REMOTE COLLABORATION WITH AUGMENTED AND VIRTUAL REALITY INTERFACES

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Abstract ***Some applications require a person in a remote location (the trainer), to instruct another person (the trainee) on how to put together a number of objects according to a precise set of spatial relationships. In this paper we report the results of using a collaborative Mixed Reality application that allows the trainer to manipulate the virtual objects in a virtual environment. At the same time, the trainee observes the virtual object manipulation as means to move the real objects accordingly. The trainer uses a Virtual Reality interface and the trainee uses an Augmented Reality one. The results show that, even though the time to complete the task using the application is longer, users perceive that collaboration using a similar application in the real world could make collaboration easier.***

Keywords: Mixed Reality, Virtual Reality, Augmented Reality, Computer Supported Collaborative Work, Networked Mixed Reality.

1 Introduction

In a globalized world, it is common for a trainer and a trainee to be located in remote places. Collaborative applications have been built to allow remote users to manipulate virtual objects in Virtual Reality (VR) environments, whether in immersive settings or not. In purely virtual applications, users need to transfer the learning that happens in the virtual environment into the real environment. With the advent of Augmented Reality (AR), it is possible for the user to perceive a combination of virtual and real objects in real time. We make use of this feature to allow the trainee to see a virtual object, manipulated remotely by the trainer, imposed over the real world. This concept could be used in real life settings such as:

- Placement of furniture when people move to a new place or office.
- Directions to leave buildings in case of emergency situations.
- Collaborative AR games.
- Directed museum visits.

In section 2 we describe similar research and how ours is different. Our application is described in section 3. Section 4 describes the experiments we conducted to test our application and the results we obtained. Finally, the conclusions and future work are described in section 5.

In this paper, the person directing the placement of the objects will be called the trainer and the person locating the real objects, following the indications of the trainer, will be called the trainee.

2 Related Work

Numerous distributed Virtual Reality and Augmented Reality applications are being developed in research settings, and deployed in industry applications. But there are very few applications that combine virtual reality with augmented reality in a single distributed application.

Azuma [1][2], reports a number of Augmented Reality applications that are being deployed in industry environments. Brooks [3] described, in 1999, a considerable amount of applications that were used in the real world, as well as the innovations that were necessary for new applications to become feasible. The magic book [4], built around the AR Toolkit describes a technique to display AR or VR graphics to a user reading a book with special markers. Schmalstieg and others have pioneered the work on distributed augmented reality systems [5][3] using the StudierStube in a variety of applications. Not much has been written on usability of Virtual and Augmented reality systems. Distributed Virtual Reality has been used successfully for supporting distance learning [6][7]. Our work follows the techniques described by Hix and others [8], in terms of user-centered design. The usability issues of the current implementation of our system have a large impact on the user performance and in the results reported in this paper.

3 Our approach: the AVRCS system

In order to test the combination of collaborative Virtual Reality and Augmented Reality, the AVRCS (Augmented and Virtual Reality Combination System) was built. In AVRCS a virtual World is maintained in a server. The trainer moves the virtual objects according to a desired plan (see Figure 1). A user in a remote client computer watches the moving virtual objects in an Augmented Reality setting and moves the real objects accordingly (see Figure 2). The trainer communicates with the trainee through visual commands.

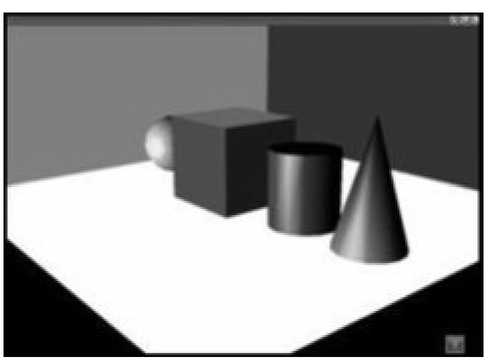

Figure 1: The trainer moves the objects in a VR environment on the server machine.

The software was developed using JAVA3D [9], an API of the Java language for manipulation of virtual environments, and JARToolkit [10], an API used for

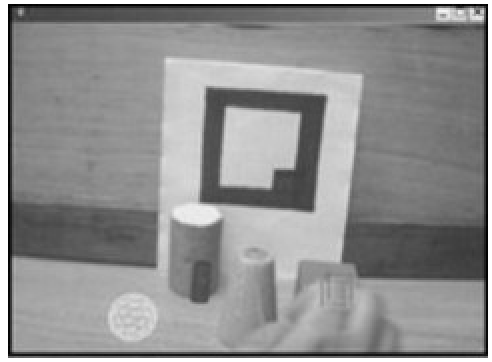

Figure 2: The trainee observes the virtual objects imposed over the real ones on the client machine.

Augmented Reality written in Java and based on the AR Toolkit. The tracking is, therefore, optic. Tracking takes place as the program recognizes the patterns that are captured trough a web cam located on top of the Head Mounted Display of the user. The position and orientation of the user's head is computed then relative to the pattern.

The client-system application allows for more than one simultaneous client. Several clients could work on their own virtual spaces.

The trainer uses the mouse for manipulating the virtual objects. The trainee, on the other hand, has two options to accomplish the task:

1. The trainee can use a static camera that takes the image of the real world with the real objects, he/she watches the augmented objects on the screen imposed over the real objects. (see Figure 3).

Figure 3: Combination of real and virtual objects takes place using a static camera.

   This option does not allow for different views of the real world. It is adapted for a small space.

2. The trainee can use an HMD with an attached

webcam, allowing him/her to move around the real World observing the combination of real and virtual objects from various points of view (see Figure 4).

Figure 4: The trainer uses an HMD with a webcam.

Using the second option (HMD plus webcam), the user can move in the real world. But due to parallax (the webcam is located various centimeters over the user's eye), it takes some time for the user to adjust to the new view. This makes the picking and positioning of real object somewhat more difficult in the beginning. Additionally, when there are no markers on the camera's point of view, the AR system stops displaying the virtual objects.

The choice of hardware directly affects the operation of the system: The type of connection, the camera resolution and the computing and graphical power of the client and server machines. These factors affect the usability of the system and therefore, users' performance.

4 Experimental Setup

The principal objective of the work described in this paper is to determine if remote collaboration is easier with a system we have built, and determine if the times and exactitude get better when compared to a face-to-face environment based on verbal communication. For this purpose, the experiments described next were conducted.

1. **Experimental Group: Remote collaboration using AVRCS**

   The trainer uses the server machine running the VR Environment. The trainee runs the AR application on a client machine. Firstly, users were given several minutes to get used to the system (the trainer moving objects in the virtual world, and the trainee placing objects in the real world).

   A sketch of the distribution of the objects was then provided to the trainer, and the chronometer was started in order to count the time it takes for the trainer to distribute the objects in the VR environment, following the sketch (this time is called *it*: for indicator's time). At the same time, the trainee begins locating the real objects and another chronometer is set to count the time it takes for the trainer to finish placing the objects (this time is called *st*: setter's time).

   Both times were recorded and a record was taken on how close the real objects were placed by the trainee. Since 4 objects were used in the experiment, a number of 4 meant all objects were correctly placed, 1 meant only 1 object was placed correctly.

2. **Control Group: Face-to-face collaboration**

   In this case, the trainer is provided with a 2D sketch with the desired position of the objects. The trainer instructs the trainee, with voice commands, to move the real objects until they coincide with the positions described in the sketch. The chronometer starts when the trainer receives the sketch and finishes when they decide that the objects are correctly placed. The trainee can only follow the trainer's commands, he/she cannot see the sketch. The number of correctly placed objects is also recorded.

Each subject pair was given a different sketch for placing the objects.

Current results and observations of the experiments suggest that the trainer and the trainee have to come up with a communication protocol in the face-to-face trial. Frequently, the trainer's commands are not precise, misleading the trainer. It's hard for the participants, for instance, to remember the exact name of the objects that are being used in the experiments, so the trainee gets confused while the indicator tells him/her about an object. In order to avoid this problem the trainers used features to identify objects uniquely, but had problems when two objects were very similar. For example: in the experiments, the participants confused a cone with a triangle, a sphere with a circle, back with up and front with down. The amount of objects used in the experiment was small, different results may arise in the presence of more objects or objects that are not so easily described with words. This situation may reflect the operation of a complex machine in a real world setting.

On the other hand, in the case of the computer-mediated-collaboration, the use of a verbal protocol was not necessary. The trainer only needs to move the virtual objects according to the sketch and the trainer only needs to place the real objects as close as possible to the positions of the virtual objects in the AR system. A feature-based description of the objects was not necessary.

The results of the experiments are analyzed next. Firstly, the times to complete the task (*tct*) and the number of correctly placed objects are described. Then some of the users' perceptions of the application are recounted.

Times to complete the task and number of correctly placed objects: Table 1 and Figure 5 show the results of the times to complete the task using the application (Ttc) and without the application (face-to-face) (Tts). The time to complete the task in the face-to-face case is smaller. We think this large difference is due to the fact that the number of objects is very low and objects are very different from each other, making their identification through verbal commands very simple.

Table 1: Time to complete the task.

	Ttc	Tts
Count	15	15
Average	75.582	46.6953
Variance	1346.09	403.435
Standard deviation	36.6891	20.0857
Minimum	34.15	18.69
Maximum	137.81	80.0
Range	103.66	61.31
Stnd. skewness	0.724092	0.281411
Stnd. kurtosis	-1.02978	-1.07785

Table 2 and Figure 6 compare the number of placed objects using the application (Nc) and without using the system (Ns). Results show that the location of the objects is less precise when the trainee

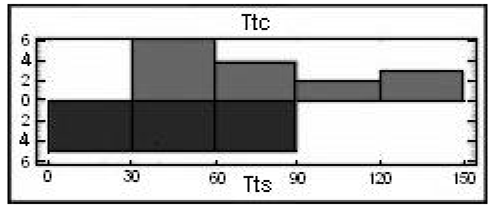

Figure 5: Times to complete the task using the application (Ttc) and in the face-to-face setting (Tts).

uses the AVRCS system. This seems to be related to the difficulty to perceive the depth in the presence of the AR application, since the virtual objects always occlude the real ones. In order to compensate for this occlusion problem, virtual objects were rendered in their wire-frame representation. But nevertheless, the relative size of the real and virtual objects seems to be a stronger indication of their depth, leading to misplaced real objects.

Table 2: Number of correctly placed objects.

	Nc	Ns
Count	15	15
Average	3.06667	3.93333
Variance	1.06667	0.0666667
Standard deviation	1.0328	0.258199
Minimum	1.0	3.0
Maximum	4.0	4.0
Range	3.0	1.0
Stnd. skewness	-0.945266	-6.12372
Stnd. kurtosis	-0.785954	11.8585

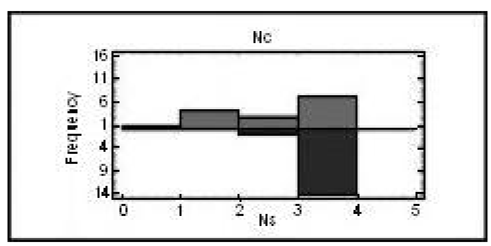

Figure 6: Number of correctly placed objects using the application (Nc) and in the face-to-face setting (Ns).

Perception of the participants used AVRCS system: A survey was conducted with all the individuals that were part of the experiment, with the following results.

- Table 3 and Figure 7 show the users appreciation of the system usability. The majority of people that participated in the experiment did not have any previous experience with other virtual systems. Nevertheless, 70% of the population considered that the system was easy to use. Out of them, 20% had previous experiences with VR systems. 10% of the users think that the application is very easy to use. Out of them, 3,33% had previous experience with VR systems.

Table 3: Usability of the system.

Frequency Table for Facil_Uso_I by Experiencia_I

	no	si	Row Total
2	1 3.33%	1 3.33%	2 6.67%
3	1 3.33%	3 10.00%	4 13.33%
4	15 50.00%	6 20.00%	21 70.00%
5	2 6.67%	1 3.33%	3 10.00%
Column	19	11	30

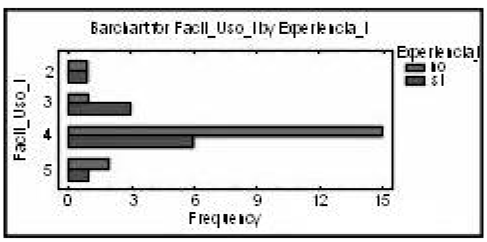

Figure 7: Perception of usability and previous experience with VR systems.

- Users perceive that the application makes remote collaboration easier. Users liked the application better than using gestures or words. (see Table 4, Figure 8).

Table 4: Perceived easiness for collaboration.

Summary Statistics for Facil_Remoto_I

Count = 30
Average = 4.2
Variance = 0.303448
Standard deviation = 0.550861
Minimum = 3.0
Maximum = 5.0
Range = 2.0
Stnd. skewness = 0.237227
Stnd. kurtosis = 0.108991

- The acceptance of the remote collaboration and the traditional mode was not distributed normally, and in the same way the perceptions of times and precise location; so there were a tendency of neutrality for the questions. Young people approve more the remote collaboration than aged people because they are more involved with technology.

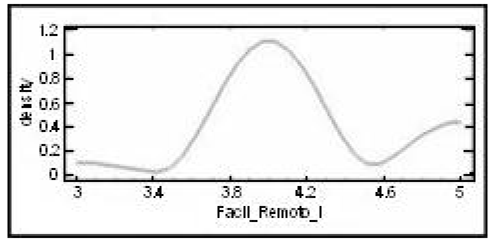

Figure 8: Perceived easiness for collaboration.

5 Conclusions and Future Work

It is necessary to conduct new experiments with larger amount of objects and with more complex relationships amongst them. This may lead to a better performance of subjects using the application.

The use of HMDs seemed to affect the performance of the subjects using the system. They seemed to perform better using the regular screen setting. Additionally, lower frame-rates seemed to affect the performance of the trainee.

The largest difficulty seemed to be the fact that virtual objects always occluded the real ones. Occlusion is known to be a difficult problem to solve in AR systems. The solution would be to track the physical objects in order to determine their actual position, perhaps with the user of smaller markers or through artificial vision techniques.

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