen knowledge and skills related to planning, organizing, and their implementation;
8. To acquire the ability to utilize technology and information;
9. To encourage the attitude of active learning and studying; and
10. To develop abilities related to independent thinking and problem solving.

New Grade 1~9 Integrated Curriculum has been introduced in 2001[1] to replace the narrowed and older courses. There are seven major learning areas including Language Arts, Health and Physical Education, Social Studies, Arts and Humanities, Mathematics, Science and Technology, and Integrative Activities. Because the outline syllabus and the learning ability indicators of new curriculum are very general in nature, preparation and selection of teaching materials will become more diversified and open. The curriculum standard focus on reminding teachers the basic abilities students should have and not providing standards and details for textbooks. The trend that a teacher has to prepare his/her own teaching materials, by searching from available educational resources, become an inevitable task on campus. This will add enormous workload to classroom teachers especially in Health Education class which correct and specialized knowledge is critical. For most of the teachers of health education did not receive adequate training of health science in teachers colleges or normal universities. In teachers colleges to cultivate elementary school teachers there is no department of health education. For junior high schools only half of health education teachers graduated from department of education in normal universities.

Through the rapid development of the Internet, the acquisition of medical and health information are now easily accessed via multiple media in Taiwan[2]. However for the general public, the retrieval of correct and unbiased health information has become a major issue for health education and self-health management. Same difficulty exists for teachers of health education because of lack accredited resources in common medical knowledge and health information.

The national Health e-Learning Network (HeN) is one of six education networks funded by the Ministry of Education (MOE) to support G1-9 IC. It is part of "Cultivate Talent for the E-generation project" in the Challenge 2008- The Six-year National Development Plan started from 2002.

The purposes of establishing a national Health e-learning Network (HeN) are: (1) to provide correct common medical and health science knowledge to improve health status for school pupils and the general public; (2) to develop an e-learning resources network for Health and Physical Education learning area of Grade 1-9 Integrated Curriculum; and (3) to establish a life-long health education portal for the general public.

SUBJECTS AND METHODS

The target users of HeN are teachers, elementary and junior high school students and their parents in Taiwan. The planning and construction project for HEN was funded by the Ministry of Education (MOE) along with other five national education networks and a common platform project in the national development Plan [3]. In this project, the participating experts were organized to three major missions: the content team, the system platform team and the knowledge management team (Figure 1).

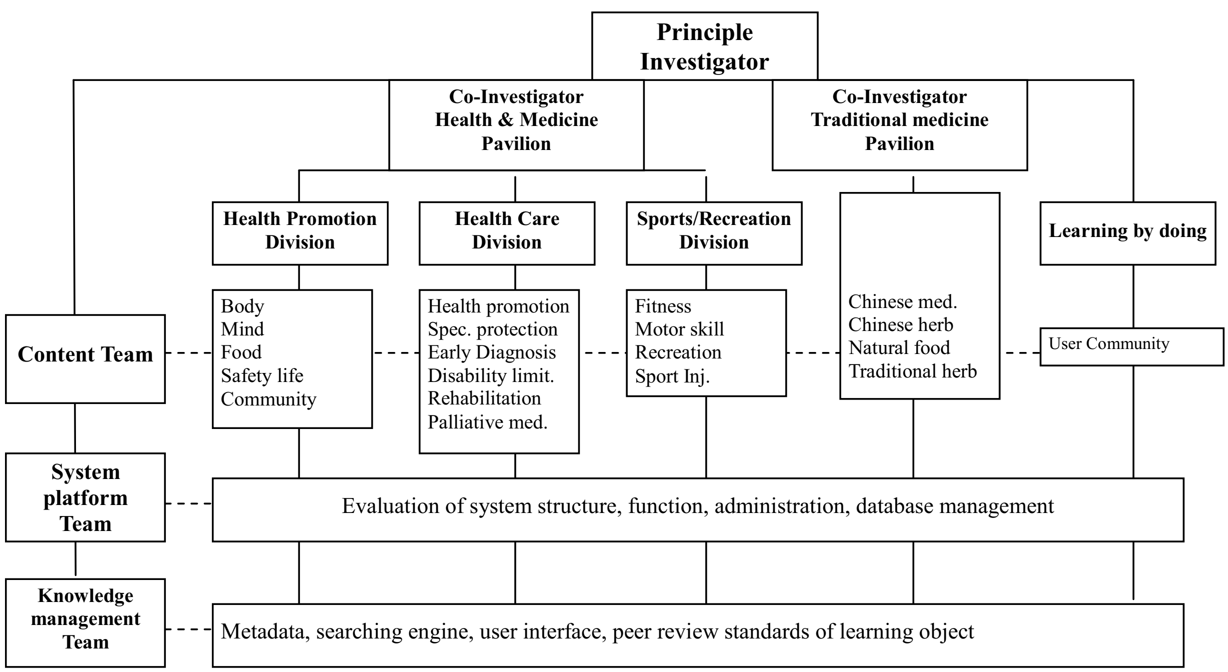

Figure 1. Organization chart National Health e-Learning Network(HeN)

Table 1. Three-stage principle & natural course of disease

Susceptibility Stage		Pre-symptomatic	Clinical Stage	Disability Stage	Death Stage
Primary Prevention		Secondary Prevention	Tertiary Prevention		
Level1	Level2		Level 1	Level 2	
Health Promotion	Specific Protection	**Early Detection Prompt Treatment**	Limitation of Disability	Rehabilitation	
Nutrition, Smoking Drinking Cessation, Diet, Sports	Vaccination Protective Equipment	Screening	**Chronic Disease Surveillance and Management**	Physical Therapy Occupational Therapy	Palliative Grieve Counseling

The collaboration is a two-dimension model to integrate domain knowledge part and technical part. Two co-investigators who are the experts of health education and traditional medicine respectively take charge in health & medicine pavilion and traditional medicine pavilion. The principle investigator coordinates the content expert, technology expert, and learning by doing promotion activities. The content structure was complied with the three-stage principle of preventive medicine incorporated with the natural course of disease (Table 1) and the seven major contents of health and physical education learning area. The three stage-principle of preventive medicine includes primary prevention focusing on health promotion and specific protection, secondary prevention emphasizing on early diagnosis and prompt treatment, and tertiary prevention targeting on limitation of disability and rehabilitation.

The three stages are closely related to the progression of natural disease process. The first stage is related to susceptible period with risk factor although subject is still in a disease free status. The risk factors can be reduced by health promotion life style such as balanced diet, exercise or vaccination. The second stage is related to an occult or latent disease status which requires periodic health examination or screening for early diagnosis. The third stage is related an obvious disease condition with definite diagnosis which emphasizes the prevention of complication and restoring the residual function. The major contents of Health and Physical Education focus on the learning of mental and physical development and health management, sports and motor skills, healthful environments, fitness and lifestyle choices. Each major contents is divided into three learning stages (grade 1-3, grade 4-6, and grade 7-9) according to the structure of knowledge concerned as well as the continuity principles of the psychological development of learning. Competence Indicators are set for each learning stage.

The system platform team surveyed existing e-learning system to evaluate the system structure, function of account administration and database management. The knowledge management team focused on the design of metadata, functions of searching engines, user interface, peer review mechanisms, and international standards of teaching material which tightly correlated with another common platform project for six e-learning networks.

RESULTS

A. System Structure of HeN

The architecture of the system is shown in figure 2. It is a 3-tier wed-based system. All the programs were implemented in object-oriented idea so that all the components in the system can be reused for other systems. The open-sources and platform-independent concepts were also considered in the designing of the system.

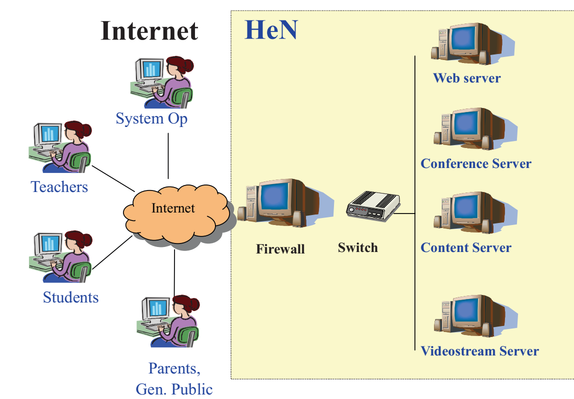

Fig2. System structure of HeN

HeN consists of a web server and several application servers including content database server, conference server, and videostream server, etc.... More application servers can be added upon the request of user needs. Open source operating system and database software were used for web servers, content database and knowledge management platform. The web server has three versions of general, children and English. The children version is specially designed for elementary school students.

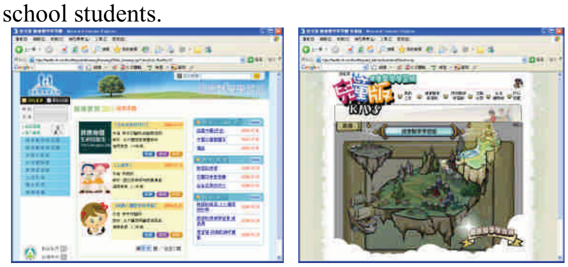

Fig 3. HeN: general(left) and children(right) versions

A low bandwidth multipoint videoconference system Multivideo was implemented for communication among teachers and also for the development team. During the videoconference the network bandwidth can be as low as 64Kbps for each site, and the conference has the capacity connecting to maximum 17 points including a point with electronic whiteboard sharing and conference chair function.(Fig 4a, 4b) For videostream server, Window Media server was installed to provide video via browser interface.

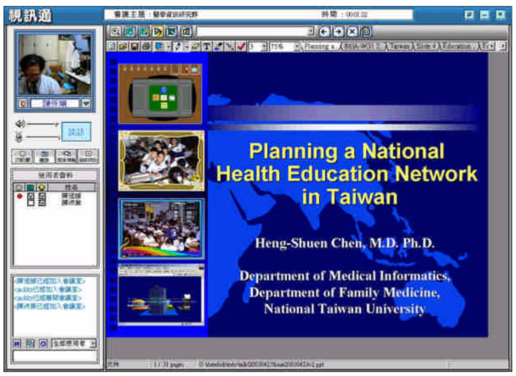

Fig 4a. Conference server: electronic whiteboard sharing

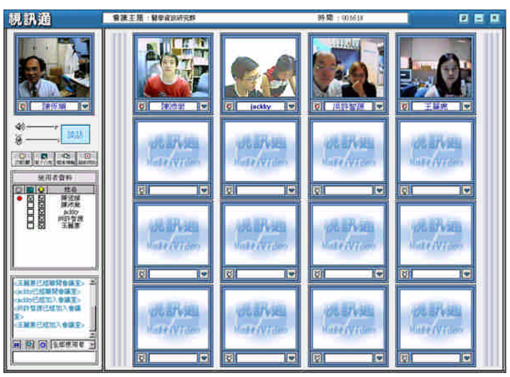

Fig 4b Conference server: multipoint videoconference

B. Functions of HeN

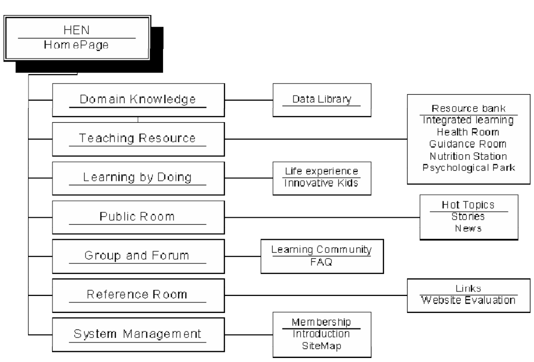

Fig 5. Function Map of HeN

Figure 3 shows the function map of HeN. There are several components designed in HeN. The first component is the data library that stores the full structure of medical knowledge contents as searchable materials. Knowledge contents were arranged in a tree structure, which were divided into 19 subgroups under Health & Medicine Pavilion and Traditional Medicine Pavilion. Health & Medicine Pavilion has three divisions: health promotion, health care, sports and recreation. Viewing from the top of the 6 national e-learning networks (Life education, Health education, Nature and Ecology, History and Culture education, Arts and Humanities education, and Science education), HeN finally has 15 level-3 knowledge base items after traditional medicine domains also integrated into level 4 and level 5 items, In total it is about 125 level-4 items and 400 level-5 sub-items. Some of the domains also started to develop level 6 items.

The second component is a teaching resource block with many sharable digital multimedia teaching materials that are represented by subject related to health education of G1-9 IC under specific divisions of Health & Medicine pavilions on HeN. The seven major contents one by one project to the 5 subgroups of Health promotion and 2 subgroups of Sports/Recreation division in Health and Medicine pavilion. These teaching materials are called multimedia e-learning unit (MeU) can be used as computer assisted instruction tools of related major contents linked to variable competence indicators. For example in elementary school the young new students always have trouble in using toilet in school. For toilet training an interactive flash game was developed. Through the collaboration among elementary education expert, school teacher, instruction designer and multimedia programmer, a vivid interactive game called “Poo War” was developed and became the most popular MeU on HeN. Fig 6 illustrates the instruction design of sequential guidance and feedback in the playing process.

Fig 6a male or female

Fig 6b.positive feedback

Fig 6c. Foot position

Fig.6d. Poo target

These flash movies or interactive games are downloadable or play online. School teachers, students and parents can access these contents freely and share their experience interactively on the user community platform linked on the website. The traditional medicine pavilion provides abundant knowledge and multimedia e-learning contents which are very unique in the world and well-recognized in global Chinese community (Fig 7a, 7b). Part of them are assigned to link to seven major contents as possible and integrated with learning by doing activities.

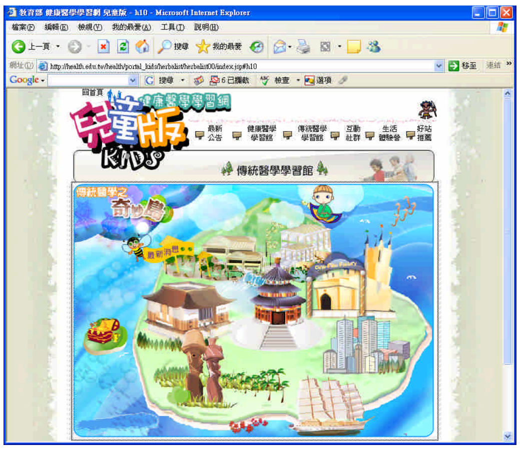

Fig 7. Webpage of Traditional Medicine Pavilion

.The third component is the area of learning by doing called Life Experience Camp. Activities of real or virtual experience are provided to teachers and students, some activities may involve school nurses and parents. From 2006, in addition to original 15 partner schools, HeN collaborated with 25 newly assigned elementary or junior high schools, one in each county or city all over the country. As many as 60 learning by doing or HeN promotion activities were scheduled during the previous year. These activities include teacher training in instruction design, lecture and hands-on practice on multimedia e-learning units to promote HeN, international exchange and promotion, exposition and press conference.

The other components of HeN provide open place for news, hot topics, forum or interactive discussion and provides answer for frequently asked questions (FAQs).

DISCUSSION

From information technology point of view, HeN is based on the ideas of consumer health informatics (CHI)[4,5] and e-learning to provide a self-directed, problem-based, cooperative and collaborative learning environment[6]. For school teachers, HeN actually is more important for them to serve as a health education teaching materials repository. Teachers can search any contents on the web with keywords, by category or by competence indicators. This would save the teachers a lot of time in surfing unreliable health information and medical knowledge on the Internet. The content structures of the system were contributed by more than a hundred experts including medical doctors, nurses, nutritionists, professors and school teachers. The integration of major contents of learning area with preventive medicine and natural history of disease also provide a comprehensive knowledge base of health which can be applied to people of any age.

During the last three year construction period, the people in the six e-learning networks and common platform projects have many chances to work together. They have shared their experience on the construction processes among different e-learning projects. In the mean time, we have reached a consensus for the specification of the system platform, single sign-on, metadata, and common functions of the user interface. In the next few years, MOE will keep funding the HEN development project with about $NT 10 millions per year. The system platform will be further improving by using a Multimedia Knowledge base management system, integrated with visual user interface, learning pathway and FAQ with natural language searching ability.

In the future, HEN will further coordinate the resources from public and private sectors to establish a health e-learning portal and provide life long health education. The family physician-based community integrated delivery system in conjunction with health information management and referral system will be integrated to provide a comprehensive and continuous holistic health care to reach the goal of health for all.

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A MULTIAGENT ARCHITECTURE FOR A LEARNING OBJECT REPOSITORY

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Up to now, the e-learning community has concentrated a lot of effort on the task of defining standards that can guarantee the interoperability and reusability (from the informatics standpoint) of didactic resources, but has tended rather to neglect their reusability (from the pedagogical standpoint) and the personalization of learning paths. It seems evident that in the field of content structuring it is the quality, as well as the quantity, of the pedagogical information accompanying the content that is most lacking. But how is it possible to divorce these from the educational context where the resource is used? Such an approach would be detrimental not only to the quality of the reuse but above all to the possibility of personalizing the learning path. Generally, when we consider an e-learning process, we tend to think that it differs from a traditional lesson in a number of different ways. Starting by drawing up specifics for describing learning/teaching scenarios, we propose an architectural model for a learning object repository with the aim of setting up a community of good practices in which teachers can not only find teaching materials but also the collection of all the experiences of other teachers who have used them.

Introduction

There is now widespread recognition that search engines are one of the most important technological, cultural and economic phenomena of our present age. In fact, together with web browsers and electronic mail, they have been defined as one of the most successful applications of the use of the Internet. Besides, from the cultural point of view it is interesting to observe that the verb *to google* has become common parlance for making a web search [14].

This can explain the growing interest in defining ever more refined and specialized search engines that can allow the user to find exactly what resource s/he was looking for. This is the background to the new web generation, the Semantic Web, where it will be possible to publish not only documents but also information and data in a suitable format for making automatic queries, interpretations and, in general, data processing [2]. This new web will enable specification not only of the desired information content but also of the context where the content should best be inserted to serve the user's interests.

These tools have already become widespread in the educational world at all levels. In Italy, the recent reform introduced by the Ministry of Public Education has given priority to rational, homogeneous programs for instruction in the use of PCs and the Internet in the school system.

Thus, the Internet has not only become a study subject but is now above all a tool for producing teaching materials and for widening knowledge in all fields. In this scenario, the problem is the great quantity of material available and the time taken to select material, that rises in direct proportion; the problem has now become severe as regards teaching materials. So, the main aim of the international community is to create a worldwide web of teaching objects (better described as learning objects) and to provide suitable tools allowing them to be shared and retrieved. A first solution was that of defining and adopting a system of metadata that describe the content of the teaching resource in more or less detail. These descriptors are aimed both at speeding up search operations and at making them more effective, by supplying results better matched to the purposes of the search. However, the use of several systems of metadata has not fostered, and indeed has hampered, the interoperability and reusability of teaching resources. For this reason, international standards were defined, such as SCORM, LOM, Dublin Core, and most teaching resources now refer to these.

It soon became apparent, therefore, that the metadata specifics needed to be refined to make them better able to respond to specific learning/teaching needs. This is one of the main problems emphasized by operators in the e-learning sector, denominated pedagogical neutrality [5]. So in recent years the research community has focused on integrating pedagogical information in descriptions of teaching resources.

The main initiatives include: the National Science Digital Library [9], that uses the DC and three of the selected elements from the LOM, the Open Archives Initiative [10], which recommends the DC but also supports the LOM, and finally, the Gateway to Educational Materials [6], that uses the DC and other elements to describe pedagogical elements. However, most works concentrate on defining domain models by using ontologies that can achieve more accurate selection and searches of materials [3, 13], or improve the description of the metadata by providing a more accurate definition of the relations among the various concepts [1, 12].

In describing a teaching resource one of the biggest problems is that of describing the learning scenario where it can be used.

One of the most complete initiatives in this context is the IMS Learning Design [7], that aims to provide a detailed description of a learning scenario by means of a special language denominated Educational Modelling Language (EML) [4]. The specifics can describe a wide range of pedagogical models or learning approaches, including work groups, and collaborative learning. The ultimate aim is not so much to define new learning models as to describe how the actors in a given scenario interact among themselves, using the teaching resources (in terms of both teaching materials and support services), and how the whole procedure can be coordinated and channelled to create a learning path. Although these specifics are complete, they are addressed to instructional designers and/or developers of e-learning materials that have informatics skills rather than to teachers. Hence the need to define specifics describing learning/teaching scenarios to be included besides the traditional metadata describing teaching resources, that do not require advanced informatics skills.

This work starts with a proposal of specifics describing learning/teaching scenarios denominated EXM (EXperiences Metadata), and then goes on to define an architectural model of a repository in which teaching experiences, metadata on teaching resources and the resources themselves can be collected. This may serve as a springboard for building an integrated software system that can make the complex process of metadata production transparent to the final user, who will thus reap its advantages.

EXM specifications

The idea of describing the teaching/learning scenario aims at allowing easier use and reuse of didactic resources. This is a fundamental aspect in distance education. The description of such scenarios allows teachers to share their experiences in using didactic resources. The ultimate goal, therefore, is to create a community of best practices in which teachers can find didactic material to use in their own didactic activities, as well as reports of their colleagues' experiences with prior use of them.

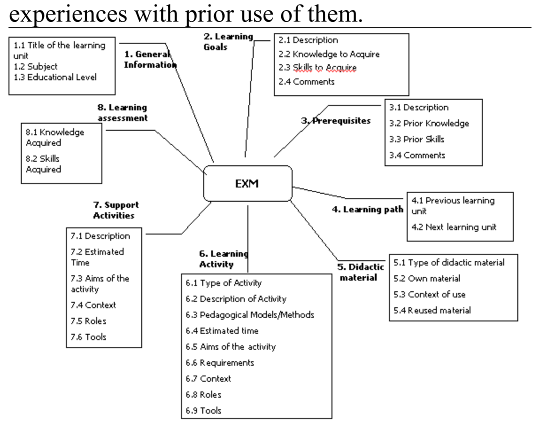

Figure 1. EXM Specifications structure

The EXM specifications have been defined on the basis of the IMS LD specification and thanks to the collaboration of some teachers. As Figure 1 shows, the specifications consist of eight categories, each describing a particular aspect of the teaching/learning process:

1. General information: describing didactic resources details to which the experience is related.
2. Learning goals: describing, in terms of knowledge and skills, the goals that the didactic resources should achieve.
3. Prerequisites: describing, in terms of knowledge and skills, the prerequisites required in order to use the resource which the scenario refers to.
4. Learning path: describing the previous and next resources related to the resource including in the scenario.
5. Didactic material: describing the type of didactic material used in the experiences, other possible contexts in which it could be (effectively) used. This category also makes it possible to describe if the didactic resource was built by the

teacher or inherited from other colleagues.

6. Didactic activity: describing details of the activity in terms of students involved, tasks assigned, teacher's roles, pedagogical strategy used, and so on.
7. Support activity: describing the role the teacher or tutor has in supporting students in their learning activities.
8. Learning assessment: describing the learning outcome in terms of quality of the learning goals attained by the student.

These specifications were the springboard from which a model of a teachers' experiences repository was defined, which can collect both learning objects and their descriptions but also sets of best practices furthering the use of these resources.

Multiagent architecture for a learning objects repository

On the basis of the problems illustrated above, it seemed wise to revise the current model of a repository, defining an architecture better suited to current lines of development. Starting from insertion of learning objects, it can be seen that the complex metadata language, as well as the need for usable work tools that should provide invisible technology (as advocated by Norman) [8], poses the risk of making the tool impractical, despite its theoretical utility. In addition, considerable experience is required to obtain a good quality of metadata, in which all the metadata present (especially subjective data) are congruous. Thus, the aim is to obtain high quality, precise metadata with the minimal possible user effort. This need can be attained with an expert system (or experience-based agent), which can draw up the metadata at expert level after dialoguing with the user (e.g. by multiple choice targeted questions).

On the basis of these descriptions, the agent itself can classify the resources in given categories. The advantage of organizing resources in categories is that it will simplify searches in the repository. The user can browse through the taxonomy of available resources until s/he reaches the desired resource. This is not the only reason why a taxonomic organization of the resources is essential in the search process. Bearing in mind the unavoidable complexity of such a search, the concept of invisible technology gives rise to the need for a knowledge-based agent that can support the user in her/his searches. The agent [11] should be able to understand, according to the user profile and stipulated specifics, what (or which) categories of learning objects are best suited to the user's needs. In these bases, a functional architectural model for a Learning Object Repository (LOR) can be defined, having the following macro-components:

- Experience-based agent supporting insertion and cataloguing of learning objects;
- User modelling component (with user models DB);
- Knowledge-based search agent;
- DB of learning objects.

Even if it is not explicitly included among the components, the interface has a fundamental importance and must guarantee user access to all the functions made available by the repository.

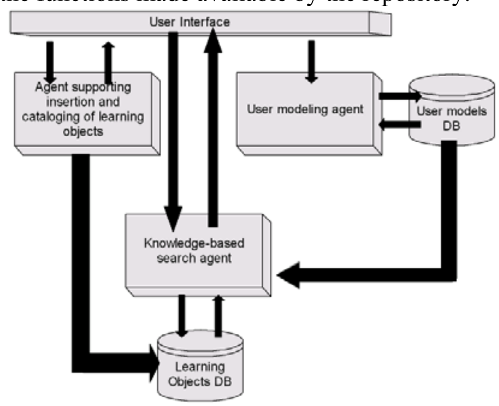

Figure 2. Agent-based architecture of the repository

Each macro-component must interface with the outside world via the Web Service and exhibit all public methods so that they can be adopted by remote call both by the repository and by any other web application wishing to use the available services. This delineates a clear distinction between the interface level and the domain level. Communication between the web service and the other applications is achieved with messages in XML (SOAP) format. Each service can be described by formal specifics, together with all information necessary to invoke it, such as localization, message or protocol format to be used. The Web Service description is in XML format, also known as WSDL (Web Services Description Language).

a. *Agent for learning objects insertion and cataloguing*

Owing to the complexity of the metadata languages Dublin Core, LOM, EXM, it is not possible for a user to insert complete, precise metadata. Therefore, an experience-based agent (expert system) must support the user's navigation in the repository, and the insertion of descriptions of learning objects in order to guarantee the semantic correctness of the

metadata, an essential condition to censure correct cataloguing of the resources.
To achieve a precise description of a knowledge-based agent, the nature of the environment where it must operate needs to be analyzed in depth, as well as the performance measure considered, and the sensors and activators the agent relies upon.
The environment consists of the set of teachers (of every school order and level) who insert learning material in the repository, and can be considered **partially observable** because a user is unlikely to be able to insert all the metadata needed to make a full (or better exhaustive) description of the resource; **stochastic** because at all times the agent's state is not determined purely by the current state and action carried out, but is strongly dependent on the user-interface interaction; **sequential** because it is not reasonable to consider all the user actions made to insert the metadata on a resource as separate actions since they all aim to achieve the same object; **semidynamic** because it must be assumed that the environment will not change while the user is reflecting, whereas the assessment of the agent's performance will decline over a period of time; **discrete** because each user search is considered on its own, **single-agent** because it does not collaborate nor compete with other agents to achieve the goal.
The performance measure serves to enhance the quality of the metadata and their organization as a taxonomy of categories. The sensors are the functions that acquire the user interface data, the activators are the functions that write the XML metadata and classify the resource in the DB.
To achieve the goals the agent needs to possess some particular knowledge. In particular, as regards the metadata support function, this knowledge can be represented (in the typical question-driven expert systems way) by a decision tree with which the agent can ask the user a series of questions and then insert the metadata on the basis of her/his answers. Metadata inserted in the form of clauses can be transformed into XML files or used by diagnostic rules to classify the resource in pre-established categories. The diagnostic rules stem from a comparative analysis of the various elements making up the metadata language. For example, if the field *teaching subject* contains the value Informatics, the *level* field will take on the value University, etc (as shown in Figure 4) so it can be concluded that the resource belongs to a given category inferred by its properties. These categories have precise properties and are organized as a taxonomy. This is not known to the agent inserting and cataloguing the learning objects but will be important for the search agent described below.

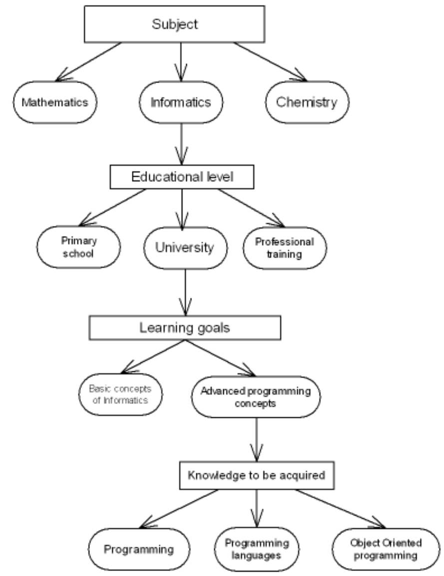

Figure 4. Classification of the resources tree

b. *User modelling component*

The user modelling component has the task of collecting all the information about the user gained during interaction with the system and processing it. This information can be collected in an explicit or implicit fashion according to the user's level of involvement.
Explicit methods for collecting information by direct involvement of the user make the user information collection process easier, and avoid the need to rely on automatic learning techniques. However, direct involvement of the user may yield wrong or only partially correct information, often due to poor collaboration of the user. This problem can be solved by using an experience-based agent, with a question-driven interface, that can ask targeted questions and decide how reliable the data inserted by the user are on the basis of the her/his answers.
As regards implicit methods for collecting information, they are primarily useful because they are user-visible. They collect information by observing how the user interacts with the system, so incorrect information is highly unlikely to be acquired. In any case, the best result is obtained by combining the two methods.
Once the user information has been collected it must be processed to elicit a series of user categories, again organized as a taxonomy.
When designing a repository model, it is not necessary to make any further examination of the user modelling technique, but it is important to

have such a mechanism to provide a further filter mechanism of the resources found.

c. A knowledge-based search agent

A complete, precise description of learning resources requires the specification of equally complete, precise search criteria. In this case, too, it is necessary to hide much of the complexity of the search from the user. For this reason, a search agent should be able to infer which resource categories are best suited to the user's requirements on the basis of the specifics and user model.

The user's requests may vary from specific requests for a precise learning resource to very generic requests. In the first case the agent has the task of providing a list of objects with the desired characteristics, while in the second it will have to compare different objects and providing the best suited on the basis of the user profile.

The environment the search agent will operate in is the set of teachers and pupils (of all schools and types) searching for teaching materials of all types and can be considered **partially observable** because a user is unlikely to be able to insert all the research parameters serving to identify a given resource; **deterministic** because the state of the agent in any given moment is entirely governed by the current state and the actions taken; **episodic** because the agent's experience can be divided into atomic episodes; **semidynamic** because the assessment of the agent's performance will decline over a period of time; **discrete** because each user search is considered on its own, **single-agent** because it does not collaborate nor compete with other agents to achieve the goal. The sensors are the functions that acquire the interface, user model and learning objects DB data, while the activators are the functions that communicate the results of the search to the interface. The knowledge the agent needs to carry out its task has to do with the organization of the learning objects in the repository, the typology of the user making the search, and the user's specific request.

The knowledge of the learning objects organization in the repository is based on a taxonomy of categories that subdivides topics into sub-topics, and further classifications according to the planned use of the object (to be incorporated in a new learning object, used for a classroom lesson, etc) and the pedagogical aspects. Together with this high level representation each object is described in detail by its metadata. The knowledge of the user is also organized as a taxonomy of categories distinguishing between teacher categories and learner categories. In addition, for each user the agent can refer to a series of detailed data on her/his personal profile.

The agent has a series of production rules and can infer what category the resources best suited to the user's request belong to on the basis of the representation of all the above knowledge and the user's request. For example, if a teacher is looking for teaching material about inductive logical programming, and states that s/he wishes to use it with learners having no prior knowledge of this subject, then the system must individuate teaching materials summarizing the essential concepts underlying logical programming. Next, the system must select the material about true inductive logical programming. Thanks to EXM, a knowledge of the propaedeutic order of different topics can easily be included in the search agent's production rules. The use of rules that can combine the knowledge of the learning objects and of the user representations can yield good results even if the request made is extremely imprecise.

Conclusions and future developments

Web-searches for efficacious learning resources pose one of the main challenges being addressed by experts in the e-learning sector in recent years. The biggest problem is the lack of pedagogical information associated with such resources, which would serve to foster reuse in different contexts. A study of the state of the art has highlighted a number of ongoing projects developing in different directions, ranging from adding elements to the standards for metadata, defining new specifics for describing learning/teaching processes, up to defining ontological models for describing teaching resources. All these proposals have scientific merit and are theoretically efficacious but they have contributed to make the activity of describing a teaching resource a highly complex task. Moreover, a solution to the problems of reusability and web-searches for resources does not lie only in the definition of specifics for describing them but also requires specialized research engines to be defined. For these reasons, the current work proposes a multiagent architectural model for a learning object repository which can on the one hand facilitate the process of describing resources and on the other, provide an intelligent research engine able to retrieve the most suitable teaching resource for the user's declared aims. Moreover, the model aims to provide a framework that could be adopted by all designers and developers of LOR, fostering not only searches for, and reusability of, teaching resources but also and above all, interoperability among the LOR themselves, so creating a single worldwide network and a dedicated teaching resources web.

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Integration of distributed Learning Objects by Wrapper-Mediator architecture

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Abstract

The main problem addressed here is the definition of a strategy to improve the sharing and reusability of learning objects in an efficient manner inside an e-Learning community, reducing the cost of creating courses and other learning objects. In particular, in this paper we present a system, for integrating multimedia heterogeneous LO repositories and retrieving distributed data. Such system uses the LOM data model and a wrapper-mediator architecture to perform this task, so providing a simple mechanism for enabling the integration while maintaining the independence of the repositories. Our system also supports a semantic search on managed objects that makes more effective the retrieval process.

1 Introduction

With the advent of new technologies and World Wide Web, enormous quantities of informative material are nowadays available on-line, and, thanks to the convergence of services offered by ICT companies, the future will be more and more characterized by the ability to provide and distribute multimedia information.

In such a context the integrated management of multimedia information such as images, graphics, video, audio, and text, is at the moment of great interest in a lot of application fields like Information Retrieval, Office Automation, E-learning, Virtual Museums, Newspaper and Magazines production, Video and Cinema Editing, Medical Applications, Geographical Information Systems Management, Biometric Security Application, and so on.

Unfortunately such produced media are not available in a unique content container, but in heterogeneous and distributed repositories as World Wide Web, professional and personal databases of different kinds (Relational Database, Object Database, XML Database, etc..), digital libraries and archives. The major challenges in this non-trivial task are due to structural, syntactic and semantic heterogeneity of distributed multimedia data repositories that make complex the data management processes.

To solve such problems it is necessary to define a data model that is capable of representing in unique logical view the multimedia data, so it can be used by applications, inside an architecture able to support in an efficient manner the management of such data. For what concerns the data model, it's natural to model multimedia data by means of objects using the object oriented paradigm, in order to capture both the different variety of real data and the different related functionalities. For what concerns the architecture, a well known strategy for supporting distributed data integration is the adoption of the "wrappers/mediator" middleware joint to database technologies.

Modern e-Learning applications make more and more an extensive use of multimedia data to enhance and speed up the learning process. In the current assumption, one or more multimedia contents are assembled together to generate learning resources that are seen as a kind of *Learning Object* (LO). A Learning Object represents small capsules of knowledge in a suitable form for didactic presentation and assimilation by learners. The LO "metadata" standardization is expected to introduce a large degree of interoperability and re-use, promoting the wide-spread investment in, and adoption of, this technology. Each learning object, by being highly atomic and complete in capturing a concept or "learning chunk", provides the opportunity for the configuration of a large number of course variations. The resulting fine-grained course customization is expected to lead to "just-in time", "just-enough", "just-for-you", training and performance support courseware.

The IEEE Learning Technology Standards Committee (IEEE-LTSC P1484) has undertaken the initiative of drafting a set of standards among which they define a data model for *Learning Object Metadata* (LOM) useful for e-learning contents authoring and description [7].

The main problem addressed here is the definition of a strategy to improve the sharing and reusability of LOs in an efficient manner, reducing the cost of creating courses and other learning objects.

In particular, in this paper we present a system, for integrating multimedia heterogeneous LO repositories and retrieving distributed data. Such system uses the LOM data model and a wrapper-mediator architecture to perform this task, so providing a simple mechanism for enabling the integration while maintaining the independence of the repositories. Our system also supports a semantic search on managed objects that makes more effective the retrieval process.

The paper is organized as follows. In Section 2 the main systems for learning object integration are described. In section 3, we outline the data model for LOs management and a functional overview of system architecture, based on Wrapper/Mediator schema. In section 4, we describe the retrieval process for LOs based on a semantic search, while in section 5 some experimental results are discussed. Concluding remarks are given in Section 6.

2 Related Works

In the literature, several multimedia integration systems have been proposed. In the following we report a short description of the main general purposes systems.

`MediaLand` [13] is a database system aiming to provide a "true" support for multimedia data management. The objective of MediaLand is to provide an integrated framework for users with different levels of experiences to manage and search multimedia repositories easily, effectively, efficiently and intelligently. For satisfying these objectives, each multimedia data is represented as a particular "object" (described by apposite metadata) and the correlation among different objects is obtained by means of "links, in order to construct "multimedia object graphs". In this way, the authors give a unique conceptual structure for describing the multimedia data, successively clustered in domains called "media class. The system presents a 4-tier architecture and supports a multi-paradigm query approach to retrieval aims.

`InfoSleuth` [3] is an agents system that proposes a semantic approach to provide heterogeneous data integration. In particular, the data integration is obtained extracting a common view of the semantic content from multimedia repositories. This approach gives an independence of requests from information structures, resolving the heterogeneity of data by means of an apposite ontology. InfoSleuth also uses a specific language, *KQL* (Knowledge Query and Manipulation Language), for communication among agents.

`Garlic` [10] is a more complete and complex system that, similarly to some of previous projects, uses an object-oriented approach to represent in an uniform way the data from different content servers. But, differently from the other approaches, Garlic provides an efficient query processing and data access layers, for efficiently managing user queries. The data model is based on *Odmg-93* and defines an apposite language for the data definition.

`Impact` [11] is an agents-based system capable of integrating heterogeneous information . Impact Architecture is based on two entities: "Agents" - software modules created from users or other agents and having high level functions - and "Impact Servers" - representing the services infrastructure crated by agents. A Multi-Agents Paradigm allows to integrate heterogeneous information using different agents with particular functions and services. A "yellow pages" mechanism is used to manage the services discovery.

At the same time, in e-Learning domain, different systems for LOs sharing and integration based on the P2P architecture have been developed. In the following the main proposals are shortly described.

`LOMSTER` [12] is a project that address sharing of LOs on a P2P base by using LOM fields both for indexing and searching data and XML as representation and query language.

`EDUTELLA` [9] is a project that address sharing and reusability of LOs on a P2P base by combining RDF and XML binding of LOM to support query, replication mapping, mediation and clustering services.

`ROSA-P2P` [4] is a P2P distributed system which provide a physical environment to carry out the integration of LOs. The environment includes functionalities for aggregation, grouping definition, election, communication, balancing and redistribution of peers.

Eventually, for what concerns the problem of retrieval of multimedia data, in [2] a system based on a multimedia ontology (represented by the TAO_XML language) concept is proposed to solve heterogeneity of semantic content of the managed objects.

3 Overview of system functionalities

3.1 Data model

We describe a learning object and support the reuse and search of such an object. According to the LOM standard metadata consists of nine sections.

`General`: this category groups the general information that describes this learning object as a whole, e.g. title, keywords and description.

`Life Cycle`: this category describes the history and the current state of a learning object and those entities that have affected this learning object during its evolution.

`Meta-Metadata`: this category describes this metadata record itself and how the metadata instance can be identified, who created this metadata instance, how, when, and with what references.

`Technical`: this category describes the technical requirements and characteristics of a learning object.

Educational: this category describes the key educational or pedagogic characteristics of a learning object.

Rights: this category describes the intellectual property rights and conditions of use for a learning object.

Relation: this category defines the relationship between this learning object and other learning objects.

Annotation: this category provides comments on the educational use of this learning object, and information on when and by whom the comments were created.

Classification: this category describes where this learning object falls within a particular classification system.

3.2 Mediator/Wrapper Architecture

The proposed architecture is based on the classic Mediator-Wrapper schema, also used in [5], and tries to satisfy the main requirements of a multimedia database management system. In this kind of approach, the wrapper explores and examines the several LO repositories and send the mediator an appropriate LOM XML description of the related information. From the other side, the mediator receives and organizes these information in order to create a single view on all repositories in order to satisfy the user queries processing. The system architecture has tree functional layers: a client layer to submit queries, a mediator layer to manage data, a wrapper layer to extract data.

The Mediator middleware (whose logical architecture is shown in figure 1) has the following functionalities:

- classify and manage the LO XML description sent by wrapper;
- manage the user query;
- manage the communication with wrapper systems.

In the classification task, a STORAGE module takes the repositories XML description of LOs from the wrappers and stores it in a special and dedicated database called METADATA DB based on a XML Native DBMS. A SEMANTIC MANAGER, based on a MULTIMEDIA KNOWLEDGE BASE, is also used after the storage stage in order to associate the repository data with a semantic concept, organized in leearning semantic domains, to be stored in the METADATA DB. To these aims, the module uses the information contained in some standard LOM metadata (e.g., title, keywords, description) of multimedia objects.

During the query processing task the user queries are submitted by means of a USER INTERFACE; such software component is also used to show related query results. The user queries are then processed by means of a QUERY ANALYZER, whose results and related information are stored in a system database, called QUERY DB. The queries are then "taken and compiled" by means of a QUERY ENGINE, using information stored in the METADATA DB, which sends the appropriate wrappers the given query. The partial and global query results are then stored in an another system database called RESULT DB. The results are managed by a RESULT HANDLER and by a TOP-K SELECTION module, which analyzes the results and chooses, by means of appropriate strategies, the best K results and reports them to an OBJECT RECOVERY module. In the choosing of best results also object semantic information (user keywords) are considered by means of a SEMANTIC REFINING module that uses a SEMANTIC NETWORK to discover hidden associations between objects having a similar semantic meaning. The SEMANTIC NETWORK is dynamically generated by means of a general knowledge base (in our case Wordnet [8]) and used for computing the semantic similarity metric described in section 4.

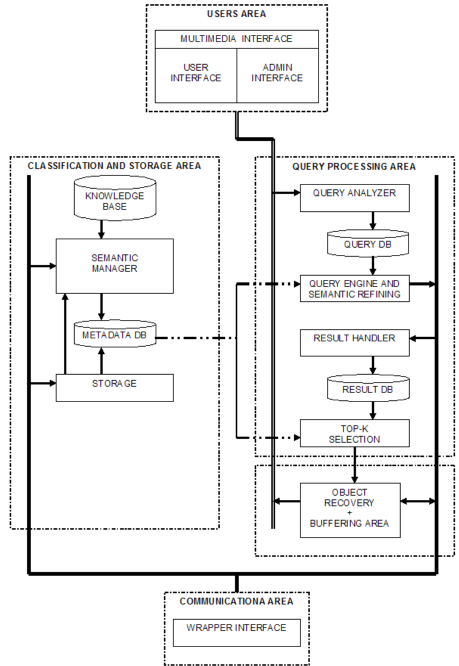

Figure 1. Mediator Architecture

The communication with wrappers is carried out by an apposite component called WRAPPER INTERFACE, that send mediator requests and picks up the "meta-information" and the related query results according to a XML-based protocol.

The Wrapper middleware (which logical architecture is shown in figure 2), entirely developed using JAVA and XML technologies, has the following functionalities:

- it has to classify and manage the multimedia LO defined by the repository administrators;
- it has to manage the mediator queries;
- it has to manage the communication with the mediator system.

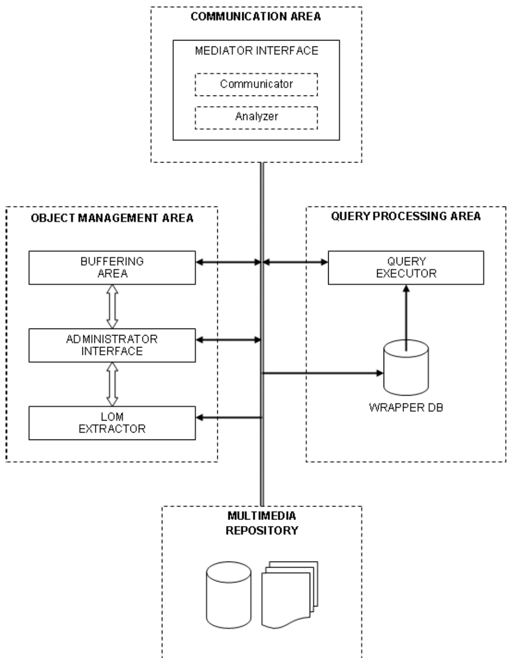

Figure 2. Wraper Architecture

In the classification task, creation of the LO XML description is the `LOM EXTRACTOR` responsibility. All the information about the metadata, defined on the created LO, and used for the query resolution, are stored in a system database called `WRAPPER DB`. A `WRAPPER ADMINISTRATOR INTERFACE` is used to describe the repositories (i.e. if they are Relational Database, Object Database, Web Page, XML Database, etc...) and the location of data. For example, in the case of relational database, the administrator must indicate the tables and the stored or external procedure which must be exported for the class definition. This interface is also called every time there are some errors in the wrapper automatic tasks.

The query processing task is carried out by means of a `QUERY EXECUTOR`, activated when the wrapper receives a mediator query request. It analyzes the `WRAPPER DB`, taking information about the LO and runs the query, in the optimal manner, on the repository. The communication with mediator system is performed by means of a `MEDIATOR INTERFACE` module, that is composed of two fundamental sub-parts: the `Communicator` and the `Analyzer`. The Communicator has the task of managing the physical communication with the Mediator. From the other side, the Analyzer has the task of interpreting the mediator requests.

Eventually, for what concerns supported multimedia queries, referring to the LOM description, the following queries can be expressed:

- metadata exact-matching queries;
- semantic keywords-based queries.

The first class of queries can be solved by the classical SQL (XPATH) approach, while for the second ones the use of techniques for multimedia data management is required.

4 Semantic Retrieval of LOs

In this section we describe an innovative metric which use semantic information, based on textual annotations, to perform a more accurate retrieval process on LO repositories.

Such metric allows to determine a grade of relatedness between user search-keywords and the LOM object description by using a semantic net generated in an automatic way thanks to *WordNet*.

The construction of this net is exploited dynamically considering the information and the structure of WordNet (i.e., in WordNet the terms are organized through their linguistic properties: each term can have different meaning or sense, "polisemy", depending on the topic area, and, each sense is then organized in "synsets" constituted by synonyms). To this aim, the system supplies an interface that helps the user in choosing the "right sense" of a term through the description retrieved from the WordNet structure (gloss).

Once chosen the sense and the appropriate synset, it is possible to build a first core of the semantic net being considered all the terms contained in the synset; successively, by exploiting the other WordNet linguistic properties related to the type of a given term (e.g., names, adjectives, verbs, adverbs), the semantic net can be extended obtaining a strongly connected net, in which the relation between the different terms are labeled using some normalized weights that take in account the strength of the relation. For measuring the correlation between terms in the LO metadata and user data the following metric is used:

$$S_{t_i,t_j} = e^{-\alpha l}\frac{e^{\beta d} - e^{-\beta d}}{e^{\beta d} + e^{\beta d}} \tag{1}$$

where $\alpha \geq 0$ and $\beta > 0$ are two scaling parameters whose values have been defined by an experimental setup and *i* and *j* are the indexes of the considered terms.

The above equation is expressed by combining the normalized distance between two terms $l = \min_j \sum_{i=1}^{h_j} \frac{1}{\sigma_j}$, where j spans over all the paths between the two considered terms, h_j is the number of hops in the j-th path and σ_j is the weight assigned to the type of relations in the j-th path, and, the depth of its *subsumer* d from the root of WordNet hierarchy (d is computed using WordNet and considering the IS-A hyponymy-hyperonymy hierarchy only).

Eventually the final relatedness measure is obtained by combining S_{t_i,t_j} quantity with the weight of a given term t_i calculated as calculated as $w_{t_i} = \frac{1}{poly(i)}$, being $poly(i)$ is the polisemy grade of t_i.

More details about the semantic net construction and the used metric are reported in [1]. Such approach is useful to solve a semantic heterogeneity in the description of the LO since the user can specify, in its query, keywords not directly present in the metadata but related to them by linguistic relations.

5 Experimental results

From one side, we suppose the presence of two LO repositories containing 50 learning resources related to the Computer Science learning domain. In particular the first repository is a MySql Relational Database running on a Linux Slackware operating system. The second repository is a Tamino XML Database running on a Windows XP operating system. The wrapper functionalities are provided with the `USER INTERFACE`.

It is possible to:

- register a new wrapper and configure the wrapper for repository communication;
- describe the multimedia learning objects;
- set communication parameters with mediator.

By the `LOM EXTRACTOR` the wrapper administrator can export from his repository the LOM metadata for the various managed LOs. The LOM tree structure is after converted in a XML format which is sent to mediator with the related data, necessary to associate to the object a semantic meaning. Eventually the description of the object is stored in the WRAPPER DB.

The query processing to/from mediator is managed by the `QUERY EXECUTOR`: such module uses the information in `WRAPPER DB` in order to translate mediator requests in the local DBMS SQL o XPATH format. Eventually the query results and the related scores are sent to the mediator.

From the other side, the mediator functionalities are provided with two different graphical interfaces. By means of the `USER INTERFACE`, it is possible to:

- submit a query;
- view the query results;
- set some communication parameters in order to optimize the transmission flow towards the user.

While, by means of the `ADMINISTRATOR INTERFACE`, it is possible to administrate and configure the system.

The main task of mediator is to store the LOM descriptions originated by the two wrappers. If the classification has a success, the mediator inserts a new object in the `METADATA DB`. The `SEMANTIC MANAGER` tries to associate a semantic concept to the wrapper objects and the semantic associations with the other objects by using the described `SEMANTIC NETWORK`.

The query processing is carried out in three phases:

- by means of `USER INTERFACE` all data (Top-K dimension, query weights), necessary to the query execution, are picked up and stored in the `QUERY DB`;
- the query, stored in the `QUERY DB`, is compiled by the `QUERY ENGINE` and sent to wrappers;
- the query results are picked up form Wrapper and, by means of the `TOP-K SELECTION` [6], the best ones are shown to the user. During the download, as specified in the user settings, the object resolution is adapted to the user device type.

We have tested our semantic metric by performing 5 queries and calculating recall on the result test. In particular we have used search keywords not present in any managed LOs metadata, but related to Computer Science learning domain. The table 1 summarizes the obtained results.

Table 1. Experimental Results

Query	Search keyword	TopK	Recall
1	Random Access Memory	50	98%
2	Cache Memory	50	92%
3	Operating System	50	95%
4	File System	50	89%

6 Conclusions

A learning object sharing and integration system has been presented. It allows a single unified database view from more LO repositories. The proposed data model is the IEEE LOM, while the system architecture is based on the Mediator/Wrapper schema in order to have a fine description and organization of data. The user query is processed by ad hoc module and sent to appropriate wrappers.

The query results are calculated taking into account their semantic meaning and using a dynamic multimedia semantic network. The reported preliminary results show the efficiency and effectiveness of the proposed architecture performances.

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Using Information Technologies to Help Doctors to Provide High-Quality Consumer Health Information

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Abstract

Laypeople have a lot of health related questions, although they can search on the Internet, they don't know what consumer health information (CHI) they can trust. There are many mechanisms to help laypeople to select the reliable CHI, including ethical codes, guidelines, web awards, accreditation logos, and portal sites. But the number of questions is much more than good answers provided by healthcare professionals, especially doctors. To help doctors to provide high-quality consumer health information easily and efficiently, this study will use various Information Technologies and free online services, including mailing list (for mutual discussion and newsletter publication), article template of good CHI, webmail (for anti-spam), URL redirecting (for easy memorization and click statistics), creative commons, wiki (for tagging and quick organization), online form survey (for collecting questions), FAX2email and online audio recording (to speed doctors' productivity). Under the cooperation of doctors and use of various Information Technologies, we believe this study will attract a lot of doctors and readers, and generate certain amount of good CHI content in three months.

***Keywords**: consumer health information, doctor, mailing list, FAQ, wiki, audio message, fax2email.*

INTRODUCTION

Knowledge is power. Education in advance is more important than compensation after bad things really happen. Therefore, getting reliable, accurate, and up-to-date health information is the most important way to prevent disease and promote health.

Since the emergence of the internet, more and more people check and search health information, but laypeople can't judge the reliability and quality of health information. To help laypeople to select the reliable health information, several organizations and institutes established ethical codes and guidelines of good health websites, web awards, accreditation logos, and health portal sites.

Though with the help of search engines and portal sites, many laypeople still can't find reliable answers on the internet, and the questions extremely outnumber the good answers provided by healthcare professionals, especially doctors. The challenge is, many Taiwan doctors type Chinese much slowlier than English, and many of them are unfamiliar with the requirement of high-quality CHI.

Purpose

The purpose of this study is to use various information technologies to help doctors to provide high-quality consumer health information easily and efficiently.

Literature Review

According to the 2002 "Outpatient health service quality telephone survey" of Taiwan Health Reform Foundation, more than 90% of the responders thought doctors' explanation about patient condition, cause of disease, treatment and health education are important, but 42% of their doctors didn't offer health education information (like diet control, exercise, notice, prevention, etc) during the visit, and 57.1% of the responders' visit time was less than 5 minutes. It's obvious that many Taiwanese doctors neglect the importance of patient health education [1].

In the Information Age, more and more Taiwan families and people can access the Internet and search information. According to the 2005 "Household Online in Taiwan Survey", 76% of households in Taiwan owned computers, 67% of households in Taiwan had Internet access and 88% of these online households used broadband, 58% of the population in Taiwan had used the Internet by the end of 2005 [2, 3].

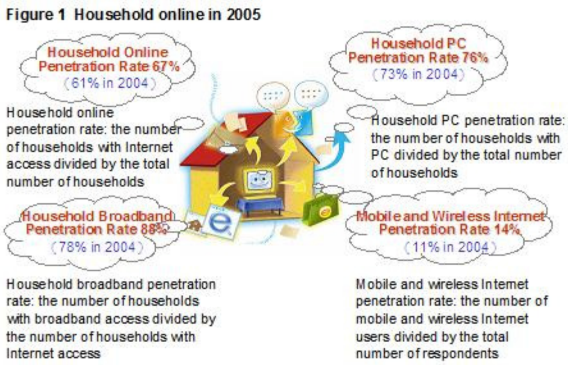

Figure 1. Taiwan Household online in 2005

According to 2005 "Taiwan Internet Users Survey", 41.4% of Taiwan Internet users browse news websites, 11.6% of them browse health websites (excluding portal sites); 73.5% of Taiwan Internet users subscribe electronic newsletters, 21.3% of them subscribe health newsletters [4]. It seems that websites (including blogs, BBS, newsgroups, wikis) and electronic newsletters are good tools to broadcast consumer health information.

Laypeople can't judge the reality and quality of health information, so some organizations and institutes establish the checklist and ethical standards of good health and medical websites, like QUICK (QUality Information ChecKlist) [5], HONcode [6] and eHealth Code of Ethics [7]. Some organizations and institutes award good health and medical websites periodically, like World Wide Web Health Awards [8] and Good Health Information Website Portal Site in Taiwan [9]. Some government institutes set up health portal sites for consumers, like Healthfinder [10], Medlineplus [11], and HealthInsite [12].

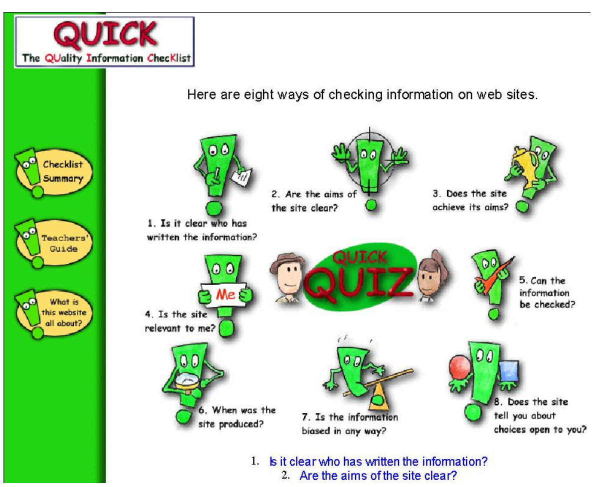

Figure 2. Eight ways of checking information on web sites

Figure 3. Good Health Information Website Portal in Taiwan

In Taiwan, many people ask health questions in related boards and channels in newsgroup [13, 14], and Yahoo! Knowledge [15, 16]. But almost everyone posts his/her questions and answers anonymously and violation of copyrights is common, and voting from laypeople can't assure the quality of health information.

METHODS

Accuracy is much more important than speed. To assure the quality of health information, this study will use free Internet services of Google Groups and 3 Taiwan portal sites to set up two kinds of mailing lists, one for invited doctors to post their consumer health information (CHI) articles and peer review; the other for readers to freely subscribe, browse and search newsletters [17, 18, 19].

Figure 4. Google Groups

The format and required fields of CHI articles will follow the HONcode and criteria of several health website awards, including title of article, title / full name / contact of authors (doctors), date of creation and last update, reference, etc.

If the authors have concern about spam emails bombing, this study will use email alias, anti-spam, filter and forwarding funcitons of free webmail service (Gmail) to hide and protect authors' email [20].

To increase the cooperation and traffic of authors' websites, this study will use free URL redirecting service (notlong.com) to calculate the click rates of each author's articles [21].

Figure 5. notlong.com

To accelerate the process of agreement and peer review, if no objection and modification opinion posted in doctors' mailing list, then proposals or articles will be accepted or published.

To maximize the number of potential audience, this study will encourage authors to use Creative Commons (CC, attribution, non-commercial, no derivative works) instead of Copyrights, then readers can forward and post our newsletter everywhere, and webmasters can post our newsletter on their websites, newsletters, wikis and blogs [22].

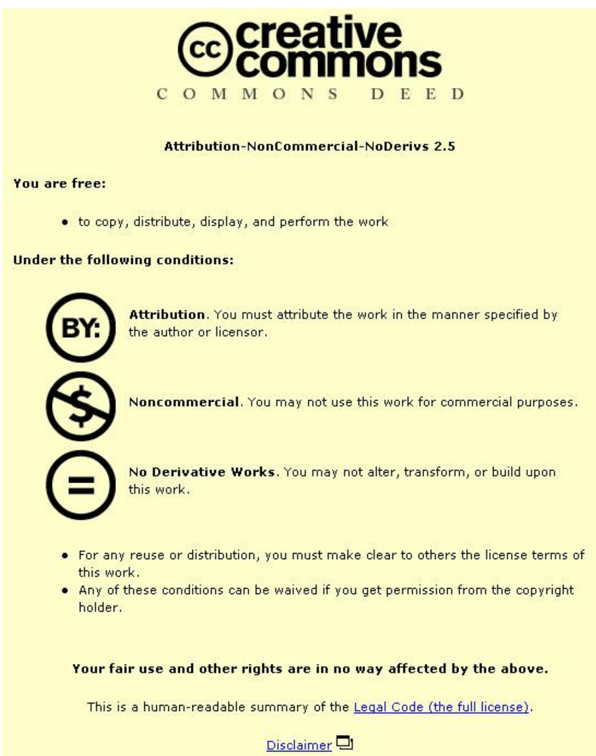

Figure 6. Creative commons

To organize and tag the articles, this study will use free standalone Tiddlywiki (a single html file) to set up a website, and readers can search texts and tags, and subscribe our RSS feed instead of subscribing our newsletter [23].

This study will collect and categorize good health questions from newsgroup and Yahoo! Knowledge, and post them for doctors' writing reference of FAQ (frequently asked question).

To assure the completeness of health questions, this study will use free online form survey service for laypeople to write down their question. Besides browsing and exporting database online, each new response will be sent to our email account [24].

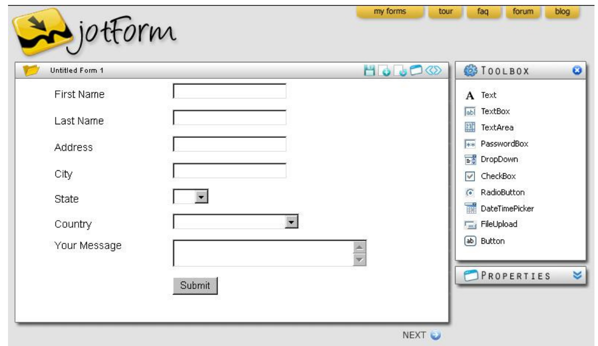

Figure 7. JotForm

If authors feel difficult in typing Chinese, this study will teach them how to use free FAX2email and online audio recording services, then forward their submitted contents to our mailing lists [24, 25]. Besides articles, doctors can also recommend good health websites, articles and activities, or comment on recent health news.

Expected results

Under the cooperation of doctors and use of various Information Technologies, we believe this study will attract a lot of doctors and readers, and generate certain amount of good CHI content in three months.

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Preschool Music Teacher e-Learning Platform

- 'Musical Magic Teacher' as the example

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***Abstract*—The essence of music education is sound, so the descriptions in textbooks are not sufficient enough to provide complete comprehension for learning. As the result, information technology, integrated with texts, musical sounds, music scores, animations, visual images and other multimedia information, together create reusable musical educational digital contents can further enrich students' musical experience and enhance the efficiency of education. In the Musical Magic Teacher e-learning system, the linkage of Internet technology and the establishment of online music e-learning platform encourage preschool teacher trainees' active learning and self-directed learning. An online canvass is created and made available to fellow trainees to share feedbacks and the experience of cooperative learning. In this study the authors have developed a set of 'Preschool Music Teacher e-Learning Platform' in accordance to the concept of information technology incorporated into musical education. The online learning system will be adopted and exercised in preschool music teacher orientation and as the on-the-job training materials in Taiwan HESS Educational Organization. The system offers a multidimensional music learning environment that is free from the restraints of time and space. The e-learning system is expected to help consolidate preschool teachers' professional music education and multimedia application ability which can further promote the development of preschool music education industry.**

Keywords: music education, preschool, teacher cultivation, pre-job training, e-learning

I. INTRODUCTION

The essence of music education is sound, so text descriptions in textbooks are not sufficient enough to provide complete comprehension for learning. As the result, information technology, integrated with texts, musical sounds, music scores, animations, visual images and other multimedia information, together create reusable musical educational digital contents can further enrich students' musical experience and enhance the efficiency of education. The linkage of Internet technology and the establishment of online digital music learning platform not only assist in the systematic structure of music education, but they also encourage preschool teacher trainees' active learning and self-directed learning. An online canvass is also created and made available to fellow trainees to share feedbacks and the experience of cooperative learning. The assignment feedbacks after learning allow instructor to perform analysis and evaluation of the education program and use them as the accordance for future improvement.

Taiwan Government has been vigorously promoting the implementation of Internet environment in recent years. The Executive Yuan announced the 10 new major construction programs in 2003, and 'Mobile Taiwan' was the most important one of them related to innovative knowledge industry. This project, jointly promoted by the Executive Yuan Science and Technology Advisory Group, Ministry of Internal Affairs and Ministry of Economic Affairs, planned to deploy Internet and wireless services of living and learning applications to make Taiwan a mobile habitation (Ministry of Economic Affairs, 2004). Given the establishment of Internet environment in Taiwan is already mature enough for the e-learning education programs to reform, the multimedia online digital learning of music becomes especially advantageous from the objective point of view. It allows the traditional music teaching method to reform into a multidimensional and interactive communication between trainee vs. instructor, trainee vs. education material and trainee vs. fellow trainees.

This study develops a set of 'Preschool Music Teacher e-Learning Platform' in accordance to the concept of information technology incorporated into musical education. The online learning system will be adopted and exercised in preschool music teacher orientation and as the on-the-job training materials in Taiwan HESS Educational Organization. The system offers a multidimensional music learning environment that is free from the restraints of time and space. Via the efficient management of this open education platform, preschool music teachers' educational demands can be more concretely fulfilled, and therefore creates a multidimensional music learning environment.

II. PURPOSE AND METHODOLOGY

*A. **Purpose***

In this study, there are three major objectives. First is to establish a 'Preschool Music Teacher e-Learning Platform' and map out preschool music teacher training program into categories of program objectives, teaching demonstrations, group discussion, assignment evaluation and trainee's presentation. At the same time, preschool music e-textbook, 'Music Magic Book' edited by Xiu Ling Gao (2002) and adopted by HESS Educational Organization, is digitalized and the contents are recorded and used for responding teaching demonstrations to act as core reference in group discussion and teaching training. In additional, face to face courses are offered to educate group trainees the multimedia application of music and also to assist them in the development of personal music education lesson plan. Each trainee's training achievement will be recorded and shared to fellow trainees on the platform to enhance their professional music education and multimedia application ability before on-boarding the job. The e-learning platform is named as "Musical Magic Teacher." The major goal of this study is to cultivate preschool music teachers with capability of multimedia application and information technology.

B. Methods

The fundamental elements to develop a music education e-Learning platform consist of multidisciplinary team, instruction design theory, digitizing tool of teaching materials, and e-Learning management system.

Multidisciplinary Development Team

The teamwork involved in this study including principle investigator (project manager), domain experts (music education expert and information science expert), e-learning platform administrator (education technologist), education designers (instructor and assistant instructor), inspector (music education and administrative supervisor), and online assistant (information technician).

Implementation framework system : eZLMS system

The basic framework of ezLMS system:

1.*Core of knowledge*: Files (overviews, documents, discussions, essences), Curricula (announcements, school timetables, learning maps, study assignments, examinations, questionnaires, class managements), Web Hard Disks.

2.*Personal homepage*: my core of knowledge (we can survey the subscribed documents, the latest documents, and discussions, etc.), reading record, personal setting, subscribing setting

3.*Core of questionnaire*: System questionnaire, curricular questionnaire.

4.*System Administration*: Statistic statements (file overviews, document overviews, users' overviews, reading records), identity managements (identity managements, group managements, deleted accounts, and ceased accounts), system managements (general setting, setting the SMTM e-mail, verification processes, trust setting, system update, backup setting, retrieval data setting).

ADDIE Instruction Design

The development of this e-learning platform applied the generic ADDIE model for e-learning instruction design in "Reference Manual on e-Learning Program Development Procedures" (Ministry of Education, 2004). The ADDIE module is the process of: Analysis → Design → Development → Implementation → Evaluation. Such standardized module acts as the foundation of digital education material development for" Preschool Music Teacher e-Learning Platform." Please see Figure 1 for illustration.

1. Analysis Stage

Demand Analysis: With the focus on the music teachers in the Philharmonic Children Music Consulting Company (Elementary School of the Hess Educational Organization), this research takes the teaching plan of "Music Magic Book" and the music teachers' need upon this learning system for reference of this learning system's function plan and the design of the instructional contents.

Learner Analysis: The music teachers in the Philharmonic Children Music Consulting Company (elementary school of the Hess Educational Organization) are the expected users of this system. With the repeated interviews with the music teachers, this research comprehends the demands and characteristics of the music teachers.

Content Analysis: The instructional content of this learning system is the "Music Magic Book" published by Philharmonic Children Music Consulting Company (elementary school of the Hess Educational Organization). The e-based instruction content concentrates on the curricula of the "Music Magic Book", including music knowledge, music stories, rhythm, music appreciation, music games, instrumental ensembles, music compositions, and so on.

2. Design Stage

Design of Website Function: In accordance with the situated-learning principle and the mathematics instructional content of the first and second Grade in elementary schools, we can divide this learning website into several functional domains: the "organization introduction," the "curriculum units," the "teaching and learning interactions and discussions," the "achievement exhibition," and the "contact."

Design of Curricular Contents: The curricula of this learning website are presented by digital images which lively contains the music knowledge. By coordinating with the curricular units of the "Music Magic Book, the design of the curricular contents in this learning website presents the notions of the teaching plan by employing concrete stories, rhythms, instruments, games and plays of percussion.

Design of Instructional Strategies: According to the system functions, the instructional strategies of this learning system can be divided into four sections: the first one is the "music stories," which mainly focus on the problem orientations and the tutorial-guided strategies. The instruction is performed via the learning thinking guided from the stories and the utilization of the software "Powercam." The second one is that "rhythm" is the strategy of situated-instruction. By following the story contents, using role-playing, and matching the rhythm, learners would be situated in the plots of the stories, so as to reach the learning effects. The third one is "instrumental ensembles" in which the instructional strategy emphasizes on learning instruments. Through the presentation of the digital images, learners can accurately understand how to perform instruments. The fourth one is that the "music games" is the strategies of situated-instruction. Learners can develop creativity and imaginations under the playing process.

Designs of Interface: The way of the interface design in this learning system mainly adopts the data-input and mouse-click on the options. In order to cooperate with teachers' demands on the achievement displays as well as viewing and learning from each other's works, it is necessary to understand how to use the software "Powercam" and how to upload the digital images to the administration platform.

3. Development Stage

System Development: Based on the decided contents of "analysis" phase and "design" phase, the framework of this whole learning system is carried out in the system development stage. The step of this development system can be divided into Web-Page Design, multimedia authoring, art designing, and system integration.

Some curricular forms are sound e-books. Most of them don't need to draw scripts, but list the contents and data.
As most curricular units are presented by images and sounds (for example, music stories, rhythm, percussion playing, and musical play), drawing the script of teaching material based on the learning objectives, instructional strategies, integrated instructional content, teaching materials of each curricular unit in the "Music Magic Book" is required. (Sketches in the homepages, massages, materials, and programming logic) the function of the script design is to provide the same communicating media for instruction designers and development groups. The curricula would be able to be started off after finishing the script designs.

4. Implement Stage

The notions and skill possessed by learners would be able to influence instructional quality in e-based curricula. For the reason, it is essential to implement a set of integrated educational training to educators. The contents of the training include:

To make the e-instructors understand what the roles they act and their importance.

To let the e-instructors be able to design the related-learning strategies for specific curricula and process assisting works.

To let instructors understand each function of the learning platform, experience the instructional environment of the e-learning system, and further design an appropriate instructional guiding procedure.

In order to ensure the qualification of curricula implement, instructors are required to possess the knowledge and skill of e-learning system.

By incorporating the specific demand of curricula, instructors can provide the basis of continued resource for platform manager, development team and related-information personnel.

5. Evaluation phase

The implemented evaluation in this research is confined to the formative evaluation for the purpose of promoting this system and evaluating its learning effect. In order to ensure the validity of the learning contents and ascertain the direction of leaning development, we irregularly invited education-technology professionals and content professionals to implement formative evaluation under the designing and establishing processes in this learning system.

After completing and before formally implementing this system, we invited four related-domain professionals (a professional music instructor, a professional music educator, and two education-technology professionals) to implement this evaluation. The contents of the evaluation embrace: the instructional objectivity, learning contents, medium's display, and sketch designing on this website. Also, this system was tried out and evaluated by platform learners (music teachers). The process of the implementation includes the purposes and directions of use, trials and observations, evaluations and discussions. Besides purposes, the chief evaluation in this evaluating stage is to collect opinions about the system's amendment, understand students' using attitude, and evaluate learning wills after they initially using this system.

III. Results

This platform adopts the PowerCam & ezLMS Learning & Knowledge Management System, researched and developed by Formosa Soft Corporation, to help develop 18 educational modules (Figure 1) that convey five categories (Figure 2: Mommy Bird): music story, musical rhythm, instrumental ensemble, and musical games. This platform plans to complete 18 educational demonstrations (Figure 3), provide canvas for group feedbacks (Figure 4) and offer digital learning environment for assignment submission and presentation of training results (Figure 5)

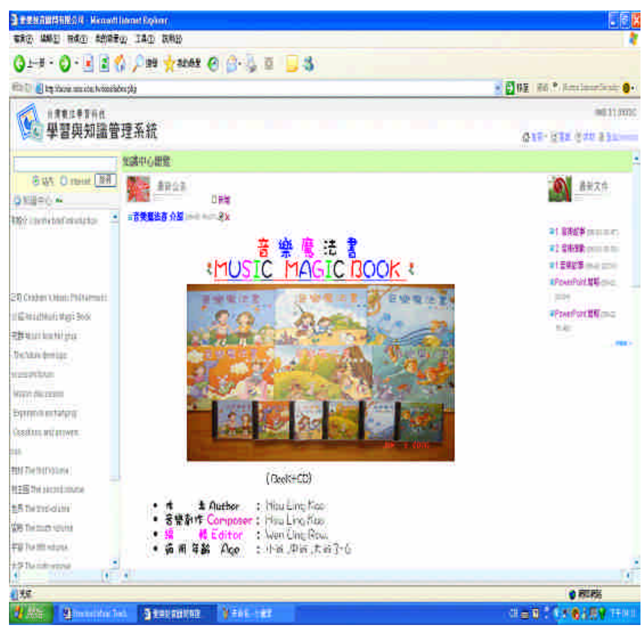

Figure 1: Musical Magic Teacher e-learning platform

Figure 2: Course Structure of 18 Preschool Music Education Modules

Figure 3: Five Categories of Teaching Skills

Figure 4: On Line Teaching Demonstration

Figure 5:On Line Group Discussion

Figure 6: Achievement Presentation of Trainees

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IV. Discussions

Application of e-Learning platform can provide an effective pre-job orientation free from the restraints of time and space. It is also very useful for on-the-job training. Repeated viewing of teaching demonstration and active participation in group discussion with fellow teachers on the e-learning platform enable an environment to cultivate young teachers.

In this study, multimedia digitizing tool PowerCam is used to convert PowerPoint presentation into digital streaming video synchronized with lecture or demonstration slides. During an ordinary PowerPoint presentation without any changes of the lecturer's habit, the teaching can be recorded and digitized to a high quality web-based teaching content including lecturer's voice and video, mouse cursor movement and animations of slides. All of the actions are done with a single record button click. After the completion of the recording, the digital contents could be packed and uploaded to the e-learning platform with the teacher's account and published publicly or privately according the setting of access privileges. The process simplicity of making the e-learning content also enhances the ability of music teacher using multimedia application.

The study attempts to enhance preschool teachers' professional music education and multimedia application ability via e-learning and therefore further promote the development of the preschool music education industry.

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DMS 2007 Call For Papers

The Thirteenth International Conference on Distributed Multimedia Systems

Hotel Sofitel, San Francisco Bay, USA
September 6 - September 8, 2007
Organized by
Knowledge Systems Institute Graduate School

SCOPE

The DMS conference is an international conference series, which covers a wide spectrum of technique discussions, demonstrations, and student program/paper contests in the fields of distributed multimedia computing. Started in 1994, the series of conference has been held at Hawaii, Hong Kong, Vancouver, Taipei, Aizu-Wakamatsu, Japan, San Francisco, Miami and Canada. This time, the conference will be held at the Hotel Sofitel, Red Wood City, San Francisco Bay, USA.

TOPICS

DMS'2007 focuses on techniques, systems, applications, and theories in the fields of distributed multimedia computing. The conference organizers seek contributions of high quality papers, panels or tutorials, addressing various aspects of distributed multimedia systems and applications, for presentation at the conference and publication in the proceedings.

Topics of interest include, but are not limited to:

audio and video compression
MPEG, Quicktime, Windows API standards
image, video, audio content analysis and indexing/retrieval
image, video and audio watermark
3D audio and video
computer graphics and animation
modeling and analysis of distributed multimedia systems
OS support for distributed multimedia systems
distributed multimedia databases and computing
distributed object management
multi-paradigmatic information retrieval
multimedia human-computer interaction
multimedia communications and network architectures
mobile networks and mobile computing
multimedia stream synchronization and QoS control/scheduling
multimedia software engineering
multimedia processors and ASIC
multimedia technologies for people with disability
intelligent multimedia computing
intelligent multimodal interaction
multi agents, mobile agents and their applications
communication encryption
security of distributed computer systems
sensor networks for multimedia computing
Web servers and services
XML applications
Java, VRML and multimedia languages
visual and multidimensional languages for multimedia applications
multimedia digital libraries and mail systems
multimedia applications for CSCW
multimedia authoring tools and intelligent tutoring
cultural heritage multimedia applications
tele-conferencing, tele-medicine and tele-lecture
virtual reality, distributed virtual environment, and their applications
virtual school, virtual university, and virtual learning community
distance learning methodology, tools and systems
e-commerce, e-education and e-entertainment

The use of prototypes and demonstration video for presentations is encouraged.

WORKSHOPS AND SPECIAL SESSIONS

This year, DMS'2007 will be held in conjunction with workshops, conferences and special sections. Papers submitted to workshops or special sessions are invited by the program committee chairs of the workshops/sections. This joint organization aims to collect research results from different perspectives. The following workshops and conferences are being planned:

International Workshop on Visual Languages and Computing
International Workshop on Mobile Systems, E-Commerce and Agent Technology
International Workshop on Distance Education Technology

Please contact the conference program co-chairs if you are interested in organizing a workshop or a special session. A one-page proposal with the following items is required:

Title of the workshop/special session
Name of the program committee chair(s)
A list of program committee members
E-mail address of the corresponding program committee chair
A brief description of the theme

Each special session should include at least 5 invited (or accepted) papers. Each workshop should include at least 2 special sessions (10 papers). Paper review process of the workshop/special session will be arranged by the individual program committee chair. It is the responsibility of the individual chairs to ensure the quality of papers in the workshop/special sessions. The schedule of workshops/special sessions will be the same as the main conference (See Important Dates below). Each individual program committee chair can set up the Web site of the workshop/special session. However papers will be printed in the same volume as the main conference.

SPECIAL ISSUE OF JOURNALS

The DMS conference is closely coordinated with the International Journal of Software Engineering and Knowledge Engineering, the Journal of Visual Languages and Computing and the International Journal of Distance Education Technologies. Usually the best ranked papers from the conference, after rigorous reviews, extensive revisions and further enhancements, will appear in one or more special issues of the above journals. Papers suggested for the special issue(s) will be reviewed by external reviewers following the standard procedure of review stipulated by the respective journal.

CONFERENCE SITE (HOTEL INFORMATION)

The DMS2007 Conference will be held at the Hotel Sofitel, Red Wood City, and San Francisco Bay, USA. The hotel has made available for these limited dates (9/5/2007 - 9/9/2007) to DMS2007 attendees a discount rate of $86 US dollars for single/double, not including sales tax.

INFORMATION FOR AUTHORS

Papers must be written in English. An electronic version (Postscript, PDF, or MS Word format) of the full paper should be submitted using the following URL: http://conf.ksi.edu/dms07/submit/SubmitPaper.php. Please use Internet Explorer as the browser. Manuscript must include a 200-word abstract and no more than 6 pages of IEEE double column text (include figures and references).

INFORMATION FOR REVIEWERS

Papers submitted to DMS'07 will be reviewed electronically. The users (webmaster, program chair, reviewers...) can login using the following URL: http://conf.ksi.edu/dms07/review/pass.php.

If you have any questions or run into problems, please send e-mail to: dms@ksi.edu.

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If you cannot submit electronically, please send four copies of the complete manuscript to the above postal address.

IMPORTANT DATES

March 1, 2007 *Paper submission due*
May 1, 2007 *Notification of acceptance*
June 1, 2007 *Final manuscript due*
June 1, 2007 *Early conference registration due*