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Conference Paper · June 2015

DOI: 10.1007/978-3-319-21413-9_16

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Challenges and Possibilities of Use of Augmented Reality in Education

Case Study in Music Education

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Abstract. *This paper aims to discuss the difficulties and possibilities of using augmented reality in education, especially for musical education. Among the difficulties addressed are the following types of issues: physical, technological, sociocultural, pedagogical and managerial. The possible solutions presented involve the use of authoring tools that are easily usable by teachers. An augmented reality application to teach musical perception was developed using an authoring tool, and tests with children are presented and discussed.*

1. Introduction

In recent years, computational resources have been increasingly present in the teaching–learning process. New technologies have provided advances in traditional teaching methods, which may make it easier for students to learn and also change the way that teachers share knowledge. In this new context, where educational issues are compelling and supported by technology in a basic and almost invisible way, educational applications should be simple to set up or adapt. They must also provide flexibility in their configuration, depending on the content generated or manipulated by the user. They must function with the minimal training that the potential user already has or that is in the domain of her/his social group, for instance, creating videos with mobile devices, manipulating videos in repositories such as YouTube, manipulating images and videos on social networks, using text editors, etc. These technological tools are dominated by users and can be mastered with ease, when those users have been exposed to environments where these technologies are naturally relevant [1].

The increasing use of these technologies in education has occurred primarily due to the lower costs of computers and the emergence of new software tools. However, some computer technologies, due to their peculiarities such as those involving Augmented Reality (AR), are not yet widely used. In a general analysis, we note that this is due to the disparity between the state of the art of these technologies and the time of maturity at which they can be implemented effectively, that is, made available easily and affordably [2].

According to Azuma et al. [3] and Billinghurst [4], AR is a technology that enables the user to see the real world, with virtual objects superimposed upon or composited with the real world. An AR system has the following three characteristics: it combines the real and the virtual, it is interactive in real time and it is registered in 3D.

AR originated from another technology called virtual reality (VR). While VR can be defined as an advanced interface with computer applications, where the user can navigate and interact in real time in a 3D synthesized environment, using multisensory devices, AR simplifies its use. A nonconventional device is not required; just a webcam and markers are needed [5].

AR was indicated by the Horizon Report [6] as one of the technologies that will revolutionize education in the coming years. This is due to its fun and interactive features, among other reasons. The use of AR education applications is made possible by the cheapening and improvement of the hardware and the need for more user-friendly interfaces for interaction with nonexpert users along with the indispensability of working with other ways of teaching, using active practices. In this sense, using computers in the classroom may allow the simulation of situations not previously possible or imagined.

This article aims to discuss the difficulties and possibilities of using AR in education. A case study was developed in the musical education area, using an authoring tool. This choice was made because since 2008, music education has again become mandatory content in Brazilian schools (Law No. 11,769 of August 18, 2008); therefore, greater attention must now be paid to the use of technology in this area of knowledge, motivating students and allowing learning beyond the classroom. Another relevant factor is the small number of studies using AR and musical education [7] [8].

This paper is organized as follows. In sections 2 and 3 are discussed some of the challenges and possibilities of the effective use of AR in education. Section 4 presents the Music-AR application for music education using AR. Section 5 shows tests performed with the application, as well as the results obtained. Finally, the implications of this work are discussed in section 6.

2. Challenges for the Effective Use of Augmented Reality

The effective deployment of emerging technologies such as AR is still a challenge, because it requires the overcoming of various barriers. The first relates to physical and technological issues, dealing with the gap between the process of development proposed in software engineering for interactive applications [9, 10] and how these projects are being developed. The second relates to sociocultural issues. The last barrier is related to pedagogical and management issues. Although one of the areas most cited for the potential use of emerging technologies is education, very few projects are in fact implemented in schools to support learning in an effective way.

2.1 Physical and technological issues

Educational applications supported by computers are usually developed by computer experts consulting with education professionals. In many cases, the applications are much more influenced by the computer specialists than by the education professionals; this is the traditional use of technology in education.

The evolution of AR environment development tools in the last decade has been considerable; today there is a range of solutions available. Nevertheless, these solutions still require a high technical knowledge and/or considerable time to generate content, which makes it a challenge to create AR educational environment and to generate content in an easy and effective way.

2.2 Sociocultural issues

Sociocultural issues have also been an obstacle to the use of new technologies such as AR. The first obstacle is training teachers in the use of this technology. In this context, the teacher must be a student using AR. Maintaining the awareness of the use of these tools becomes essential in order to stay focused on one's purpose; otherwise there is a movement of some teachers to the use of technologies, as stated by [11].

It is also necessary to promote technology usage that is safe, healthy and responsible, that is, it is necessary to pay attention so that students do not become dependent on technology in the classroom, hampering their learning.

In the Brazilian socioeconomic environment, equal access to technology should be considered. It is therefore necessary to ensure that everyone in the classroom has the same rights, and if there are extra activities, it must be ensured that everyone has equal access to educational tools.

2.3. Pedagogical and management issues

Content creation for AR applications demands considerable time and effort. To develop such content, not only computational technical knowledge is needed, but also a knowledge of the subject as well as teaching skills. Because most development tools are not high-level or easy to use, teachers feel unable to generate applications. The solution found by some teachers is to search for support staff, but this restricts the technology to only a few institutions and people.

For educational content to be broadly developed, the tools have to be easily usable even for complex tasks, allowing teachers to focus on the content of the lessons. That way, teachers do not need to have a thorough knowledge of the underlying system (e.g., knowledge of computer graphics, programming languages, interface with the operating system, etc.). It is also necessary to create educational methodologies for the use of such technologies. In addition, all created material should be conceived to function within a dynamic new type of classroom.

On the other hand, teachers also need to be trained so that they feel safe and capable in using the technology in the classroom. Open basic courses and training in

the creation and manipulation of images, videos, stories, etc. are needed in order to resolve or alleviate this problem [1].

Technology should improve communication and education management. The technology in education should not be a barrier but should be a means of stimulating communication between parents, teachers and students.

3. Possibilities

There are many people without programming skills, such as teachers, who are interested in developing AR applications. To work around this problem, there are some authoring tools to provide resources for nonprogrammers, so that they can create their own applications [12]. It is important to mention that these applications must be independent of compilers, operational systems and programing languages, but should, instead, use text editing, configuration procedures, visual interface and tangible actions.

An example of a high-level tool is Flaras [13]. This tool is free open-source software available on the Internet at http://ckirner.com/flaras2. It includes support material such as downloadable versions of the tool; tutorials based on texts and videos; FAQs; an e-book; a repository with various online applications, accompanied by their respective projects, open and licensed for the adaptation and creation of derivative works; and information about the software developers. Flaras can be used with a single marker (a drawn card with a frame and a symbol therein) and is based on the concept of spatial points with stacked virtual scenes containing images, sounds, videos and 3D objects.

However, it is important to mention other tools that can be differentiated by their degree of ease in creating material for nonspecialist users and also by their limitations. Among these, the following can be highlighted.

- ARToolKit [14] is one of the first AR tools that used markers and computer vision. To use it to create AR applications, developers need to have skills in programming in C/C++. Its content design tool eliminates the dependence on the programming language, replacing it with the description of the virtual objects and their relationships with the real environment.
- DART [15] is a tool implemented on Macromedia Director, using a model of a visual type of authorship “drag-and-drop” and an interpreted scripting language (textual descriptions).
- AMIRE [16] is based on a structure that uses oriented components technology, providing a minimum set of components for demonstration, a collection of reusable resources and a visual authoring tool.
- ComposAR [12] is an extensible tool for authoring AR applications for nonprogramming users. It supports a scripting and interface type of “drag-and-drop” and interpreted input in real time as well as features added by users.

- ARSFG [17] is a software tool for the rapid prototyping of AR applications, based on scene graphs, which enables remote collaboration through an XML-based protocol.
- BasAR [18] is an authoring tool where the authoring layers are separated into infrastructure, structure, content, performance and behavior.
- FlarToolKit [19] is a library developed in the ActionScript language. It runs on a majority of web browsers that support the technology of the Adobe Flash Player. Therefore, the development of FlarToolKit applications enables applications to run AR on the Web, providing greater flexibility on the issue of access to applications.

Another important issue for the development of these tools involves the fact that an educational application, involving various media, can be designed or planned using the approach of the problem of division, also known as a "top-down" approach [9]. In this approach, a complex problem is divided into smaller and smaller parts until all of them can be resolved.

On the other hand, most applications developed by professionals in the technological area are presented to users as a whole, integrating the structure and content. This makes it difficult to make any adjustments, due to system complexity, since programming changes are required in most cases. The application of a division in structure and content enables making changes of substance in a more simple way, allowing the participation of teachers and students in changing the applications.

This approach to problem-solving of dividing into smaller parts and the implementation of a division in structure and content, along with a simple tool, creates favorable conditions for the development of educational applications for teachers and students. These simple tools should be based on visual actions, should be easier to use and should allow adaptations to the project, enabling the creation of applications from which others can be derived through changing the content and possibly the structure [1].

4. Music-AR

According to Schafer [20], music is an organization of sounds (rhythm, intensity, melody and timbre), with the intention of being heard. In this regard, the vision of musical art transcends the orthodox definitions of classical, popular and folk music and personal preference. Music can also be described as an imitation of nature or of daily sounds. The awareness of environmental sounds occurs through much training, and musical education provides training so that people become able to preserve familiar sounds and create new ones. Thus, the leaners should listen to, analyze and make sounds. For the authors of this paper, musical education should be constantly linked to experiences and discovery, just so efficient results can be achieved. These are the experiences and discoveries that happen very early in childhood.

Music should elicit different emotional responses in listeners. It is assumed that these responses are generated because different extremes related to sound characteristics (e.g., high and low, strong and smooth, short and long, fast and slow)

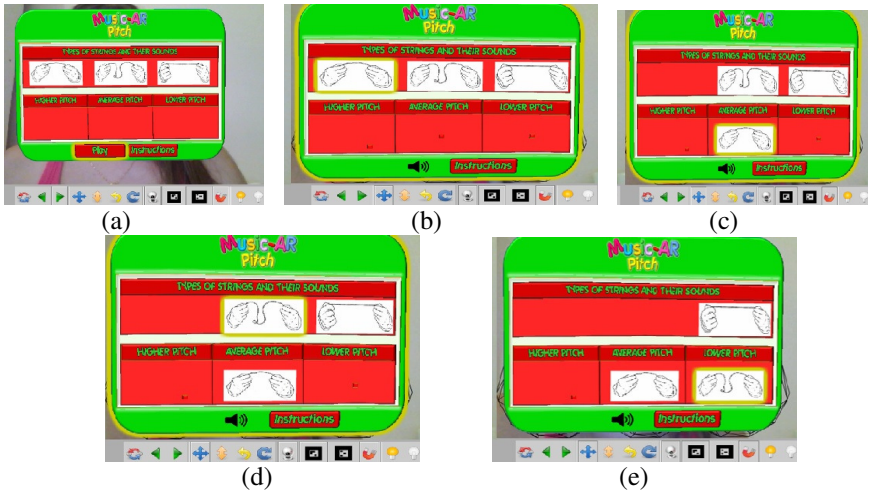
must have some power over emotions. This fact can be used to create a composition with a specific character that may affect the listeners' emotional states [21, 22].

Music-AR is a set of short games that was designed based on interviews with a music teaching expert, the Arts Coordinator of a private teaching school located in the city of São Paulo, Brazil. Information gathered through this interview revealed shortages of software for teaching musical perception to children. According to the person interviewed, few software aim to teach trivial details such as musical notes. However, it is necessary to teach sound properties that precede musical teaching, such as pitch, rhythm and timbre. Thus, the goal of the researchers was not to teach music or a musical instrument; rather, the core focus was to develop an application that could teach musical perception in children.

The Flaras tool was used to develop the application. Although it is possible to import ready-made 3D objects, for reasons of ease and the adequacy of the objects, they were created in this case. As the target audience was made up of children, Music-AR needed to meet the requirements of being attractive, playful, easy to use, easy to learn, fun, intuitive and visually pleasing. The development took about two weeks and involved a first-semester student of computer science without a deep knowledge of application development.

To achieve these goals, short and intuitive games (exercises) were generated. All games allowed the child to hear/see explanations about them and then use the concepts learned to solve the exercises. These exercises encompassed the following sound features:

- Pitch: This refers to the bass, midrange and treble, that is, how high or low a sound is. Figure 1(a-e) shows a sequence in which the user performs one of the games related to the topic, "Pitch." To explain the concept of pitch, the application uses the idea of the stretching and loosening of a rope to represent a high or a low sound, respectively. This is what really happens with stringed musical instruments.



(a) (b) (c)

(d) (e)

Figure 1. Main screens running the game on the Pitch

- Intensity: This is the strength at which the sound occurs. Figure 2(a-d) shows the main screen for the application relating to sound intensity, the strength at which the sound occurs. In this exercise, after hearing an explanation about "Sound Intensity," the sounds of three bees buzzing are presented to the child, giving the feeling of distance (the sound of the closest or the farthest bee) and the sound with greater or lesser intensity.

(a) (b)

(c) (d)

Figure 2. Main screens running the game on the Intensity

- Duration is the variation of time during which the sound endures, whose extremes are long and short. Figure 3(a-d) shows the main screens for the application with respect to "Duration." The child should listen to the explanations of short and long sounds (the variation of sound time). Afterward, the child should hear a certain sound and decide whether it is long or short. A screen with feedback on the correctness or the error is then shown to the child.

(a) (b)

(c) (d)

Figure 3. Main screens running the game about Duration

- Timbre is the sound quality that distinguishes instruments. It is the personality of the sound. Figure 4(a-e) presents the main screen for the application about "Timbre." This concept is related to the personality of the sound; it is the ability to distinguish two sounds from different instruments, such as the sound of a piano and the sound of a violin. After listening to the explanations about timbre, the child must decide which sound he or she is listening to. A screen with feedback is then shown to the child.

(a) (b) (c)

(d) (e)

Figure 4. Main screens running the game about Timbre

5. Results and Discussion

In order to validate the applications (games) developed, two types of evaluation were performed: tests with potential end users and an evaluation with a music teacher.

For tests with potential end users, a group of 14 children of both genders (nine girls and five boys) was selected. The age of the children is presented in Figure 5. Five children had had previous contact with AR. Eight children had had contact with musical education.

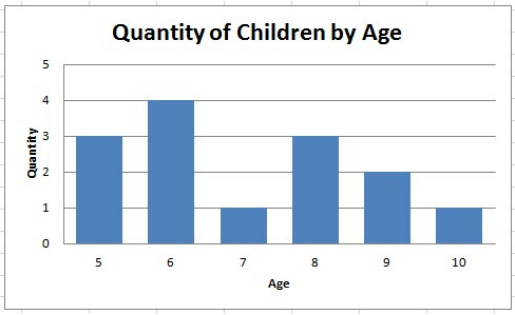


Figure 5. Quantity of Children by Age

The following methodology was applied for the tests with potential end users. First, we collected parental permission for the children to participate in testing. Some questions about their profile were asked. For each child who did not know AR, its principles were explained, and a small demonstration was performed. Subsequently, each child was asked to carry out the execution of the applications about sound properties. Finally, some questions were asked about usability.

The physical environment used for the tests was not a controlled environment. The tests took place in the users' homes in order not to cause a nuisance to the children's usual environment. The users were then asked to run the applications.

During the test sessions, the tester, by observation techniques, noted some information about the use of the applications:

- Five children had some difficulty performing the activities;
- This difficulty was not related to the lack of musical education nor to a lack of interest;
- This difficulty was related to problems of usability of the technology itself, such as those caused by inadequate light or a lack of detection of the marker within a few moments;
- 100% of the children could understand the musical perception using the applications.

These were the children's responses to the usability questions:

- 100% of the children believed that the layout of the four applications was appropriate and attractive;
- 11 children considered the mouse interaction to be good, and 13 considered the marker interaction to be good;
- 100% of the children liked the sounds of the applications;

- 100% of the children liked using the applications and would like to use this type of technology frequently.

In interviewing the music teacher, the following results were obtained:

- The teacher did not k0now the technology of AR but considered it important to use for music education;
- The teacher considered the applications very interesting and fun and felt that they could really help in teaching music;
- The age range for children to use such games should be between four and six years;
- The teacher believed that these games were easy to manipulate and that many kids would not have a problem with them;
- She thought that more games should be developed and then organized into a kit and distributed to children.

6. Conclusions

This paper discussed the difficulties and possibilities of using augmented reality in education, especially in musical education. Physical, technological, sociocultural, pedagogical and management issues are among the difficulties inherent in the use of this technology, and the possible solutions presented involve the use of authoring tools that are easy for teachers to use.

We also presented a case study that uses AR for teaching musical perception to Brazilian children, especially the topics of pitch, sound intensity, duration and timbre. From the observation results, we can conclude that the children could understand, through using AR, the concepts of pitch, sound intensity, duration and timbre, sound properties that must be learned before teaching music. All children could solve the musical perception exercises.

According to the questionnaire results, the children felt motivated to use the technology. Another important observation was that children seemed to understand how to use the AR as soon as they began to interact with the technology.

Through an interview with a music teacher, it was concluded that AR could be used for music education; applications developed can motivate children to learn music.

AR seems to be adequate for use with children, due to the playful nature of its technology. AR can be used as a tool in the learning–teaching process with respect to musical perception.

Flaras is a very easy tool to use for nonspecialist people. On the other hand, it is a little limited, for exactly the same reason. Some types of exercises on musical perception could not be performed due to a lack of resources in the tool. For example, it is impossible to include a selection command (if-then and if-then-else). This command is used by programmers to determine what will happen if a certain event occurs. In the case of the “if” statement, if a certain event is true, then the command will be executed.

However, the results show that we can use AR as an educational tool. This technology has a considerable potential impact on the teaching–learning process. In

future work, we aim to investigate tools and techniques for creating educational AR learning objects that can be easily proposed to suit different learning contexts.

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