

Distribuzione Sicura di Oggetti Musicali Multimediali

Safe Distribution of Multimedia Musical Objects

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Abstract

Il valore aggiunto della distribuzione digitale e di Internet risiede nella possibilità di ottenere oggetti che presentano nuove funzionalità, specialmente interattive. Da questo punto di vista le immagini di partiture non sono interattive, non possono essere facilmente manipolate, pertanto i costi per preparare la musicaper concerti o per il lavoro nelle scuole di musica sono comparabili all'uso della carta. I teatri, le orchestre, le scuole di musica, i distributori di musica, gli studi di registrazione, le persone non vedenti e le biblioteche hanno necessita' di utilizzare musica interattiva. Tale musica e quella che può essere manipolata, arrangiata, trasposta, modificata, riformattata, stampata in Braille, etc. Queste sono reali necessita' per preparare concerti studiare musica, analizzare musica, imparare uno strumento, etc. Queste operazioni possono essere permesse solo nel rispetto dei diritti del proprietario. Pertanto, la protezione della musica e' un aspetto importante che deve essere garantito per mezzo di tecniche di: protezione della distribuzione della musica con modello di transazione sicuro, protezione passiva tramite tecniche di crittatura, gestione dei Digital Right Management, e impiego di tecniche di marcatura (watermark) per file audio e partiture, etc. In questo lavoro sono presentati i principali risultati del progetto WEDELMUSIC IST riguardo ai meccanismi di transazione e distribuzione della musica. La soluzione proposta e' stata studiata per permettere agli editori e ai fruitori di gestire partiture musicali nel rispetto delle leggi sui diritti di autore.

An added value of digital distribution and thus of Internet is the possibility of exploiting new functionalities related to the interactivity. From this point of view, images of music sheets are not interactive and thus the related costs for using that music for preparing performances in orchestras, in music schools, etc., are comparable to those of using traditional music sheets. Theatres, orchestras, music schools, music distributors, recording studios, blind people, and libraries need interactive music; that is, music that can be manipulated: arranged, transposed, modified, reformatted, printed in Braille, etc. These are real needs for preparing performances, studying music, analysing music, learning instruments, etc. These operations can be only permitted according to the owner rights. Thus, a very important aspect is the protection of music which involves the: protection of music distribution with a safe transaction model, the passive protection of digital objects with suitable encryption tools, the Digital Right Management, and the watermarking of digital objects such as audio files, music sheets, etc. In this paper, the main results of WEDELMUSIC IST project regarding the transaction model and music distribution are reported. The proposed solution has been defined to allow publishers and consumers to manage interactive music respecting copyright laws.

1 Introduction

Big publishers are becoming to exploit Internet potentialities for music distribution. Systems, such as NAPSTER and GNUTELLA, are rapidly transforming the distribution of audio files, they adopt a Business-to-Consumer model, B2C. Digital Music is also music scores, music related documents, music

cataloguing management, documents about lyric, music videos, etc. Presently the market of music scores is a small part of the activity related to digital music. Recently some examples of music sheet distribution on Internet are available (MusicSales, Net4Music, etc.). Most of them are based on the distribution of score images in PDF or PostScript files. Music sheets cannot be manipulated by the end users. These solutions are a surrogate of the classical distribution of music sheets via music shops. On the other hand, the acquisition of music sheets by image scanning is the first step to put in digital the music sheets that are present in the publishers' archives. The digitalisation of historical music archives can be a way to go on the Internet market and at the same time to save the cultural heritage. In fact, in many cases the archives of institutions, conservatories, foundations, and of big publishers contain also historical music that risks to be destroyed by the time. This huge amount of cultural heritage should be saved in digital and valorised.

Images of music sheets are not interactive and thus the related costs for using that music for preparing performances in orchestras, in music schools, etc., are comparable to those of using traditional music sheets. Theatres, orchestras, music schools, music distributors, recording studios, blind people, and libraries needs interactive music; that is, music that can be manipulated: arranged, transposed, modified, reformatted, printed in Braille, etc. These are real needs for preparing performances, studying music, analysing music, learning instruments, etc. Presently, this is not possible since music scores are only distributed as music sheets. In order to be manipulated the music has to be in some specific symbolic format.

A large number of symbolic formats for modelling music notation is available. Great part of these formats and music notation editors were realised for printing music (Score, Finale, Sibelius, etc.) [Sel97], [Bel99]. Most of these formats are not structured for modelling and managing symbolic music to be distributed on the Internet. The main obstacle of these formats to be used in the new emerging applications is the formal modelling of music: the net distinction from main score and parts, the lack of modelling relationships among music notation symbols, the lack of distinction between music modelling and formatting aspects, the private format adopted, the lack of integration of the several aspects of music, the lack of a support for protecting music, etc. To this end, several new solutions have been proposed as interchanging and Internet formats (SMDL, NIFF, XMLmusic, etc.). Unfortunately, as demonstrated by CANTATE and MOODS research projects [Bel99] these formats are unsuitable for supporting the applications of the Internet age. Therefore, in these years, we are assisting to a strong effort in transforming the old solutions towards the new needs of Internet and its users.

The real added value of digital distribution and thus of Internet is the possibility of exploiting new functionalities with a particular attention to the aspects related to the interactivity. A symbolic description of music sheets allows manipulating music in several manners: transposition for different instruments, content search, formatting, piano reduction, rearrangement of music, etc. On the other hand, the manual production of symbolic music is quite expensive. The generation of symbolic music from Optical Music Recognition systems is not reliable enough on real music. The 95% of music contained in the publishers' archives is on paper.

Another very important aspect is the protection of music which involves the: protection of music distribution with a safe transaction model [Inm98], [Jaj97], the passive protection of digital objects with suitable encryption tools [Seb89], the Digital Right Management (DRM) such as [SDM99], for tracing and accounting the exploitation of interested functionalities, and the watermarking of digital objects such as audio files, music sheets, etc. In addition, the DRM has to be accompanied by mechanisms for distributing music by publishers: renting, selling, disseminating demos.

In order to cope with the above mentioned problems the WEDELMUSIC (WEB Delivering of Music Scores) project and solutions have been developed [WED00]. WEDELMUSIC has been defined to allow publishers and consumers (theatres, orchestras, music schools, libraries, music shops, musicians) to manage interactive music respecting copyright laws and publishers' rights. WEDELMUSIC is an innovative format and solution for preparing performances, studying music, analysing music, learning instruments, distributing music at low cost, etc. WEDELMUSIC is an IST project with partners: DSI, University of Florence, Italy; ARTEC Group, Belgium; Casa Ricordi, Italy; FNB, The Netherlands; Scuola di Musica di Fiesole, Italy; IRCAM, France; FHG-IGD, Germany; ILSP, Greece; CESVIT, Italy; Edizioni Suvini Zerboni, Italy.

The paper is organised as follows. In Section 2, the structure of WEDELMUSIC objects (in short WEDEL objects) is presented considering the most important features and components. In Section 3, the transaction model and watermarking mechanisms (in short) used in WEDELMUSIC are presented. In Section 4, the digital right management of WEDELMUSIC is discussed. Conclusions are drawn in Section 5.

2 WEDEL Music Objects

WEDELMUSIC solution proposes techniques for distributing multimedia musical objects. WEDELMUSIC objects present an integration of symbolic format with images of music sheets, audio files, etc., and a set of protection mechanisms. Each WEDEL object present several components covering different aspects of a music piece. These components/aspects presents relationships and functionalities (see Fig.1):

- **Identification and classification.** Each WEDEL object as well as each of its components includes classification and identification fields. They have been mainly defined according to standards: Z39.50, UNIMARK, ISBN, ISMN, etc. The proposed model integrates in a unified model all the fields of these classifications and identification standards.
- **Symbolic Music** section describes the scoring information, musical notation symbols, and their relationships. Symbolic music can include main score and parts. This section also includes, music notation fonts, formatting rules, and versioning aspects associated with the symbolic music coding.
- **Image of Music Sheets** section allows to integrate images of music scores into the WEDEL object without converting them into symbolic format. Thus, in the same WEDEL object both symbolic notation and original images of music sheets can be present in the same object. This allows building WEDEL objects to compare original music score with revised and currently used symbolic versions. For example, the old style music (such as that of Uccellini, 1603-80) and its rewriting in western music notation. This is a suitable mechanism for revitalising old material and recovering cultural heritage.
- **Protection** section models details of encryption and watermark of music (audio and music sheets). A table about the music permissions is also available for the definition of Digital Right Management policies as described in more details in section 4.
- **Printing** section includes the description for printing music packages contained in the WEDEL object. The documents may be remotely printed with specific fingerprint and watermark [Kut99], [Pet99]. The watermark is a hidden code included into a digital object that allows to demonstrate the music object ownership in the case of copyright infringement verification.

- **Audio** section may contain one or more audio files. These can be watermarked according to the parameters of the WEDEL object.
- **Performance** section describes the synchronisation aspects between each audio file and the music score that can be shown on the computer screen. The synchronisation of audio file allows the contemporaneous visualisation and listening of the music score, considering the audio of real performances, controlling the execution velocity, etc..
- **Documents** section may include none, one or more structured documents such as author biography, critical description of the piece, description of the performing orchestras, etc.
- **Lyric** section may present none, one or more elements containing the text of the lyric associated with the music score and thus with the WEDEL object.
- **Video** section may contain none, one or more videos. These are very useful for presenting the hands of piano player, the live recording of a performance, etc.
- **Image** section may include none, one or more colour images such as the portrait of the author/performer, the picture related to the music or opera, etc.

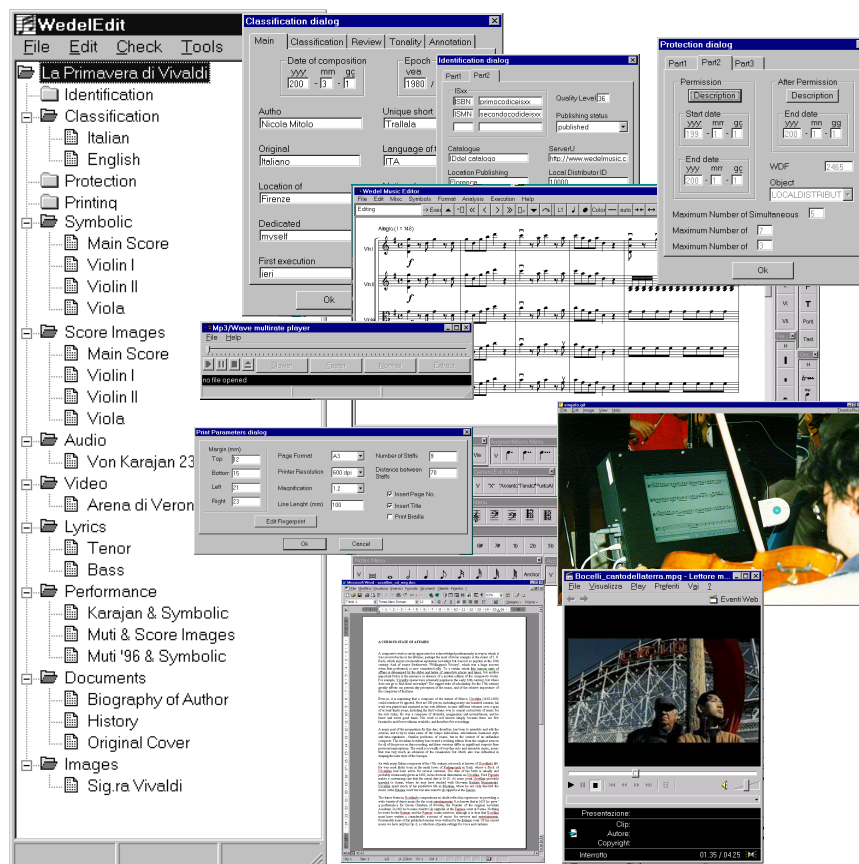


Fig.1 -- WEDEL Editor for manipulating WEDELMUSIC object and components.

In each WEDEL object, several relationships among its components can be established. These allow the definition and exploitation of new functionalities. For example, it is possible to:

- associate different lyric files to the same symbolic file/part, with multilingual and versioning support;
- pass from a music notation symbol to a document, video, image, audio file: relationships are performed via http links;
- listen real audio performance synchronously with the visualisation of (i) images of the music score, or of (ii) the symbolic music notation;
- modify music notation: annotation, formatting, arranging, fingering, adding/deleting notes, transposition, editing multilingual lyric, managing versioning, etc., in the respect of copyrights;
- print music score or other components of the WEDEL object;
- analyse music score, comparing and searching into the database, performing a piano reduction;
- extract excerpts of the music score, audio, and images of the music score;
- execute music notation generating MIDI file or audio files (WAVE, MP3, etc.);
- edit music for visually impaired people, print music in Braille, get a verbal description of music score;
- acquire music from other formats FINALE, SCORE, MIDI;
- searching music into the database on the basis of content (music melody), classification and identification aspects.

For the navigation in the WEDEL objects, a specific user interface has been implemented, as depicted in Fig.1.

Most of the above listed features are innovative and only possible on WEDELMUSIC model. Others classical features have to be considered innovative since in WEDELMUSIC they are allowed in respect of the owner rights. In each WEDEL object, the several features may be allowed or inhibited. In general, the availability of these functionalities has constrained to design a sophisticated set of tools to protect WEDEL objects and at the same time to permit and control the exploitation of the new functionalities. This has been performed thanks to the definition and implementation of:

- (i) a unified XML-based format for modelling music including audio, symbolic music, image of music scores, documents, videos, lyric, colour images, cataloguing information, etc., that can be associated with a music piece. The several components of each WEDEL object present relationships that allows the navigation among them and the exploitation of functionalities [Bel01];
- (ii) reliable mechanisms for protecting music:
 - transaction model for safe distribution of digital music objects,
 - symbolic format including protection aspects such as the watermark of music sheets while printing them,
 - images of music sheets including watermark,
 - audio files in different formats including watermark;
- (iii) sophisticated mechanisms for DRM over the limits of SDMI (Secure Digital Music Initiative) [SDM99]:
 - protected music that can be manipulated: transposed, arranged, modified, etc., respecting the owners' rights,
 - formal definition of allowed functionalities of the integrated multimedia WEDEL objects,
 - formal definition of the temporal exploitation of the permitted or inhibited functionalities,
 - supporting transaction models for selling, retailing, renting and demo distribution,
 - tracing (for statistical purpose and accounting of exploited functionalities).

3 Transaction Model and Protection Mechanisms

E-commerce for music distribution is not acceptable for publishers without the support of adequate protection mechanisms. WEDELMUSIC enables publishers to protect their music and at the same time to allow the users exploiting the above-mentioned functionalities of WEDEL objects according to the permissions and prices established by the publishers. To cope with these problems, WEDELMUSIC presents sophisticated mechanisms for protecting musical objects that include:

1. encryption techniques to support the transferring and storage of WEDEL objects;
2. watermarking audio files in different formats;
3. watermarking images of music score sheets;
4. watermarking music sheets while they are printed from symbolic notation files.
5. definition of Digital Rights Management policies (see section 4);

In this section, point 1 is discussed, while points 2, 3 and 4 are discussed in subsection 3.1.

WEDELMUSIC transaction model is based on the distribution of music from publishers to customers (end-users) by means of the Local Distributors, LD, (see Fig.2). They:

- can be libraries, theatres, conservatories, music schools, music shops, recording studios, foundations, etc.,
- are WEDELMUSIC registered institutions with authorised and certified client computers;
- collect and distribute WEDEL objects coming from several publishers;
- store the WEDEL objects into their local database in encrypted form. This confers an absolute safety to the Local Distributors, which are generically considered non trusting environments;

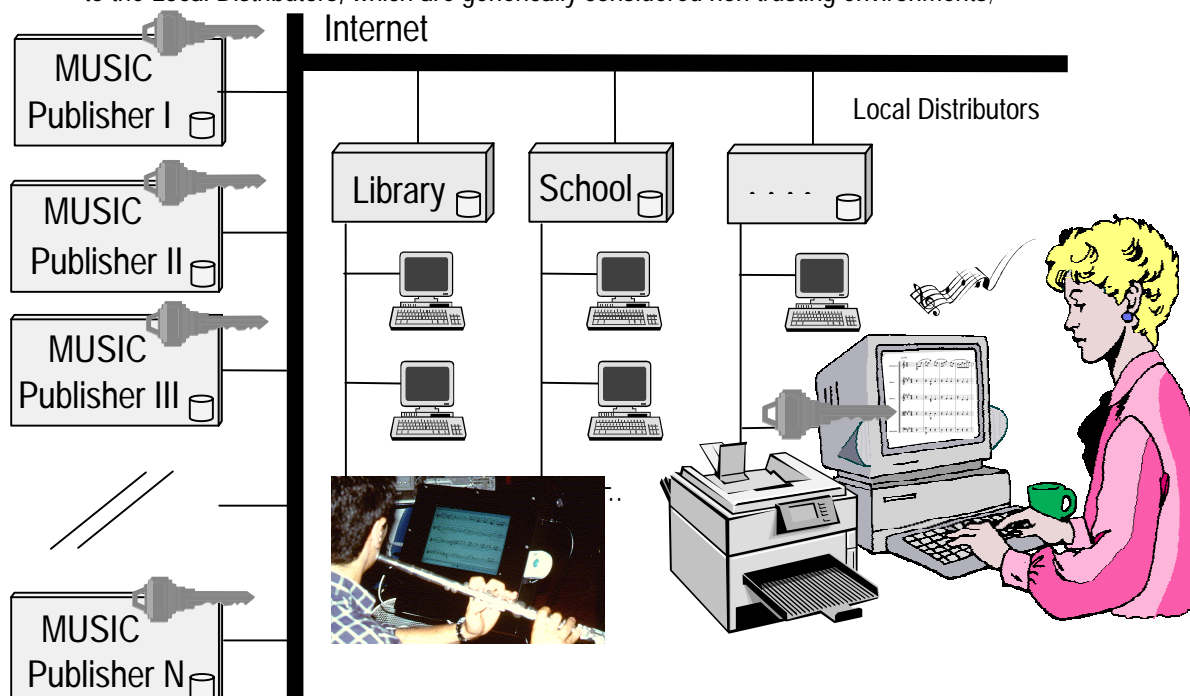


Fig.2 -- WEDELMUSIC transaction model, servers, Local Distributors and clients.

- may also collect WEDEL objects and components in non protected format. This allows to use the WEDELMUSIC local server (the local Digital Asset Management) for all the digital music of the Local Distributor;
- support the retrieval of WEDEL objects on the basis of classification, identification, and content aspects. The content analysis is performed by using the capability of WEDEL editor to process and compare music scores.

The WEDELMUSIC transaction model is mainly based on Business-to-Business, B2B, model to have at a second layer a Business-to-Consumer transaction, B2C. WEDEL objects may be very complex and large (with high-resolution audio, image, and video files) as well as very simple and manageable to be transferred in few minutes/seconds. For this reason, the adopted transaction model allows to completely customising the service of music distribution. WEDEL objects are built and encrypted on the publisher site by using a specific key for each LD to which they are sent. Each WEDEL object is delivered encrypted to the LD together with an information file in XML standard (called WEDEL Clear Header, WCH). It includes the cataloguing and identification information and it is used for storing and indexing the WEDEL object into the LD database. If the WEDEL object presents several components it can be partially stored into the LD. The rest may be left on the publisher Server and downloaded/requested when needed. For these reasons the B2B transaction model ranges from on-line to off-line transaction, with the on-line to the off-line distribution of the digital objects.

The LD manager may navigate via Internet on the Publisher WEDELMUSIC Servers in order to select the WEDEL objects that would like to have on the LD (see Fig.3, arrow (1)). This is simply performed by working with the WWW pages of the WEDELMUSIC servers.

The Clients/Attendees of the LD are allowed to make queries to the LD database on the basis of cataloguing and identification aspects (2) and (6). This is performed by using the Local Distributor WEB Server. The Local Distributor Clients present specific tools for visualising and editing WEDEL objects (WEDEL Editor, WEDEL Music Editor, Audio player, image score viewer, video player, image viewer, lyric editor/viewer, etc).

The Local Distributor Clients may browse the internal main components of the WEDEL objects by using the WEDEL Editor (see Fig.1). This is possible by using the WCH file. Once the client attempts to open a component of a WEDEL object, the encrypted WEDEL object is sent from the LD to the client (4). In order to open the encrypted file the WEDEL Editor contacts a special service called UKM (User Key Manager) to ask for the decryption key (3). To this end, the UKM contacts the WEDELMUSIC Server of the Publisher to get the requested key via (3) and (5) of Fig.3.

Please note that the communications performed for (i) getting the key needed for opening the WEDEL objects, and (ii) transferring the WEDEL objects, and for (iii) any other message/data passage are protected by using a couple of temporary keys [Sch94]. This confers a high safeness to the transaction models since the Local Distributor contains only encrypted objects and these are decrypted at the moment of their usage by the WEDEL Editor getting the key from the WEDELMUSIC Server via the UKM. In order to permit the continuity of the operating conditions of the WEDEL Editor, even when the connection with the Server is not possible, the UKM presents a mechanism of key caching.

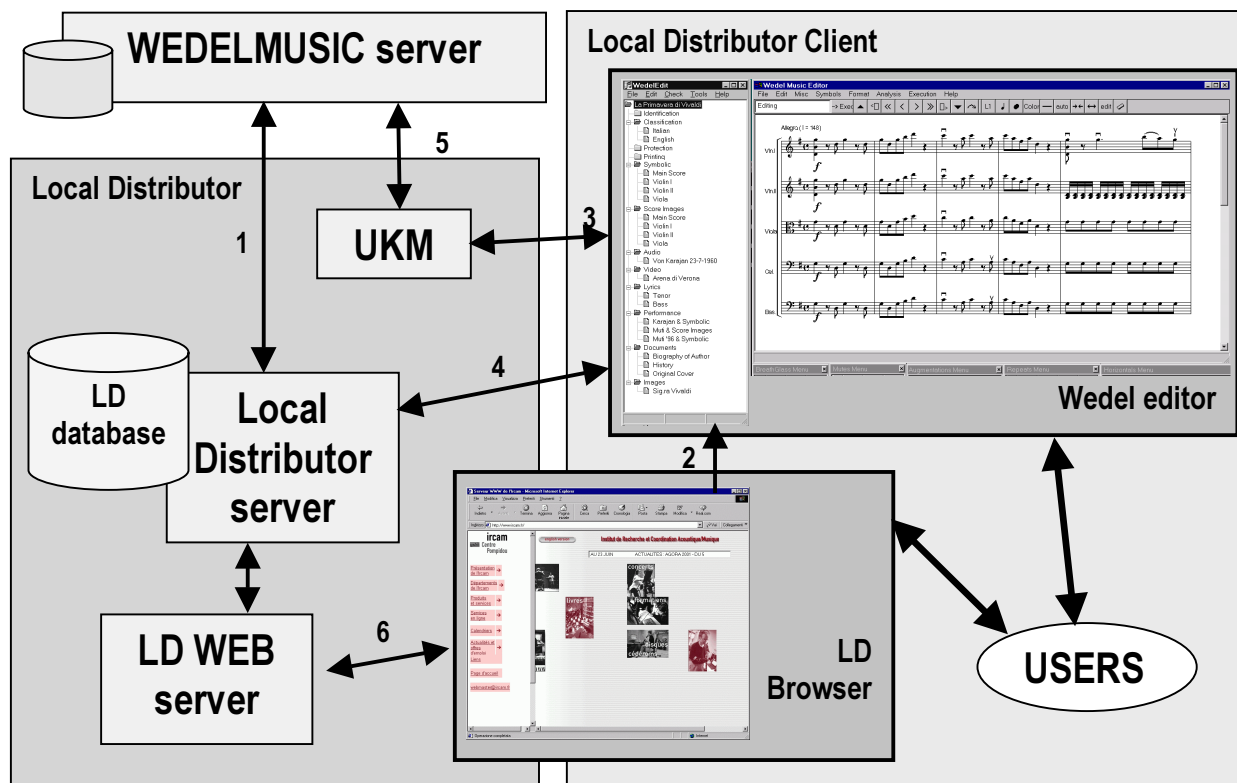


Fig.3 -- WEDELMUSIC transaction model, from server to clients. The numbers are referred in the text, and they order is meaningless.

3.1 Watermarking Music

Watermarking allows hiding information into digital objects such as images, videos, audio files and text pages [Bus00], [Cer00], [Sch01], [Kut99], [Pet99]. These techniques are adopted to hide codes that can be used for demonstrating the ownership of the digital object in the case of verification of the copyright infringement. To this end the hidden code contains the publisher identification code, the music piece code, and the LD identification code. The possibility to hide this information and read it after several types of attacks makes watermark suitable for property right protection. Watermarking tools are supported by a watermark reader to read the hidden code from a grabbed music sheet or audio file.

In digital music distribution, such as in WEDELMUSIC, the music sheets are printed on the client site with traditional systems. These music sheets may be distributed with a simple fingerprint reporting the music code, the publisher name, etc. In these conditions, the insertion of a hidden watermark in music sheets becomes the key part for music protection. New techniques for watermarking music (in image format and/or during the printing of music sheets) were implemented in order to protect the WEDELMUSIC printed sheets. The solutions have been obtained after a deep analysis of the possible solutions to hide data code into music sheets.

WEDELMUSIC techniques for watermark [Mon01], [Bus00] have been designed with the aim of presenting the following capabilities:

- The watermark inserted in the printed sheet without disturbing the music reading and playing.
- The watermark inserted into audio files without disturbing the listening of music.
- The watermark remains readable after music sheet acquisition with scanner and its reprints as well as after photocopy with distortions, filtering, zooming, rotations, cropping, noise addition, flipping, etc.
- The watermark has to resist the attacks or copying during sheet manipulation until the music printed is considered unreadable.
- The watermark removal with image processing techniques has to be more expensive than buying the same music sheet.

Among the used techniques that proposed in [Mon01] is suitable for adding a high amount of information in the music scores when it is printed from a symbolic file (see Fig.4). The technique consists on modifying the lines' thickness in order to insert a binary code comprised of several bits. Modulated lines can be easily noted if their presence is known whereas they are not perceived if the solution is unknown. The validity of this approach has been confirmed during a validation phase by means of a user group of experts of WEDELMUSIC project. The user group is mainly comprised of musicians, copyists and music publishers. The user group results has confirmed that the chosen watermarks are almost invisible/un-audible.

The solution proposed permits to hide a considerable number of bits in several instances. This makes the solution particularly suitable and robust to permit the watermark reading even from a small part of the music score.

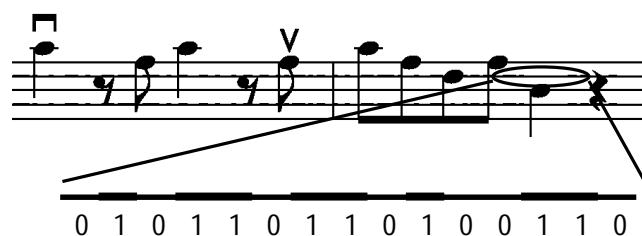


Fig. 4 - Staff lines thickness modification

The watermarking solution of WEDELMUSIC for audio files allows inserting non-detectable code into WAVE and MP3 files [Arn00]. The approach is based on the psycho-acoustic model of humans and therefore the presence of the watermark is not audible. The watermark reader can be profitably used for demonstrating the copyright infringement.

4 Digital Right Management

Client computers may print protected music sheets (original and customised). Attendees/clients of Local Distributors may work on a large WEDELMUSIC database located in the Local Distributor. Each Local Distributor may concentrate the WEDEL objects coming from several publishers.

The attendees may perform several different operations without violating the copyright and the permissions imposed on the available WEDEL objects: processing music, arranging, transposing, reducing for piano, listening, printing, querying, converting, extracting excerpts, etc., according to the allowed operations, etc. See for other examples those reported in Section 2. Each formalised operation that can be performed on a WEDEL object can be permitted or inhibited. More than 50 different multimedia functionalities have been identified and may be distinctly managed by the publisher. The allowed operations are listed in a so-called Permission Table.

A permission table is available for their usage with specific Digital Right Management policies. A price can be associated with each permitted operation. When the WEDEL object is opened on the WEDEL editor the several enabled operations can be performed. Every times that the user attempts to perform a controlled operations the WEDEL editor communicates the price at the user and if it is accepted the operation is performed communicating the action to both the UKM and the Local Distributor. Non permitted operations of a WEDEL object can be on-line requested and obtained when needed from the publisher. This allows at both the publishers and the Local Distributors to take trace about the functionalities used. The publisher can use this information for:

- updating the account of the Local Distributor,
- knowing the most interested and requested functionalities. This allows analysing the needs of the end-users with statistic tools,
- assessing the interest of the clients on the basis of their profile. This can be communicated in impersonal manner from the Local Distributor.

WEDELMUSIC allows the clients/attendees of the Local Distributors to navigate on the Local Distributor archive in order to look for their preferred music. The selected music can be listened, visualised and eventually printed at specific costs. A clear advantage with respect to the traditional distribution consists in the fact that the customer may have the following advantages:

- the music score can be viewed and listened (real performance audio e not the simple MIDI) at the same time,
- the music score can be transposed and modified (annotated, arranged, etc.) before the printing,
- the music score can be identified by performing a search on the basis of the content (a melody described as a sequence of notes). In this case, the WEDEL editor use a simplified notation description of each music piece stored into the Local Distributor database,
- the music score can be even only partially printed: a single part, the main score only with some selected parts, etc.,
- the music score can be printed by performing the piano reduction.,
- the music score (in symbolic or in images) is accompanied by several other information such as documents, images, etc., that can be printed to produce a customised dossier of the music selected.

Specific transaction policies may be defined according to the publisher's needs and interests. The permission table depends on the several states of the WEDEL object: demo, rented object (specifically set up for theatres), when it has been sold, when the renting period has been expired (see Fig.5).

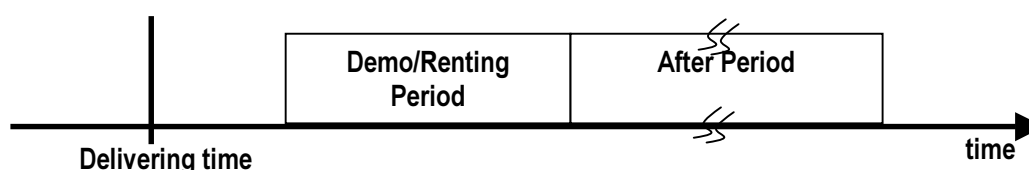


Fig.5 -- Temporal management of the permissions tables

The publisher may define two different permission tables and a general behaviour and table. The general behaviour is applied from the delivering time to the starting of the demo or renting period, and from the end of the After Period. The Demo/Renting profile is identified by two dates, while the After Period is identified by its ending date since its starting date is considered to be equal to the ending date of the Demo/Renting Period.

5 Conclusions

The WEDELMUSIC solution and format allow exploiting new multimedia functionalities of digital music in the respect of the rights owner. The concept of WEDELMUSIC object is strongly innovative and could be a good model for supporting a fast, smooth, and in any way flexible, passage to digital world of several music archives. WEDELMUSIC model is a suitable solution for integrating images of old music sheets and symbolic description of new music. The solution is supported by a set of tools for protecting music, save transaction model, a sophisticated Digital Right Management, and watermarking tools for audio files, images of music sheets and the watermarking of music sheets produced from symbolic description of music.

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