COLLABORATIVE AUGMENTED REALITY ENVIRONMENT FOR EDUCATIONAL APPLICATIONS

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Abstract: The face-to-face and remote collaborative learning has been successfully used in the educational area. Nowadays, the technological evolution allows the implementation and the improvement of interpersonal communication in networked computer environments, involving chat, audio and video conferencing, but the remote manipulation of objects remains a problem to be solved. However, the virtual reality and augmented reality make possible the manipulation of virtual objects in a way similar to real situations. This paper discusses those subjects and presents a solution for interactions on remote collaborative environments, using conventional resources for the interpersonal communication as well as augmented reality technology.

1 INTRODUCTION

The collaborative learning, as an educational approach centered on students and based on group activities, is growing along the years. That approach takes into account that the learning involves an active process and: it uses constructive process; it depends on richer contexts; and it involves heterogeneous groups of students. In this way, the students are exposed to situations, in which each one can evolve, work in group, compete, cooperate and exercise the concept of responsibility.

Collaborative learning and the development of abilities in group have been implemented in local (face-to-face) environments, supported or not by computers, and in remote environments supported by computers and communication networks (Billinghurst, 2003)

The great advantage of pure local collaboration is related to the easy interaction among people, who use verbal communication, gestures, and facial expressions for the manipulation of objects. When the application involves the computer in the local environment, part of those characteristics persists, but the object manipulation is modified, through the use of computer interface and interaction devices. In remote applications, the interaction among people becomes more difficult to be implemented, but the richness of the applications tends to overcome those difficulties. In that case, communication and multimedia techniques, involving text, voice, video and animation, are used to imitate and better explore the local interaction characteristics. However, the problems with objects manipulation remain being difficult to be solved.

To enable the manipulation of objects in a more natural way, virtual reality is used, allowing the implementation of three-dimensional interfaces. In this case, visualization and manipulation occur like the actions in the real world, but demand special devices, as gloves and helmets. In virtual reality environments, the user has to enter in the context of the application executed in the computer, demanding that the user be able to navigate in that new environment and to use special devices. Despite the benefits of a more natural interaction, the need of special equipments and training restrict the use of virtual reality.

A solution for that kind of problem was given by augmented reality, which mixes the real scene with virtual objects generated by computer and produces a virtual environment in the physical environment in front of the user. Besides, the user can use the hands to manipulate the real and virtual objects of the

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mixed scene, without the need of special equipments. Therefore, the augmented reality and computer networks make a convergence of multimedia resources that allow to the people getting benefits of face-to-face interactions, even being in remote environments.

Those characteristics allow the development of collaborative applications, exploring the advantages of educational games, taking into account the user involvement, the development of abilities and the construction of knowledge.

This paper presents the characteristics, resources and educational applications of augmented reality, showing the implementation of an educational game in collaborative environment with augmented reality, to justify the pointed out advantages and to emphasize its potential benefits. Section 2 presents the concepts of augmented reality, section 3 discusses collaborative environments with augmented reality, section 4 shows a multiuser educational application implemented in a distributed augmented reality environment, and, finally, section 5 gives the conclusions.

2 AUGMENTED REALITY

Augmented reality is a particularization of a more general concept, denominated mixed reality, which consists in overlapping real and virtual environments, in real-time, through a technological device. One of the simplest ways to get an augmented reality environment is based on a microcomputer with a webcam, executing software using techniques of computational vision and image, processing to mix the scene of the real environment captured by the webcam with virtual objects generated by computer. The software also takes care of the positioning, occlusion and interaction of the virtual objects, giving the impression to the user that the mixed scene is unique and real.

Mixed reality can receive two denominations: augmented reality, when the user interface is based on the real world, and augmented virtuality, when the user interface is based on the virtual world.

Therefore, augmented reality can be defined as the overlapping of virtual objects in the real world, through a technological device, increasing the user's vision and other sensorial aspects (Azuma, 1997). It is important to point out that the virtual objects are brought to the user's space, which is familiar to him/her and where the user knows to interact with objects, without training.

However, in order to visualize the overlapped objects, it is necessary to use special software and devices. Some devices used in virtual reality environments, as the helmet (head mounted display), can be adapted and adjusted in augmented reality environments. The main differences found among virtual and augmented reality devices are placed in the displays and trackers.

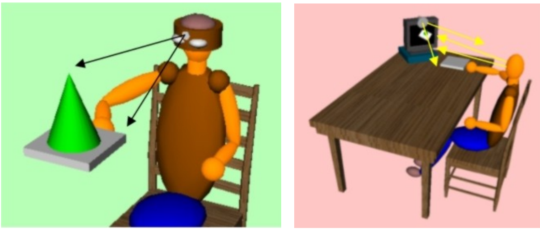
2.1 Types of Augmented Reality Systems

The augmented reality systems can be classified according to the type of used display (Milgram, 1994), (Azuma, 2001), involving optical (see-through) vision or video based vision, creating four types of systems: (a) direct optical vision; (b) direct video based vision; (c) video based vision using monitor; (d) optical vision using projection.

Direct optical vision systems use glasses or helmets, with lenses which allow the direct reception of the real image, at the same time that the virtual images, properly adjusted with the real scene, are projected into the user's eyes, mixing the view scene. A common way to get that characteristic is to use a sloping lens to allow the direct vision, reflecting the projection of images generated by computer directly into the user's eyes. Figure 1a illustrates a direct video based system type using helmet (hmd).

Direct video based vision systems use helmets with a video micro camera coupled on it, pointing to the same direction of the eyes. The real scene captured by the micro camera is mixed with the virtual objects generated by computer and presented directly into the user's eyes, through hmd displays.

Video based vision systems using monitor use a webcam to capture the real scene, mixing it with the virtual objects generated by computer and presenting the result on the monitor. The user's point of view is usually fixed and depends on the positioning of the webcam. Figure 1b shows a video based vision system using monitor.



(a) using helmet (hmd) (b) using monitor

Figure 1: Video based vision systems.

Optical vision systems using projection uses surfaces of the real environment, where images of the virtual objects are projected, in a way that the result can be visualized without the need of any auxiliary equipment. Although interesting, those systems are very restricted to the conditions of the real space, because of the need of projection surfaces.

The direct vision systems are appropriate for situations where the loss of the image can be dangerous, as in case of a person walking through the street, driving a car or piloting an airplane, for example. For closed places, where the user has control of the situation, the use of the video based vision is suitable, because in case of loss of the image, it can remove the helmet with safety, for example. The direct video based vision system is cheaper and easier of being adjusted.

2.2 The ARToolKit Software

ARToolKit (Lamb, 2007) is a free software, indicated for the development of augmented reality applications. It is based on video to mix the captured real scenes with the virtual objects generated by computer. To adjust the position of the virtual objects in the scene, the software uses a type of marker (plate with square frame and a symbol inside it), working as a bar code (see Figure 2).

Figure 2: ARToolKit marker and virtual object.

The frame is used to calculate the marker position in the space, depending on the square image in perspective. The marker needs to be previously registered in front of the webcam. The internal symbol works as an identifier of the virtual object, associated with the marker in a previous stage of the system. When the marker enters in the field of vision of the webcam, the software identifies its position and the associated virtual object, generating and positioning the virtual object on the plate. When moving the plate, the associated virtual object is moved together as if it was grabbed on the plate. This behavior allows the user to manipulate the virtual object with the hands.

ARToolKit can be used with direct video based vision devices, such as helmets, and with video based vision systems using monitor. With direct video based vision, the user sees the real scene with the virtual objects, through the video camera adjusted on the helmet and pointing to the eyes direction, giving the impression of a real manipulation and promoting the immersion sensation. With the system based on monitor, the user will see the mixed scene on the monitor, while he/she manipulates the plates in his/her physical space. If the webcam, which makes the capture of the real scene, is on top of the monitor, pointing to the user's space, the monitor will work as a mirror, so that when the plate approximate or go away of the webcam, the image size of the virtual object increases or decrease, respectively. If the webcam is beside the user or on his head, pointing to the physical space between him and the monitor, it will result in an effect similar to the user's direct vision. As the objects are placed closer to or more distant of the user, they will appear larger or smaller in the mixed scene, shown in the monitor.

3 COLLABORATIVE ENVIRONMENTS WITH AUGMENTED REALITY

Nowadays, there is research being developed toward the use of computers in collaborative activities, involving mainly remote participants. The area of Computer Supported Cooperative Work (CSCW) presents many application examples involving: chat, audio and video-conference, virtual reality collaborative systems, and hybrid systems (Billinghurst, 2002), (Billinghurst, 2003).

However, to get the collaboration supported by computer, including the natural manipulation of objects, innovative interfaces were developed more recently using augmented reality. Those interfaces include face-to-face and remote collaboration, involving real and virtual objects.

The face-to-face collaboration with augmented reality (Schmalstieg, 2003) is based on the sharing of the physical environment mixed with virtual objects and visualized through helmet or monitor. The participants of the collaborative work act on the real and virtual objects placed in the same environment. Each one has his/her own vision, depending on his/her position, using a helmet with a coupled micro camera, or the same vision, when a monitor is used with a webcam. Both possibilities use video based vision system.

In the case of the use of the helmet, the interface is quite intuitive and toward to the collaboration in the real world, keeping the current social protocols of the face-to-face characteristic. When the monitor is used to visualization, some adaptation is need to manipulate the objects, because the real and visualized hands positions are different.

The main characteristics of that collaborative environment with augmented reality are: virtuality, augmentation, cooperation, independence and individuality.

As virtual objects present characteristics similar to the real objects (dimension and positioning), they can be manipulated with tangible techniques of augmented reality, as touch, transport, etc.

In the case of the face-to-face collaboration with augmented reality, using video based vision, monitor and webcam, the users manipulate the objects, visualizing them in the monitor, without independence and individuality characteristics. The interface is similar to the previous one, except that all the users utilize the same point of view, shown in the monitor, and the visualization, instead of happening in the physical space, where there are the hands, will appear on the monitor.

The remote collaboration with augmented reality is based on computational interfaces which share information and overlap several users' physical spaces (as a table, for example), using a computer network. In this way, each user can put his/her virtual objects on the shared real table, visualizing the whole set of virtual objects from all users and manipulating them. In applications implemented with Using ARToolKit, each user can put their plates in the field of vision of the webcam, seeing and manipulating their virtual objects and the virtual objects of the others which appear in the scene, performing the remote collaboration.

The integrated use of audio and video-conference tools, with interaction in networked augmented reality environments, allows the implementation of collaborative distributed environments, keeping the advantages of the face-to-face collaboration.

The success of the application depends on: processing power, available for execution of the augmented reality application using ARToolKit software; and speed of the communication network to allow communication and interaction in real time. The current microcomputers present appropriated computational power for augmented reality applications. However, the communication networks are the bottleneck, once they need to sustain the minimum requirements of multimedia flow (audio and video) under variable traffic flow. The solution involves the improvement of the facilities and/or of procedures that minimize the traffic and overcome problems of delay and overload. Nowadays, in some situations, where the broadband is already reality, those applications work adequately, but for extend their use, there is still a lot to do. Meanwhile, multiple solutions, which allow the coexistence with the heterogeneity of computers and communication networks, are being developed to offer different qualities compatible with the available resources.

4 A COLLABORATIVE APPLICATION WITH AUGMENTED REALITY

In order to test a collaborative application running in a computer network, an application was developed, using augmented reality, video based vision on monitor, webcam, computer network connection and user's communication based on text, audio, video and tangible actions. This application, the tic-tac-toe game in distributed environment with augmented reality was implemented to work in two remote computers, according to the Figure 3.

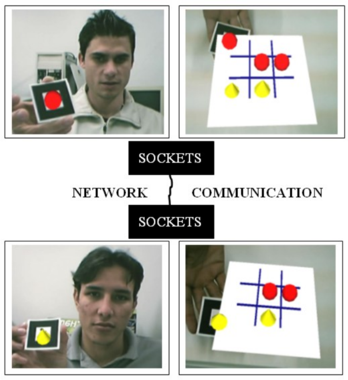


Figure 3: Environment of the Tic-Tac-Toe game.

ARToolKit software was used for sharing the game overlapping it in the users' physical environments, so that all instances could work as a unique environment. The local applications of augmented reality (the game) communicate among themselves by sockets, integrating the environments. The user's communication use multimedia communication tools such as: Chat, Skype and

Messenger, or similar resources, allowing the user to communicate with others by text, voice and video.

First, all resources are activated to contribute with the collaboration. The placement of a marker corresponding to the game board, in any of the remote environments, generates a virtual board for each user, placed a little above the surface of the table, captured by the webcam. This procedure put all markers below the virtual board, hiding them from the users. Then, each user will go putting their markers with virtual game pieces (colored cones and cylinders, for example), visualizing the whole game in the monitor. When one of the users gets to align his/her pieces in the horizontal, vertical or diagonal position, he/she will place the marker, corresponding to a bar of the same color of his/her pieces and indicate in the board that he/she was the winner.

In the same time the user carries on the actions, he/she can communicate by: text messages in the chat window, talk through the voice channel and see the other through a video window. Depending on the quality of the network and traffic flow, some of those support elements will be disabled so that the system continues working. The only element that can not be disabled is the augmented reality application, which is the game and potentially demands less traffic in the network.

Some adjustments in the system were carried out, aiming to minimize the traffic related to game information. Initially, the information about the virtual board and pieces positions were sent continually to guarantee the consistence of the positions for remote users, generating an intense and unnecessary traffic of information in the network. To reduce this traffic, it was developed a program which analyzes the positions that store the previous and current positions collected by the ARToolKit. If the position (X, Y or Z) of the virtual board or pieces differ less than a certain tolerance (for example 0.5 cm), the current information does not need to be sent; otherwise, it is sent and the current position is updated to the previous one. In this way, the information is only sent when there is a meaningful alteration on positioning of board or pieces. Thus, with a small traffic of short information, the network can support the augmented reality application, even in low speed conditions.

5 IMPROVEMENTS

A way to make the Collaborative Augmented Reality Environment more powerful for local and remote applications is creating new functionalities making easy the user's actions on handling the virtual objects. The authoring of virtual environments using only the hands and some markers is a typical application which satisfies people with no specific skills on virtual reality.

The development of such authoring tool requires a real environment containing:

- a catalog of virtual objects with markers;
- a virtual scratch pad to receive the selected virtual objects ;
- a set of paddles (markers) with specific actions to make easy the authoring activity besides the storage and recovery of the resulting virtual environment.

In this way, the first approach to solve the problem has resulted on the functionalities below:

- copy and transportation of virtual objects from the catalog to the virtual scratch pad;
- delete specific objects on the scratch pad; store the scratch pad content (file with positions and virtual objects references) to continue the activity latter or to send it to another people;
- recover the scratch pad content (from file) to continue the authoring activity or to see the authored virtual environment prepared by another people.

The Figure 4 shows the authoring tool components, using augmented reality techniques.

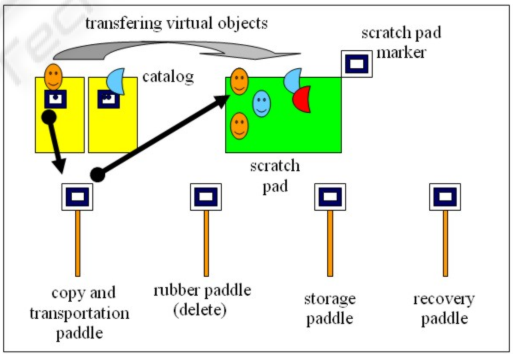


Figure 4: Authoring of a virtual environment.

The activity begins when someone place the catalog with the printed markers in front of the webcam as well as a marker related to the virtual scratch pad. Using the copy/transportation paddle, the user choose a virtual object on the catalog and capture a copy of it to place on a position on the virtual scratch pad. If the user is not satisfied with the position of a specific virtual object, he/she can use the rubber paddle to delete it, so that, repeating the copy/transportation action, the object can be placed on a new position. When the virtual environment on scratch pad is ready, or the user wants to pause his/her work, he/she can use the storage paddle to store the authored environment. Using the recovery paddle, the user can restore the authored virtual environment over the virtual scratch pad to continue the activity or see what was done.

That environment allows face-to-face collaboration of many people working with paddles in front of a computer, or remote collaboration manipulating objects on a shared collaborative virtual scratch pad.

Those activities can be used for distance education learning supporting synchronous collaborative applications (in real-time) or asynchronous collaborative activities, leaving students contributing for authoring environments alone and/or participating in a group, so that, at the end of the task, the result can be sent to teachers by email, for example. Figure 5 shows the copy/transportation paddle in action.

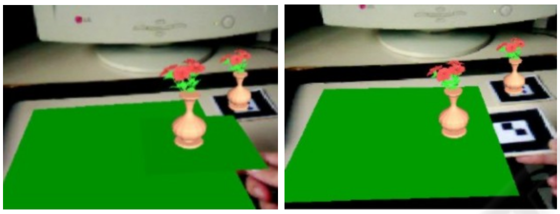


Figure 5: Copy/transportation paddle in action.

It was implemented two ways to manipulate the virtual objects with the copy/transportation paddle:

- using proximity to capture the virtual object from the catalog and pad inclination to leave it on the virtual scratch pad;
- using proximity to capture the virtual object from the catalog and paddle occlusion to leave it on the virtual scratch pad;

The inclination is easier than occlusion to use, but the second has better precision during the placement of the objects on scratch pad.

As the positions changing of virtual objects on the virtual scratch pad are difficult to do, using rubber and copy/transportation paddles, it was implemented a new paddle only for transportation virtual objects on the scratch pad. This improvement has simplified the authoring work, once the user can select and copy virtual objects from the catalog, so that he/she can arrange them later using the transportation paddle.

6 CONCLUSIONS

Augmented reality applied to educational environments can contribute in a significant way to the users' perception, interaction and motivation.

This paper discussed collaborative environments with augmented reality and stressed that it is possible to create collaborative environments, through the use of the ARToolKit software and communication resources operating over computer networks. Such collaborative environments are very useful to stimulate the learning and the development of abilities in group. The work also pointed out network problems and ways to overcome the existing difficulties.

Using an application related to authoring of virtual environment with a toll based on augmented reality, the paper showed that this technology can be applied in a powerful way, giving to users many functionalities and options to operate on virtual objects on real world using the hands and markers.

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