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Augmented Reality Scenarios for Guitar Learning

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Abstract

In this paper, an experimental self-teaching system capable of superimposing audio-visual information to support the process of learning to play the guitar is proposed. Different learning scenarios have been carefully designed according to diverse levels of experience and understanding and are presented in a simple way. Learners can select between representative numbers of scenarios and physically interact with the audio-visual information in a natural way. Audio-visual information can be placed anywhere on a physical space and multiple sound sources can be mixed to experiment with compositions and compilations. To assess the effectiveness of the system some initial evaluation is conducted. Finally conclusions and future work of the system are summarized.

Categories: augmented reality, information visualisation, human-computer interaction, learning.

1 Introduction

In the past years, online or CD-ROM books tend to replace the traditional paper based music books. E-learning has been on the focus of an enormous amount of research, both from academic and research communities. However, just a few experimental approaches have been developed trying to enable a complex computer interaction through the physical use of a musical instrument and digital information for the sake of learning.

Augmented Reality is a technology that supplements the real world with virtual information that appears to coexist in the same space as the real world. Digital information does not have to be restricted only to vision but it can vary to other types of sensory information including hearing, touch and smell [AB*01]. Obviously, the most important requirements for successful AR applications are to realistically overlay computer generated information with the real environment and also to run interactively in real time performance.

On the other hand, when graphics and sound are combined together they can strongly affect imagery [BC01] and can enhance the sense of immersion [LVK02]. Augmentation of graphics annotations can be used to identify specific parts, describe their functionality in detail and present other important information [KA*97]. On the other hand, sound tends to establish a sense of place [MBW98], so it can operate as its own additional system to be read along with the graphics and textual information. The integration of spatial sound can offer new solutions to generate audio in a simulated three-dimensional space.

In the real world, audio is a process that is heard spatially and thus it is very important aspect for any simulation scenario [Beg94]. A 3D sound system can contribute to the sense of immersivity of an AR system because augmented sound can either replace or complement the existed spatial attributes using virtual auditory information. The most important issue when designing 3D sound is to 'see' the sound source [Yew99] because in AR environment it will give the psychological impression that the sound source exists. In the system the sound source is presented as virtual speaker.

In this paper an experimental AR system capable of simulating and superimposing 3D audio and 3D visual information is presented. The aim of this work is to teach the basics of electric guitar in a more efficient way than the traditional methods through the use of a prototype AR interface toolkit [LWL04]. Learners are not required to have previous musical experience although they must be familiar with a computing environment.

The outline of the remainder of this paper is as follows. Section 2, summarizes the background work done during the last years. In section 3, a brief description is given of how the system operates while in section 4, the software and hardware components used are described. Section 5, illustrates the issues involved for designing the teaching material whereas section 6, describes how the audio-visual augmentation is performed with the aid of different scenarios. Section 7, illustrates the learning scenarios that have been implemented and in section 8 some initial evaluation of the application is performed. Finally, in section 9, the results are discussed and future improvements are proposed.

2 Related work

Apart from the traditional guitar of self-learning tools such as music magazines, other popular multimedia tools exist on the web that can help improve significantly the learning process. In addition, guitar teaching software tools, such as self-help computer software that illustrates positions of the chords and scales to guide guitarists can provide a small home-based digital musical simulation. For virtual auditory worlds, Röber et al., [RM04] researched on the methods and techniques required for sonification and interaction providing the listener with enough information for a clear interaction and navigation.

During the last few years, a number of projects and experimental AR auditory systems have been developed. The LISTEN project aimed in placing the notion of visual, auditory and imaginary space based on AR and auditory user interfaces. Users can "automatically navigate an attached acoustic information space designed as a complement or extension of the real space" [Eck01]. Augmented Groove [PB*00] is a musical interface for performing multimedia musical performance based on AR, 3D interfaces and physical tangible interaction. Music can be played with or without music instruments by manipulation of physical cards.

An intuitive AR interface for 3D music creation in clubs and discotheques is AR/DJ (Augmented Reality Disk Jockey) [Sta03]. The DJ can play a variety of sound samples and place them anywhere in the club. Another application is an AR based learning assistant for electric bass guitar [CBC03]. A finite state machine is defined to represent the sequences of notes played by the user. The system plays a note from the state machine, overlays a small dot to the user showing where the note is on the fingerboard and waits until the user plays the note. Finally, Handel [CR01] is a wearable AR system that detects pianist's hands in order to provide textual information. The system also provides the pianist with a score at the end of the play.

3 System Overview

The effectiveness of any technological self-learning system depends on both high quality video rendering and accurate 3D restitution of the sound space. The architecture of the application is based on the prototype AR interface toolkit [LWL04] which is capable of rendering in real time performance audio-visual information in indoor environments. Based on the robust integration of the above, an experimental application focused on guitar learning is designed. The operation of the proposed system is presented in Figure 1.

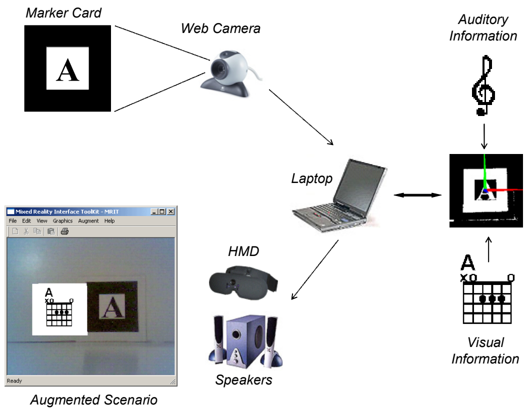

Figure 1: *Operation of the system*

A USB web-camera captures the real environment and sends the video stream into a computer (Figure 1). When one of the predefined marker cards is detected (i.e. marker A) then the position and orientation of the camera is recovered. Graphics and sound are processed into the processing unit (section 4) and meaningful audio-visual information is added to the real environment. The audio output is send to the speakers while the audio output to a standard display monitor.

To operate the system, the learner is equipped with a set of marker cards and a guitar (which can be classic, acoustic, electric, etc). To learn a specific chord, the learner just positions the correspondent marker card on the environment. If the camera detects the marker, the application overlays a static image indicating how the fingers must be placed in the guitar. In addition, a pre-recorded sound of the chord is automatically played.

The learner can naturally interact with the augmented information by manipulating the marker cards in 3D space (Figure 8). To practice in a different chord, the learner has simply to remove this card and replace it with the corresponding card. Other interactions within the system are performed similarly to the methods presented in [LS*04] and [LM*04]. Users can manipulate the virtual information either using standard I/O devices, using the interface menu, or by the natural manipulation of the generated marker cards.

4 Software and hardware components

With regards to the hardware technologies used, the application requires a personal computer (desktop or laptop) equipped with speakers, a sound card, and a commercial web or video camera. In this experimental setup a Toshiba Laptop with Intel Pentium M processor at 2.0 GHz, 1GB memory and nVidia GeForce Go5200 with 64 MB graphics card. On the other hand, two types of software technologies were used: software tools and software libraries. Software tools include both off-line developments done to create the content which is used in the application (section 5). In terms of software libraries, the prototype AR interface is built on top of five different types of libraries as illustrated in Figure 2.

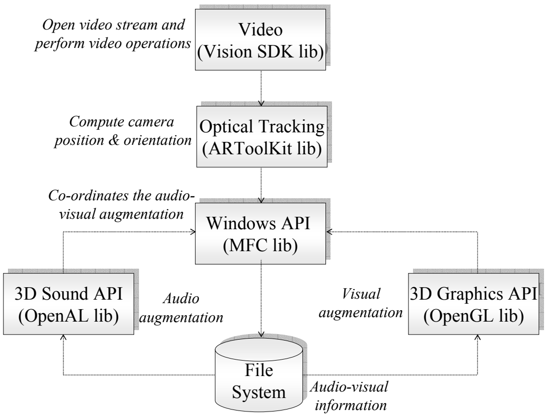

Figure 2: *Library architecture*

ARToolKit's tracking libraries [KB*00] are used for the calibration of the web camera and the detection of marker cards used in the learning scenarios. Although ARToolKit provides a limited framework for rendering VRML97 models, the graphics operations are processed by an implemented high-level C++ rendering engine which is based the OpenGL API and it is capable of the realistic rendering of both VRML [LM*04], [LS*04] and 3ds file formats [LWL04]. Furthermore, the 3D sound processing is built on top of OpenAL API which allows the easy integration of multiple sound sources [OSR00]. Finally, the interactive Graphical User Interface (GUI) framework is a user-friendly windows application implemented in MFC that provides interaction tools to control the augmentation in a simple and efficient way.

5 Content creation

The target of a musical teaching session is to transfer the appropriate knowledge to the learners in an effective manner. This can be achieved using different learning scenarios and methodologies depending on many issues such as the teacher's expertise, past experience of the learner, etc. The generation of the teaching material is an off line process and consists of three parts: *marker generation*; *digital information*; and *tutorial implementation*. Figure 3 presents diagrammatically, the type of information required for the teaching session in the AR environment.

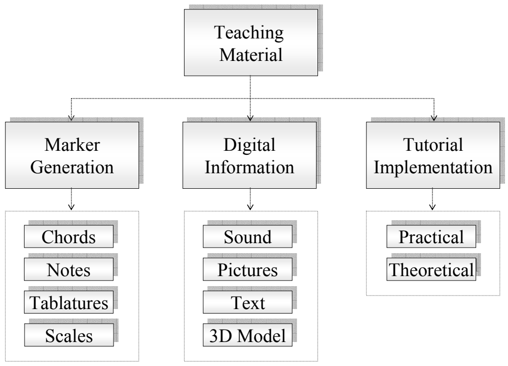

Figure 3: *Teaching Material Pipeline*

The generation of the markers plays a significant role because firstly they are used for computing the position and orientation of the camera and secondly because they act as the tangible interface between the real and the digital information which determines the audio-visual augmentation. Digital information represents the computer generated information including pictures, 3D models, textual descriptions and auditory information which is stored in the file system (Figure 2) and accessed in real time by the application. Finally, the implementation of tutorials consists of a number of carefully designed learning scenarios which include both theoretical and practical exercises. Each category is briefly illustrated in the following sections.

5.1. Marker Generation

One of the most important tasks in any learning and teaching environment is to effectively define a set of distinctive and effective marker cards which are also representative of the teaching material. Clearly, the way the teaching material is presented to the learners can play a significant role. Therefore, the marker cards were carefully designed to make a complete set of chord theory. Drawing from experience in music theory, the chords follow notes notation, i.e. A, B, C, D, E, F and G. For each note there are a number of chords that can correspond to. For example only for the A chord there are eight basic variations A+, A7, A-, A-7, A6, A-6, A+7 and A9 as illustrated in Figure 4.

Figure 4: *Markers designed for 'A' chord*

The same principle has been applied for the rest of the chords. Apart from the chords, distinct sets of marker cards in a rectangular shape were carefully created for other theoretical parts like notes, scales, tablatures and songs. A simple example of this is illustrated in Figure 5, where a rectangular marker card is used as the user's physical learning tool for understanding how notes are structured visually but also how they sound like when inserted into the AR environment.

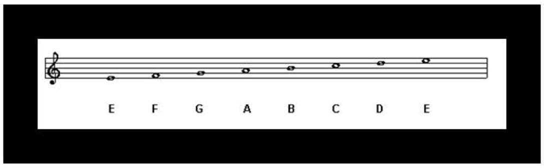

Figure 5: *Example of marker used for notes*

All the markers were designed using MS PowerPoint and they were 'trained' using ARToolKit. To achieve a wider range of operation and calibration accuracy these type of marker cards are designed larger and in orthogonal shape. Even if the robustness of ARToolKit's tracking libraries is poor on longer distances [OXM02], most of the cards are 20cms wide so that it can be also distinctive and clear to read.

5.2. Generation of digital information

The digitalization of the teaching material must have an educational taste otherwise the information will not have any effects. The digital information used in the audio-visual AR interface toolkit includes 3D models, images, textual information and sounds [LWL04]. To keep the complexity of the system low, only a few 3D models were designed but emphasis has been given to the design of images and descriptive textual information. The static images have been designed using an image processing tool while the text was generated in a commercial text editor.

For the generation of sound material, a standard microphone, music editing software and an electric guitar plugged into a sound card were employed. First, all the major chords as well as easy songs were recorded and stored. Next the recorded audio data were further sound processed on professional audio processing software package to become suitable for the 3D audio augmentation. CoolEdit Pro [CEP04] was preferred as an offline tool to record all the necessary wave samples either from the microphone (for voice sounds) or by plugging the guitar to a sound card (for guitar sounds). However, since each type of electric guitars produces a different sound and also a percentage of noise is always introduced, further sound enhancements were performed to produce the best sound quality samples.

5.3. Tutorial generation

The final part is the generation of a set of introductory practice session tutorials. Based on personal musical knowledge an experimental set of learning tutorials has been designed. Each one aims in introducing a number of important theoretical and practical issues to the learner. The tutorials implemented up to this stage can be categorized into: *description of guitar parts*; *introduction to chord theory*; and *introduction to easy songs*.

All three categories make use of all four types of audio-visual information including 3D models, text, images, and sound. However, most of the content required for a music application is usually pictures, text and sound. 3D model visualization is performed only for illustration of guitars and for 3D representation of sound speakers so that the users feel closer to the traditional ways of learning.

6 Augmenting audio-visual information

The visual augmentation incorporates elements from computer graphics algorithms in order to try to match reality as close as possible. The image augmentation can support photographs or images in BMP and TGA file formats. BMP is the most popular texture format while TGA supports the alpha channel so it is possible to blend the images into the environment. Therefore the files were saved with 32 bits/pixel having 8-bits per channel (RGBA). On the other hand, the textual augmentation is based on the traditional and well known ASCII format. A clever parser [LWL04] allows the interactive textual insertion into the scene and the user can select between projective (2D) view or perspective (3D) view.

The sound methodology has been based on similar principles with three previous works. The LISTEN project [Eck01] that augments visual and auditory information for immersive environments, the HyperAudio project [PA*99] where an audio commentary starts when the visitor approaches the artifact and the Augmented Sound Reality (ASR) approach [DHS02] on which the user can manipulate intuitively the sound source in 3D space.

Unlike these experimental approaches and most current self-learning systems, the proposed system allows learners tangible interaction with various types of multimedia information through the functionality of the AR interface toolkit [LWL04]. Users can control fully the type of learning using different scenarios and by placing virtual sound sources in different locations in the environment using the user-friendly GUI. The architecture of the audio subsystems is illustrated in Figure 6.

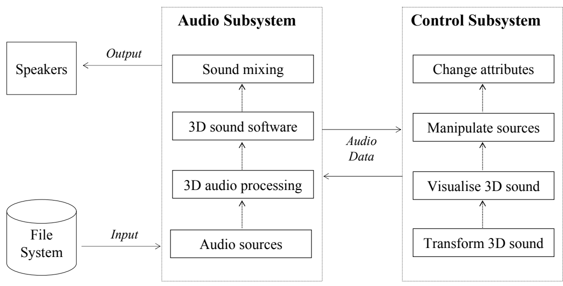

Figure 6: *Audio architecture*

The audio subsystem can simulate effectively static or dynamic sound sources which are located inside the real environment. One of the most important capabilities of the system is the simultaneously multiple sound augmentations using a single marker card. Instead of having just the visual information superimposed on the marker cards, multiple sound sources may be rendered.

Furthermore, the AR interface can handle multiple sound sources and mix them together by either pressing a key in the keyboard or choosing an option from the interface menu. The learner can move the sources in 3D space using either the keyboard or by manipulating the marker. This can be very useful as a tool for either mixing songs as presented in [Sta03] or for composing music using a variety of pre-recorded sound sources. The environment has been tested with up to eight simultaneous sound sources. The pseudo-algorithm used for the implementation of 3D audio is presented in Figure 7.

```
Check Scenario Type
Initialise sound attributes (position, velocity and orientation)
For each video frame calculate the camera position and orientation
    Calculate the transformation matrix
    Invert the matrix to estimate the camera pose
    Store the recovered values
Represent distance between marker and camera using different linear functions
Update camera position and orientation
Augment audio-visual information onto marker cards
    Draw virtual speakers
    Draw relevant pictures (if required by the scenario)
    Place 3D sound sources
```

Figure 7: *Pseudo code for audio implementation*

The bottleneck of this algorithm is that although it can handle satisfactory more than a dozen different sound sources assigned on different marker cards, it can not effectively handle a much larger scale of sound sources. This occurs because both the pattern recognition algorithm used (template matching) and the OpenAL API are designed to handle very limited number of marker cards and sound sources respectively. In the next section, ways of mixing auditory and visual information with the real environment are proposed for presenting the learning material in an educational and appealing way.

7 AR presentation scenarios

The practice section begins by augmenting the appropriate visual information into the learning environment. For the current implementation, learners can access different learning scenarios through the use of a user-friendly GUI. Based on this, the user can control the presentation so that it fits their personal taste. For example, the auditory augmentation can be inserted or stopped at any time during a scenario. In spite of this, for the purpose of this research only a representative number of learning tutorials have been implemented. A brief overview of the capabilities of each tutorial is illustrated in the following sections.

7.1. Introduction to theoretical scenarios

The first set of tutorials involves the understanding of some basic components of the guitar. Therefore, the user will not start practicing on how to play the guitar but will observe and conceptualize the basic theoretical framework. This can be achieved through the use of 3D models, sounds and textual augmentations that have been specifically designed to describe best the appropriate theoretical part. The tutorial starts by presenting a 3D representation of various guitars ranging from classical to electric guitars.

As soon as a virtual guitar is superimposed, auditory information narrates its main characteristics (i.e. brand, category, etc). Learners can thus, perceive educational audio-visual information in a compelling way and get a broad idea in 3D of what categories of guitars exist. Figure 8 presents how a learner can examine three different virtual guitars intuitively.

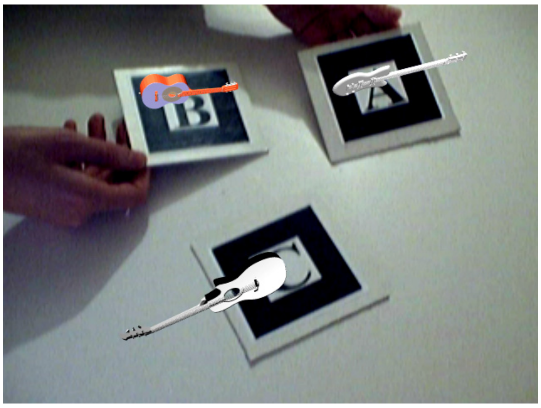

Figure 8: *Interactions with the AR scene*

Learners have the freedom of manipulating the 3D representation of the guitar using either the mouse, the keyboard, or by the physical movement of the marker card [LS*04]. Moreover, in the second part of the tutorial, the practicality of textual annotations in the learning process is illustrated. Annotations that describe the most characteristic parts of any type of guitar can be visualised by placing a marker card on the surface of the guitar. Figure 9 shows an acoustic guitar with meaningful textual annotations (descriptions about its parts) superimposed using as a reference a marker card.

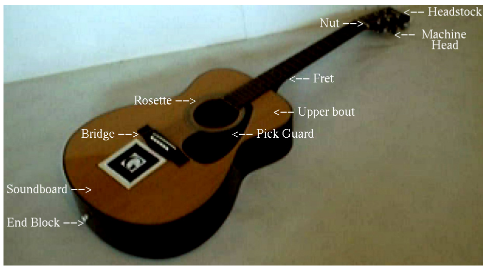

Figure 9: *Textual augmentation of guitar parts*

It is important to note that for this visualization scenario the calibration is performed by trial and error because each guitar has different physical characteristics (i.e. size, length, etc). The same technique is applied for electric guitars with the only variation that some components differ.

7.2. Theoretical and practical scenarios

The purpose of this learning scenario is to provide multimedia information using a tangible AR interface. Learners can use this framework to combine theory and practice at the same time. The theoretical parts are presented through textual and pictorial augmentation while the practical is based on auditory augmentation. The practice session starts with a brief overview of chord theory using representative marker cards as the main interaction tool. The user selects a chord that wants to practice and places the correspondent marker card on the table so that the camera has the marker on the viewing frustum. Figure 10 shows an example of how the learner can understand where must place his/her fingers to play the 'A' chord.

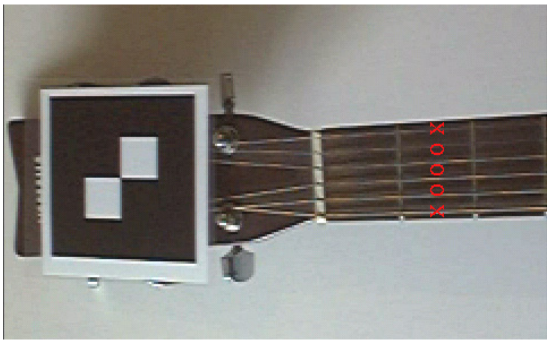

Figure 10: *Example of a theoretical scenario*

To obtain more information, as well as practice the theory, the learner can get an interactive audio-visual augmentation. Figure 11 shows an example of a practical scenario showing how theoretical information can be superimposed onto the learning workspace.

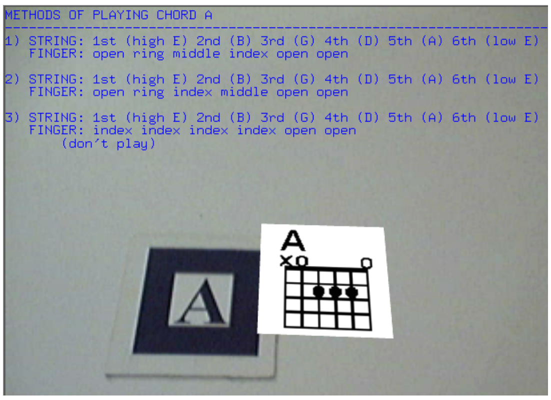

Figure 11: *Example of a practical scenario*

Tablature information is augmented in conjunction with descriptive textual information which presents three different ways of playing the chord (Figure 10). In addition, a pre-recorded sound file that corresponds to 'A' chord can be inserted into the position of the marker. The sound file is played on a continuous loop with a delay of three seconds between intervals. When the learner is satisfied with the practice then another marker card can be placed on the table and continue the practice session.

7.3. Learning complete songs

Another learning visualization scenario is to help the learners to play easy but complete songs in any type of guitar. The minimum requirement of playing a song in a guitar includes some basic chords and the corresponding lyrics. Similarly to the previous tutorials, the appropriate markers have been designed and they are used to simultaneously provide textual information for the lyrics and the musical representation of a song. A multi-marker which consists of six smaller markers is employed for the chords while a bigger marker for the textual and auditory augmentation as illustrated in Figure 12.

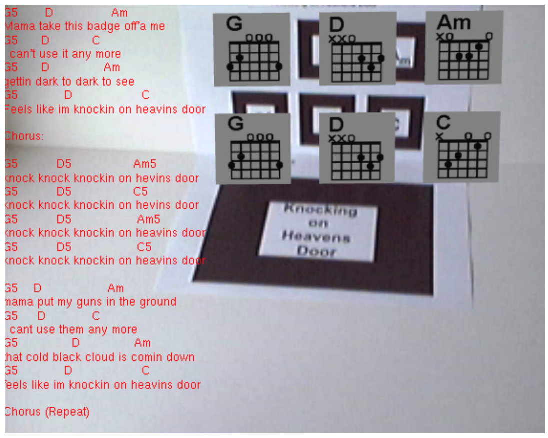

Figure 12: *Augmenting lyrics and chords of a song*

The user can read the lyrics (of a 'Bod Dylan's' song called 'Knocking on heavens door') and the corresponding chords from the monitor and try to improvise the song in the guitar. To aid the learning process more, the song is also inserted in the marker and automatically played in a loop in the same way as previously explained. The same process can be then repeated for other pre-recorded songs. The major difference between the previous tutorials is that seven markers have been used simultaneously. Although this reduces the efficiency of the operation of the system it is still a very nice tool which can be used to create unique learning combinations in a number of ways depending on the application demands.

8 Initial Evaluation and Limitations

Even if there is still a lot of development to be done before the system can be used in practice, the presented approach looks very promising as an interactive learning tool. However, to assess the system properly a user study evaluation has to be done to resolve usability issues such as: system lag, mobility, safety and motion sickness. In order to obtain a number of useful conclusions regarding the technicalities and practicalities of the system some empirical research was conducted. A questionnaire was developed to evaluate the experimental system from the user's point of view. The aim is in assessing the usability of the system in the learning process as well as its overall operation as a learning tool. The questionnaire was disseminated to nine users (Figure 13) that had previous computing experience but no guitar knowledge and the main question was whether the system would be better than traditional methods (i.e. a book or some online pages with appropriate linked sound).

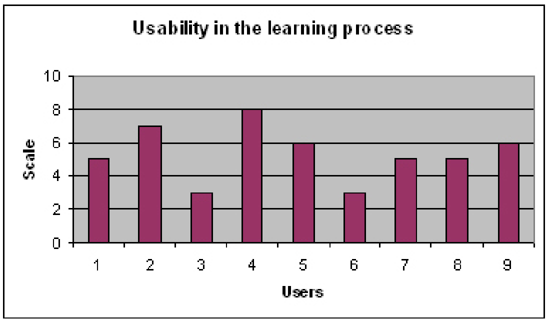

Figure 13: *User feedback regarding the usability of the system in the learning process*

The feedback received following the completion of the evaluation process was very positive. All users agreed that the system is easy to use and that the visualisation process is more than satisfactory (with 5 the average, Figure 13). In addition, participants found the interaction techniques very useful and easy to use in contrast to commercial software learning tools. Although they liked commercial software packages they found them very difficult to use without training, In terms of the technical part of the evaluation, as expected, most of the users preferred the monitor based visualisation versus the HMD based visualisation.

On the other hand, users complained when they tried to move with the camera because they could not keep it in line with the sight of view with the marker. Overall, it was a profitable experience to complete the cycle of this research. The greatest limitation of the proposed framework is the robustness of ARToolKit's tracking libraries. It was experimentally measured that the effectiveness of the system when one marker is used is in the range 35 to 50 fps. However, when two markers are used then the efficiency drops between 30 to 40 fps and for three markers to 25 to 30 fps.

9 Conclusions and Future Work

This paper summarizes the steps taken in designing a prototype system for teaching the basics of music to beginner level students, by combining visual and auditory information using the functionality of a previously implemented augmented reality interface toolkit. The interactive AR scenarios illustrate the potentials of learning and training through natural human-computer interaction techniques allowing learners to enjoy an entertainment and interactive music guide. Another advantage of this approach is that it is generic and can be easily extended and adapted to other areas of music. Currently the framework provides visual and auditory information to potential learners but can not perform a comprehensive sound-simulation nor provide real-time feedback. A robust music tool would perform a comparison between the sounds outputted from the user and the theoretical 'correct' sounds stored in the filing system. The correction of the auditory information can be performed using Digital Signal Processing (DSP) filters and the suggested information must be provided to the learner in real time.

This experimental work is under continuous development. Several prototypes exist and the first experiments pointed that a combination of vision and sound increases the immersion of the system and the learner can not only feel more comfortable but also gain a unique learning experience. Unlike other AR interfaces, this work is explicitly focused on multimedia augmentation and interaction techniques for learning musical instrument (i.e. guitar). In the future, all the learning scenarios which are currently fixed in the system will be stored in a database system so that users can access it from anywhere. Undoubtedly, AR interfaces are capable of exploiting a number of different approaches and can provide unique solutions for many potential commercial applications. In the coming years, AR learning systems will provide automatic feedback for actions or situations that are otherwise impossible to achieve. However, to increase the usefulness of learning applications more sophisticated teaching environments must be designed to provide a complete and powerful solution to modern education.

Acknowledgments

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