Using 3D Visualisations of Motion Data for Collaborative Multimedia Music Learning and Playing

A. Khan, B. Ong, K. Ng
ICSRiM – University of Leeds, UK
kia@icsrim.org.uk

P. Bellini, P. Nesi, N. Mitolo
DSI – University of Florence, Italy
nesi@dsi.unifi.it

Abstract

This paper discusses utilisation of 3D gesture and posture visualisations to facilitate collaborative music learning and playing involving musicians from geographically disparate locations. Availability of 3D gesture and posture information (in addition to audiovisual data) to participants of a musical collaboration can aid communication, eliminating the inherent limitations of perspective views associated with 2D media. The paper describes how I-MAESTRO, a project supported by the European Commission, is developing an interactive multimedia environment with gesture and posture support for technology-enhanced music learning and playing. In addition, the paper proposes the use of recent advanced high-throughput networking technologies for efficient data transmission, in conjunction with distributed processing of received 3D data at local site, to meet the demands of real-time collaborative musical performances.

Keywords

Gesture; posture; multimedia; music; collaborative; motion capture

1. Introduction

Collaborative music learning and playing conventionally involves the use of 2D media e.g. video, images etc. for audiovisual communication between participants during different stages of the collaboration. This paper discusses the importance of gesture and posture in collaborative music playing and learning, and explains how using 3D visualisations of gesture and posture, in addition to 2D media, can be employed in effect to provide pivotal information necessary for musical collaborations. It then relates the aims and objectives of a project called I-MAESTRO, which is developing interactive multimedia environments with gesture and posture support for technology-enhanced music learning and playing. This paper also proposes a framework that incorporates distributed processing over LAN for efficient analysis of 3D data in an attempt to realise real-time musical collaborations.

2. Gesture and posture

Gesture is “a form of non-verbal communication made with a part of the body, used instead of or in combination with verbal communication” [17], “the use of motions of the limbs or body as a means of expression” [18]. Posture is “the position or bearing of the body whether characteristic or assumed for a special purpose” [18]. In this paper, by gesture, we refer to musical gesture, which simply means the physical motion of playing an instrument, involving one or more parts of the instrument and/or the body of the player; and by posture, we mean the way a musician positions him/herself while playing a musical instrument.

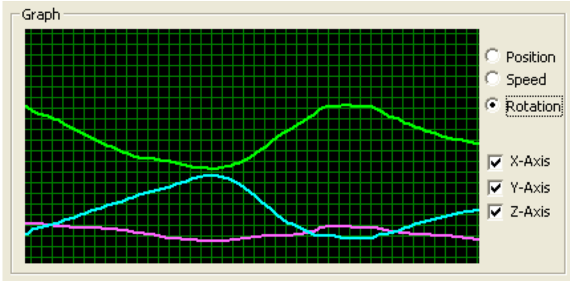
Music playing is essentially a process of audio generation that depends greatly on time synchronisation, particularly when several musicians are involved in a musical performance. Various aspects such as starting and ending of a music piece, phrasing, changes in tempo and dynamics etc. need to be addressed by musicians to carry out a successful musical collaboration. Verbal and/or non-verbal means of communication are typically used by musicians to signify these different parts of collaborative performances. Non-verbal means of communication i.e. gestures particularly play a very important part in collaborative music playing as well as learning. For instance, they aid collaborating musicians to synchronise their music in a playing scenario and, from a learning point of view, students' gestures are observed by teachers and vice versa as part of music training process.

Furthermore, playing an instrument is a physical activity and potentially detrimental in an absence or lack of proper technique. Like athletes, musicians too need to be aware of their playing posture, especially those in the initial stages of training, to avoid acquiring a habit of incorrect posture that may lead to subsequent fitness problems. Adoption of correct playing posture not only prevents such problems but also facilitates the musician to achieve the most economical output with the least physical effort.

2.1. Support for gesture and posture

Currently, gesture and posture support for conventional music training and learning is typically provided by using audiovisual data. However, this is generally not effective due to the inherent limitations of perspective views of 2D media. In case of a real-life collaborative music learning scenario, while a teacher may be able to look at a student's performance from all angles and spot flaws easily, a student can only look at his/her performance from one angle provided by the medium of self-monitoring in use (a camera, a mirror).

To overcome such limitations, 3D Motion capturing technologies can be utilised to record performances or practice sessions in 3D. Using an optical motion capture system, for example, along with reflective markers placed on strategic locations (e.g., joints of the body), the spatial positions of those markers can be found. These 3D coordinates can be used along with a model to create a 3D representation of the musician which supports perspective views and provides comprehensive gesture and posture support. This data can also be used to plot line graphs and display the consistency of a student's bow gesture for instance. These visualisations and graphical feedback can serve as a 3D enhanced mirror to musicians for improved communication as well as for self-assessment of posture and gesture. In this context, the I-MAESTRO framework is developing several related software modules for gesture and posture support.



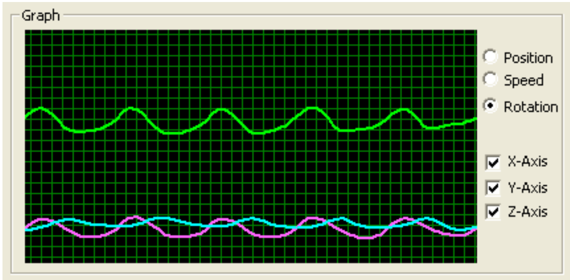


Figure 1(a) and 1(b). Graphic visualisations representing bow gestures

3. I-MAESTRO EC IST project

The I-MAESTRO project [10] is a new project partially funded by the European Community under the IST Sixth Framework Programme. It is developing interactive multimedia environments for technology-enhanced music learning and playing. The aims of I-MAESTRO include development of innovative solutions for music training both in theory and performance, using recent advancements in computer and information technologies, development of new pedagogical paradigms with cooperative and interactive self-learning environments, gesture interfaces, and augmented instruments; provision of computer-assisted tuition in classrooms; and provision of technology-enhanced environments for ear and practical training, creativity, analysis, theory training, ensemble playing, composition, etc.

Current work in hand for I-MAESTRO gesture-based supporting tools can be categorised into:

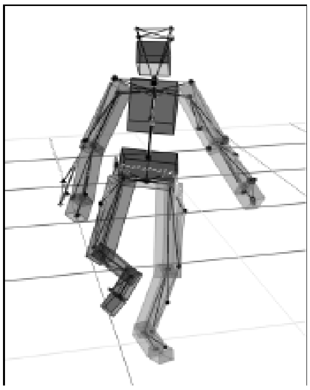
(i) Instrument (bow and the main body of the instrument);

(ii) Arm gesture (with respect to the instrument and upper body);

(iii) Body (head and upper body); and

(iv) Overall motion (including body to body gesture communication).

The main functionalities of these tools are to provide automated analysis of the playing. They analyse the playing gesture to provide information on the relationship between the player and the instruments and the bow and the instruments, such as joint angles, space, flow, etc., acting as a 3D digital "enhanced mirror" that can reconstruct the playing to facilitate further the understanding of the relationship between physical and musical gesture [4].



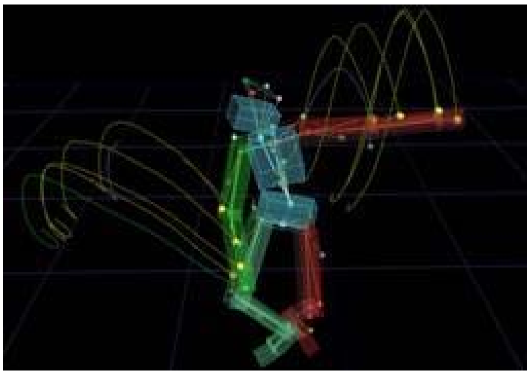


Figure 2(a) and 2(b). Rendered 3D motion data

In a learning scenario, a music teacher can setup (by recording or from some predefined gesture library of motion data) certain 3D gesture and posture visualisations to support a specific exercise according to the student's capabilities. During practice, a student can view these 3D visualisations of gesture and posture sequences (see Figure 2.a and 2.b) as prepared by the teacher, selecting viewpoints and studying the recording without the limitation of a normal 2D video. A student can also use I-MAESTRO to capture and study their own gesture and posture, or to compare them with some selected models.

Another instance of a learning scenario for correct playing posture may involve the use of pressure sensors on different parts of the instrument e.g., on the neck, chinrest or shoulder pad etc. The motivation is to monitor common beginner mistakes that have the potential of hindering mobility of the head, neck and shoulder. These include holding the instrument with an extremely tight grip unintentionally or building up the height of the chinrest or the shoulder pad for a secure hold etc. Similarly, 3D motion data of student's performance may be analysed with specific focus on the dynamics and distribution of angles of joints etc. in order to discover any rigid and or locked parts and to assess the extent to which the student uses his/her body as a whole to play the instrument.

As mentioned earlier, since gesture and posture contribute to various aspects related with communication and expression in a musical performance, one of the aims of the I-MAESTRO gesture and posture support tools is to analyse the inter-communications of two players (in a chamber scenario) to understand performance gesture for synchronisation (starting, ending, tempo, dynamics …). For instance, in a duet scenario involving a violinist and a cellist, gesture communication between them plays an important role and it would be very interesting to study patterns in their gesture movement to find out how musicians communicate non-verbally in a group performance.

Moreover, based on the Gesture analysis, creative interfaces can be created by utilising several I-MAESTRO tools to provide Gesture controlled performance for motivating music learning at early stages and also to support casual interests. Gesture mapping using these technologies can be adopted to map different input for multimedia controls providing accessibilities to all.

The outcomes of I-MAESTRO will be validated through a set of tools and methodologies including (i) tools and methods for music courseware production; (ii) interactive and creative tools for instrumental training in different environments such as classrooms and cooperative work, on different devices such as

PC and Tablet-PC; and (iii) assessment and pedagogical models for music training.

4. Real-time distributed collaborative music performance

Demands of a “real time” distributed musical performance complicate further the issues such as synchronisation etc. associated with distributed musical collaborations. In such a scenario, it can be advantageous to link geographically-dispersed participants using high-bandwidth high-throughput networking technologies capable of supporting real-time activities.

4.1 Use of networking technologies

New World Symphony [16] makes use of the Internet2 to transfer high-quality audiovisual data for collaborating music performers, music students and music teachers; going one step farther from everyday video conferencing over the Internet.

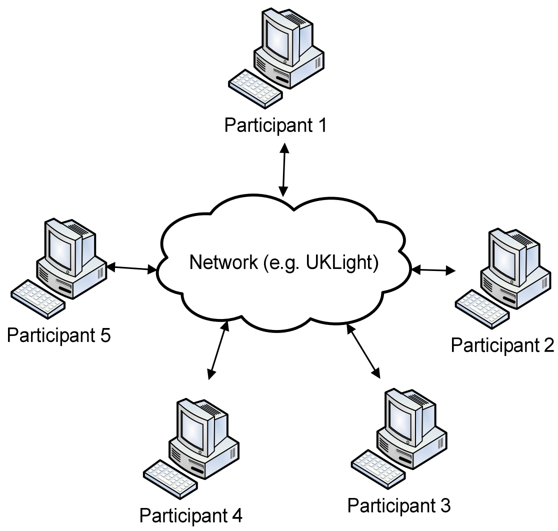


Figure 3. Using high-speed networks for real-time distributed collaborative music playing and learning involving musicians from geographically disparate locations

This paper presents a framework that proposes the use of UKLight [11] for transferring among musicians 3D motion data in addition to high-quality audiovisual data for controlling the non-verbal communicative requirements of distributed collaborative music playing and learning. This relatively comprehensive information would facilitate the participating musicians to collaborate in a finer manner. As discussed earlier, motion data of a musician’s performance could be acquired using an optical motion capture system along with pressure sensors for example, and 3D visualisations of this data could be transferred (along with audio/video) to other participants.

4.2 Distributed processing of received data (at local site)

This framework also proposes the idea of processing the received data (from remote site) in a distributed fashion over a local area network.

As shown in Figure 4, musician at the remote site captures 3D motion data of the performance and sends it over the high-speed network to the local site. This data is received by a machine (master), which is responsible for distributing the received data among N worker machines. Each worker can be configured to analyse and process data for a unique specific purpose. For example, one worker may be assigned the job of rendering 3D motion data and displaying the 3D performance on screen, another work may be used for analysing and processing 2D data and displaying it, a third worker may be employed to analyse the bow gesture consistency of remote musician’s performance and to show assessment results against a predefined model, and so on.

Figure 4 also shows a motion capture system connected to a machine that sends real-time (or recorded) 3D data of a performance to the master. The master then sends it over the network to remote site where a similar setup or configuration may be employed.

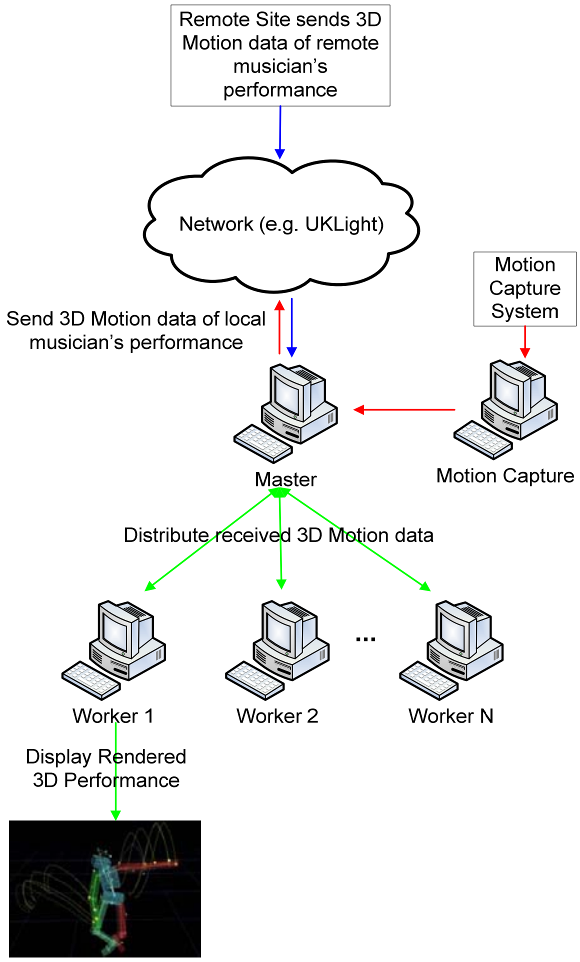


Figure 4. Using high-speed networks and local-site distributed processing of 3D data for real-time collaborative music playing and learning

5. Physical movement

Several domains including music (and sports science etc.) borrow from a method, known as the Alexander technique, for learning and practicing correct posture and gesture to achieve optimal performance. Various studies of the Alexander technique have been carried out with emphasis and focus on correct posture for musicians.

5.1. Alexander technique

F.M. Alexander [13] was the inventor of Alexander technique, "a principle that influences health and well-being … and encourages all the body's processes to work more efficiently as an integrated, dynamic whole." [13].

One of the most fundamental aspects of music playing is the manner in which the instrument is held in relation to the body of the instrument player. "The optimal relationship between the head and the neck is not a fixed position". It is determined by "a dynamic balance by which the weight of the head is balanced under the changing conditions of the body in activity" [12]. This dynamic head and neck relationship has the tendency to be impeded as a musician holds the violin or viola into a firm grip, (often) more tightly than he/she should (especially learners) by pressing down the head onto the chin-rest. In order to "capture a secure instrument hold, some players build up either the height of the chinrest or the height of the shoulder pad, often to the point of immobilization of the head, neck and shoulder." [12]

For larger sound, string musicians are typically "taught to increase the amount of weight going into the string through the bow". This increase needs to be antagonised by an equal but opposite force (from the violin), so that the increase of the weight through the bow may not force the instrument downward. Some players "instinctively increase the support of the instrument" with the increase in the weight exerted through the bow. This is normally achieved by pressing down hard on the chin-rest with the head, in turn, causing "over-tensing of the neck muscles; drawing up of the left shoulder, requiring relatively vast amounts of energy; or using the left arm as a rigid support beam, thereby impeding the left arm movements necessary to playing the violin or viola". A certain musician may (or may not) show evidence of a blend of any or all of these inclinations. He/she may quite possibly even achieve the desired increase in the resistance of the instrument (against the increase in weight on the bow) by using "the leverage in the largest muscle groups of their body, those of the back" [12].

Because of the placement of the instrument on one side of the body, violin (and viola) playing is usually said to be using "asymmetrical posture" which over time "can result in muscle imbalance, with the muscles on the left side becoming shorter and stronger than those on the right. Muscle imbalance can lead to joint dysfunction and so on". [14] The idea of whole body mechanics in music playing was put forth by Polnauer [15] who noted that it was not enough to focus on bowing as a “mechanical-physiological problem of the bowing arm only”. For correct and “a highly perfected” technique, it is necessary to include the “bio-mechanical functions of the entire body”. He stated that “the older concept of the arm performing the bowing is being replaced now by the concept of the body performing this function. It seems to us more useful not to think any more in terms of a "right" and "left" hand technique, but rather of an "entire body" technique.” [15].

6. Conclusions and Future Directions

This paper discussed the role of gesture and posture in music playing and explained the advantages of using 3D visualisations of motion data for facilitating collaborative multimedia music learning and playing. It also discussed the I-MAESTRO project and presented its basic aims and objectives. The paper focused on the discussion on gesture-based analysis area, exploring a number of supporting tools to facilitate string instrument learning and teaching. A framework was also proposed to process 3D data in distributed manner over a LAN for efficient real-time collaboration. Future work in this area can involve the use of supplementary systems along with optical motion capture for better monitoring and assessment of gesture and posture of musicians in a collaborative playing or learning environment.

Acknowledgements

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