

Case Studies on the Development of Games Using Augmented Reality

Claudio Kirner, Member, IEEE, Ezequiel R. Zorzal, Tereza G. Kirner

Abstract—Games have fascinated people in activities related to entertainment, education, health care, etc. The use of augmented reality technology, using computational support, brings the game from the computer to the user space, making the interaction friendlier. This paper introduces augmented reality and makes considerations on the ARToolKit software, pointing out its interactive processes. The use of augmented reality in the development of games is illustrated by five case studies of games implemented with ARToolKit. The main characteristics of each game and the exploration of the augmented reality resources are discussed.

I. INTRODUCTION

People play games for several purposes, including education, health care, entertainment, etc.

Games can be played in different ways, using paper, orally, manually or with the use of electronic medium. Games that use paper, oral or manual medium do not necessarily need technological devices for their execution, allowing the use of natural interaction. Moreover, electronic games move the user to a virtual world, crossing the limits of the logic and imagination, allowing the use of the hands directly or through special devices to support the interaction. The main disadvantage of conventional electronic games is the user adaptation required to manipulate unnatural interface devices.

With the technological advances, through techniques of augmented reality, virtual world could be brought to the user space, providing a natural and pleasant experience with the new environment. Here, computer combines the real environment scenery with virtual objects, showing a single mixed environment in front of the user, who can visualize this environment directly through a head mounted display or indirectly through a monitor, for example. Using the hands, in an augmented reality application, the user is able to manipulate real and virtual objects in the mixed environment, without the need of special equipment such as joystick, keyboard and mouse.

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C. Kirner is with the Graduate Program in Computer Science, at the Methodist University of Piracicaba, Rodovia do Açúcar, Km 156, Piracicaba – SP, Brazil (e-mail: ckirner@unimep.br)

E.R. Zorzal is with the Graduate Program in Electric Engineering, Federal University of Uberlandia, MG, Brazil (e-mail: ezorzal@gmail.com)

T.G. Kirner is with the Graduate Program in Computer Science, at the Methodist University of Piracicaba, Rodovia do Açúcar, Km 156, Piracicaba – SP, Brazil (e-mail: ckirner@unimep.br)

This paper presents augmented reality as a useful technology for developing games. Some games, implemented by the paper's authors, are described, being emphasized their potential use and the advantages of that technology. Section 2 introduces augmented reality. Section 3 describes the ARToolKit software, pointing out its interactive processes. Section 4 presents five augmented reality games, developed by the authors, using ARToolKit. Finally, section 5 gives the conclusions.

II. AUGMENTED REALITY

Augmented reality is usually defined as the overlapping of three-dimensional virtual objects, generated by computer, with a real environment, through some technological device [14]. This concept can be better understood through its insertion in a wider context related to mixed reality.

Mixed reality combines real with virtual environments and includes two possibilities: augmented reality, whose predominant environment is the real world, and augmented virtuality, whose predominant environment is the virtual world [11], [14]. Figure 1 presents the diagram of continuous reality/virtuality, based on [14], showing the gradual possibilities of overlapping of the real with the virtual environment and vice-versa.



Fig. 1. Diagram of continuous reality/virtuality

Augmented reality provides a friendly human-computer interaction, since it brings virtual objects for the user space, enabling him/her to visualize and manipulate both real and virtual objects. That functionality is obtained through techniques of computer vision and virtual reality, which enable to overlap virtual objects with the real world [2], [5], [7], [8], [9].

Besides, augmented reality allows the user to handle objects with the hands, making possible attractive interactions in the mixed environment [6], [15], [11], [16]. In order to do that, it is necessary to use a software capable to track hand positions or something equivalent to that. Although some devices used in virtual reality environments could be used in augmented reality environments, they sometimes need adaptations [3], [4].

A simple platform to develop augmented reality applications is based on a microcomputer with an installed web cam. In this environment, a way to mix the virtual with the real environment is to use any software that captures the image frames from the real environment through the web cam and processes them, placing the virtual objects in the real scenery. Furthermore, the software also needs to manage interactions with the virtual objects, changing their positions and other characteristics in real time, giving the impression of a unified environment. Figure 2 shows this augmented reality model, which provides a vision by video, based on monitor and web cam.

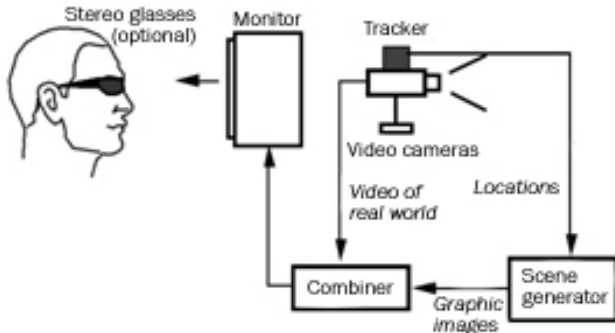


Fig. 2. Augmented reality based on monitor and web cam [3]

III. USING THE ARTOOLKIT SOFTWARE

ARToolKit [1] is a software indicated for the development of augmented reality applications based on real world captured by camera, which uses techniques of computer vision, image processing and space positioning.

Among the difficulties related to the development of augmented reality applications, there are many activities being executed in real-time, including: tracking of real objects, calibration and positioning of virtual objects, combination of real and virtual environments and interaction with virtual objects. In that context, the ARToolKit minimizes problems, using web cam and plates as references to insert virtual objects in the real scenery. It allows the tracking of the position of reference plates (markers) relative to the camera, making possible to put virtual objects near them. Besides, the software allows manipulating the plates together with the associated virtual objects using the hands.

During the application execution, ARToolKit first transforms the video image captured by the camera in a binary image with black and white values and examines the image, trying to find square areas. Then, ARToolKit analyzes the images inside the squares (symbols equivalent to bar codes), working as a pattern, comparing them with pre-registered symbols. Consequently, if there is a similarity between a captured symbol and a pre-registered symbol, ARToolKit will find a reference marker out. After that, ARToolKit uses the known size of the square and the pattern orientation to calculate the position of the camera relative to the marker, determining the coordinates and orientation of the marker used to draw the virtual object precisely over it [10].

A. Interactive Actions with ARToolKit

ARToolKit can be used in augmented reality applications using plates (reference markers), where the virtual objects are placed when they appear in the view space of the camera. Since ARToolKit has an open source, new functions were developed by the authors of this paper, to expand its usability and potential for developing new applications [15]. In this context, some interactive processes were developed, such as: changing of the virtual object, when a specific reference marker (control marker) enters the view space of the web cam; copying or capturing and transporting virtual objects between markers in the scene, using transporting markers; playing sound associated with virtual objects, starting when the virtual objects are put on markers; changing virtual objects in real-time, based on acquired external data.

B. Control Markers

This type of interaction allows the virtual objects over markers to be controlled and modified dynamically when a reference marker (control marker) enters the space view of the web cam. Several virtual objects from a list are associated with a marker, so that a control marker can start the exchanging of virtual objects, deleting the virtual object and putting the next from the list over the marker [15], [16]. In this way, each marker can show several virtual objects, depending on the entered sequence into the space view of the web cam. That procedure works like a reuse of markers and it is useful for making a sequence of scenes and sounds controlled by the user.

C. Transporting Markers

This interaction is based on a special marker (transport marker), which allows the copying or capturing of a virtual object from a marker and transporting it to another marker, working as a paddle. When the transport marker enters the scene, ARToolKit calculates the distance from it to the other markers until it becomes close enough to a particular marker. In this situation, it copies or transfers the virtual object associated with that marker to the transport marker. When the transport marker approaches another marker, the last one receives the virtual object from the transport marker by copy or transfer. In order to do that, it was necessary to change a portion of the ARToolKit source code to make possible the identification of the distance between plates [15].

D. Insertion of Sound

This interaction [15] is related to the play of an audio file when the virtual object is placed over the marker. An efficient solution used to solve that subject was the creation of a thread, started in parallel with the process of virtual object placement. Each time the marker enters the scene, the virtual object is placed over it and the sound is played. If the plate is taken back and the sound is still playing, it is interrupted.

E. Changing Virtual Objects during Execution

It is possible to modify virtual objects during the application execution through changes in the ARToolKit code and additions of specific comments on VRML code indicating data to be changed. In this case, it was necessary to carry out some alterations on parameters in the

ARToolKit code, such as scale, rotation and translation related to virtual objects. However, it is also possible to accomplish some changes in the VRML code of the virtual object during execution, followed by a *redraw* process involving those objects. It means that the virtual objects should be recharged again during the running process. The VRML code can be changed while ARToolKit is being executed, but when the changing marker enters the scene, ARToolKit executes the *redraw* process, showing the new virtual object that reflects the change.

IV. GAMES DEVELOPED WITH AUGMENTED REALITY

A. Three-Dimensional Jigsaw Puzzle

A virtual jigsaw puzzle was built, using cubes as pieces of the game. Each cube contains six different symbols that correspond to the same virtual piece registered in different angles and/or positions, according to figure 3.

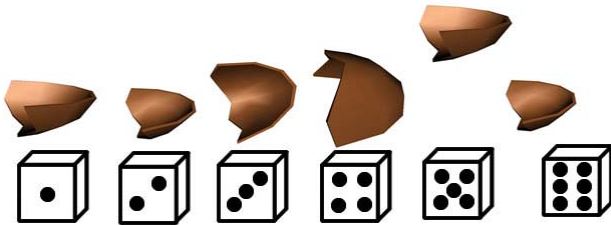


Fig. 3. Virtual object in different angles and positions

The user must find the correct combination of all the cubes to complete the space jigsaw puzzle. That range of possibilities turns the game more complex and attractive, stimulating the user's perception capacity and space reasoning. Figure 4 presents the 3D environment of the jigsaw puzzle.

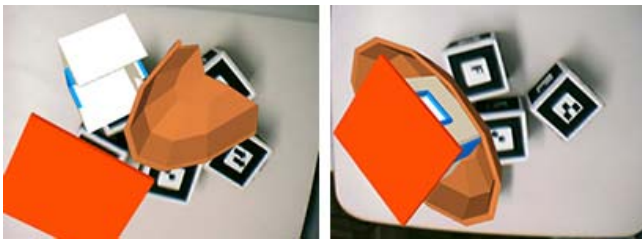


Fig. 4. Environment of the jigsaw 3D puzzle

B. Tic Tac Toe Game

The tic tac toe game was developed using two remote computers communicated by sockets [12].

ARToolKit was used to manipulate virtual elements of the game and to allow the sharing of the users' physical environment, so that people could work in the same space.

The functioning of the virtual tic tac toe game is similar to the conventional game. One of the participants creates the virtual board, that becomes available to the other remote participant, and the game begins. The participants play, placing pieces until one of them forms a sequence of three adjacent symbols in horizontal, vertical or diagonal orientation. When one participant wins the game, he/she uses of a virtual ruler indicating his/her victory, according to the figure 5.

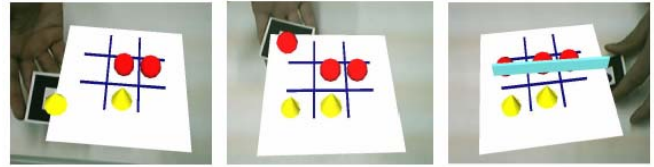


Fig. 5. Stages of tic tac toe using augmented reality

This game provides an interaction not only virtual but also human, because the participants can play with their opponents, without the computer interference. It is possible to include the computer in the process, helping the winner identification and establishing who gets to play. The game allows users to establish opportunities to find solutions and to interact with other users, through collaborative activities using collective strategies. Figure 6 illustrates the structure and environment of tic tac toe game.

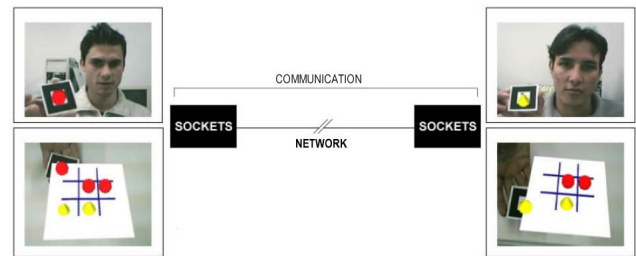


Fig. 6. Environment of tic tac toe game

Parallel to the actions, the users can communicate through text messages in a chat window, talk in voice channel and view in a video window. Depending on the quality of the network and the traffic situation, some of those communication elements could be deactivated for the system to work adequately. The only element that can not be disabled is the augmented reality application, which is the game itself and potentially demands less traffic in the network.

Adjustments in the system were carried out in order to minimize the traffic of information related to the game. Initially, the information concerning the board and pieces positions was sent continually to guarantee the consistence of the positions for the remote users, but it generated intense and unnecessary traffic of information in the network. To reduce that traffic, it was placed a program to analyze marker positions collected continuously by the ARToolKit. If the old and new positions (X, Y or Z) of the board or the pieces differ less than a pre-defined tolerance (0.5 cm, for example), the information does not need to be sent. The information will only be sent, when indeed there are considerable alterations in positioning of the board or the pieces. Thus, with a small traffic of short information, the network generally supports the augmented reality application, even in low speed conditions.

C. Game of Words

In this application, the ARToolKit was used to overlap and adjust the virtual objects in the scenery, using plates containing the symbols of the alphabet [17]. Thus, when setting up a word completed by the plates in front of the web

cam, the related virtual object appears over it, allowing its visualization and manipulation. However, those plates and their respective virtual objects should be properly registered in its database in advance.

Figure 7 presents some examples of plates that were used together, allowing the visualization of the related virtual objects.



Fig. 7. Example of plates and their virtual objects

This game motivates the user to interact and create solutions in an attractive environment.

Figure 8 displays plates used as pieces for putting words together in this game and the scenery of the word game developed in the augmented reality environment.



Fig. 8. Game of words

D. Musical Games

To explore the use of augmented reality in effective musical learning, some applications were developed focusing on different areas of music.

The first developed application uses techniques of occlusion of markers to interact with the user. When the user places his/her hand on one of the markers previously positioned in the environment, the system notices the absence of that marker and executes an action, playing the corresponding musical note. That behavior is obtained by starting a thread [15] in parallel to the execution of ARToolKit.

The thread seeks a midi file in the disk and executes it. The advantage of midi files is their reduced size, which increases their portability, while the disadvantage is related to the fact that the sound can escape completely from the original, in certain cases. Figure 9 demonstrates the process of occlusion of a marker and the activation of the thread for playing the sound file.

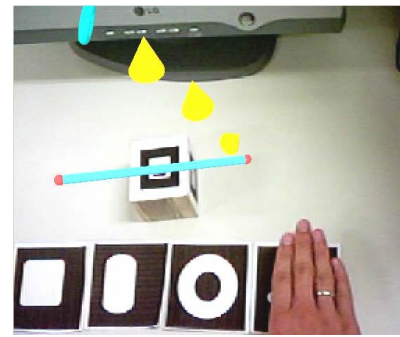


Fig. 9. Process of occlusion of a marker

With the process of occlusion of the markers and some previously positioned symbols, it is possible to get a great variety of user interactions, as the creation of personalized melodies and even a simple musical experimentation.

However, the application was developed with a module of lively virtual objects that work as a guide for the execution of a simple and popular melody. Each virtual object has similar format to one of the previously positioned symbols. A virtual ruler is positioned in the scenery so that virtual objects can lively descend towards it. At the instant time that an object touches the ruler, the user should make the occlusion of the corresponding symbol. When he/she hears the sound, the user needs to leave the symbol free again for recognition of the web cam. This way resembles a karaoke system and interactive dance games. Hence, keeping the objects correctly to fall rhythmically on the ruler, it is possible to execute several melodies, respecting the duration of each note.

The musical guide melody can be easily changed with the replacement of the source file of the lively symbols or through a control plate [15]. Thus, it opens up a vast range of possibilities for musical execution, making the application more attractive and diversified for the user.

The musical area explored by this application is the rhythmic, because the user needs to touch the markers in the correct time intervals to get the expected final result, that is, the complete melody.

The second developed application uses the technique of dynamic markers. Those markers can be modified by the user, changing the shown symbol. That characteristic extends the possibilities of the application, since with only one dynamic marker it is possible to alternate among several symbols and actions.

The marker used in the application consists in a fixed square, containing the five lines of the musical notation, and a movable part that allows modifying the vertical position of a circle in the lines of the notation. In this way, it is possible to represent some musical notes in its natural environment that is the musical notation. It is interesting to emphasize that movable parts can be changed easily for other ones with a different symbol, making it possible to represent also the tone of the note. Figure 10 displays the format of the dynamic marker that was built.

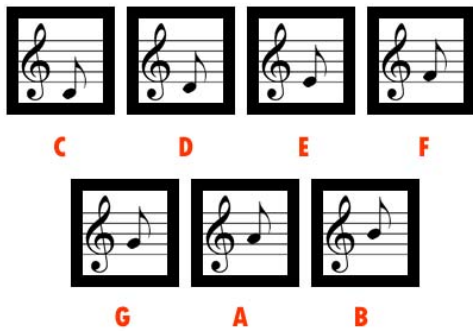


Fig. 10. Dynamic markers

When ARToolKit recognizes a symbol composed by the dynamic marker, immediately it is put upon the object a type of legend with useful information, as the name of the note, its duration, etc.

In parallel, a thread starts playing the sound related to that symbol, enlarging the cognitive characteristics of the presentation, since learning is accomplished by multiple sensorial channels, as vision, touch and audition. Figure 11 illustrates the recognition of a symbol by the system, the overlap of informative legends and playing of the appropriate sound.

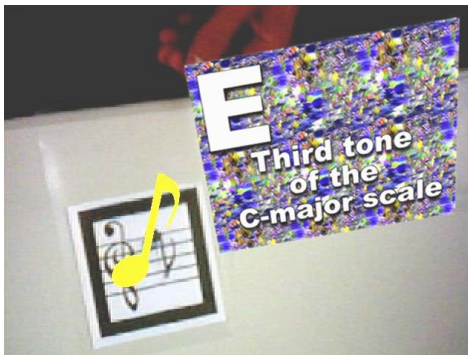


Fig. 11. Environment of the musical game

This application is very interesting and valuable in the study of musical notation for people from several age groups, facilitating the understanding of the concepts involved in this reading form and helping the memorization of the notes. Besides, the possibility to visualize the symbol and immediately associate it to the corresponding sound is a powerful tool for the adequate musical learning.

E. Magic Cubes

The implemented magic cube is composed by 8 wood or plastics linked cubes [13]. Each side of that cube has an image drawn on paper and glued on its surface. Figure 12 presents the forms of the magic cube

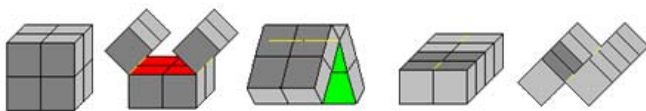


Fig. 12. Magic cube [13]

Figure 13 displays the model regarding the construction of the magic cube, where the yellow rectangle represents the part that should be bound with an adhesive tape or other sticking material.

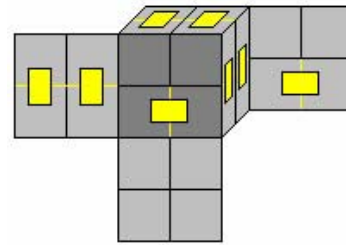


Fig. 13. Model for the construction of the magic cube [13]

Each position of the magic cube can represent a specific scene of a story, containing the picture and a specific marker used to put the virtual scene and play the sound that tells the story. Figure 14 presents the markers and their respective virtual scenes built for this application.

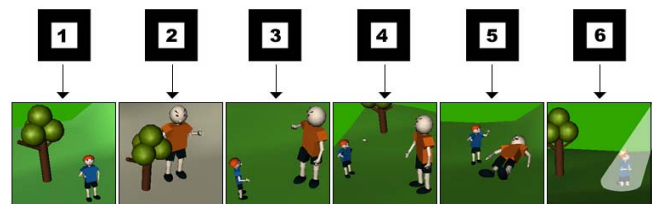


Fig. 14. Built markers and their respective virtual scenes

That application presents the biblical story of David and Goliath in 3D environment. In order to be able to hear the story and examine the scenes from several angles, the correct positioning of the cubes is essential. Figure 15 displays the environment related to the magic cubes application.

That game wakes up the user's interest since, besides attending the story, the user can also interact and have fun with the magic cubes.

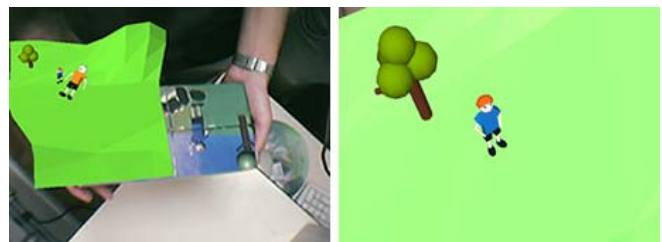


Fig. 15. Environment of the magic cubes

V. CONCLUSIONS

Augmented reality contributes in a significant way to the area of games, providing to the user an attractive visualization and natural interaction. In addition, augmented reality environments does not requires special devices and intensive training for the users.

This work focused on augmented reality technology, stressing the resources offered by the ARToolKit software. It is a software available by the Internet, at no cost, which is

indicated to implement augmented reality-based applications.

The paper described five games in augmented reality, developed by the authors using ARToolKit. The presented case studies, all ready to use, suggested that it is possible to develop games using popular resources, including hardware and software suitable for augmented reality applications. It is important to emphasize the creativity to give new characteristics to known games and to develop new ones.

The usability of the games is being evaluated and, according to the results obtained, necessary improvements will be performed in the games.

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