Usability in Virtual and Augmented Environments: A qualitative study

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Abstract

Virtual and Augmented reality are developing rapidly: there is a multitude of environments and experiments in several laboratories using from simple HMD visualization to more complex and expensive 6-wall projection, CAVEs, and other systems. Still there is not yet a clear emerging technology in this area, nor commercial applications based on this technology are used in large scale. In addition to the fact that this is an emerging and relatively recent technology, there is little work to validate the utility and usability of these Virtual and Augmented environments when compared with traditional desktops. However, usability evaluation is crucial in order to design better systems that respond to the users' needs, as well as for finding applications that can really gain from the use of these new technologies.

In this short paper, we present a preliminary qualitative usability study of a Virtual and Augmented Reality environment under development at the University of Aveiro. The main goal is to find clues on how to develop better evaluation methods for systems based on AR/VR technologies.

Key words

Virtual Reality, Augment Reality, Usability, Evaluation.

1. INTRODUCTION

Virtual Reality (VR) is an important emerging technology with applications in many different areas, such as automobile industry, civil engineering, aeronautics, medical science, education and entertainment.

In VR, as for any other product or system, designers should consider usability issues: the ability to carry out tasks effectively, efficiently and with satisfaction by their intended users [Marsh99]. That is, design systems as simple and usable as possible. Although VR technology has improved in the last few years, it is still necessary to define methods and parameters to test and evaluate the usability of those systems during their development and implementation cycle [Paelke00]. If usability evaluation tools, methods, and techniques are well defined for 2D environments, there are relatively few for the evaluation of 3D Virtual and Augmented Reality systems [Marsh99].

It is a common idea that technology and Virtual Reality systems can facilitate the execution of tasks. But, if they are not well designed, users will face usability problems, such as motion sickness, difficulty of navigation or spatial disorientation [Ware00][Smith04]. Furthermore, there are other problems specific to these technologies: high cost, performance and availability of software, database management, input and output devices, data visualization, mathematical description and representation of physical processes. Due to all these limitations, many experts still find traditional desktop systems easier to use than virtual systems [Demiralp06]. Usability evaluation also faces another problem: few companies are interested in investing money and resources to evaluate usability; this may result in systems that are not adapted to intensive work and are used only due to innovation or curiosity without providing any real benefit.

The work described here is a first step towards evaluating the usability of a low cost Virtual and Augmented Reality environment under development at the University of Aveiro [Moreira05]. This is a generic prototype for exploration of three-dimensional models and data that uses a head-mounted display (HMD), a video camera, orientation sensors and an accelerometer.

2. TEST ENVIRONMENTS

Our environment can be used in two different modes: Augmented and Virtual Reality. In what follows we describe the experiments and applications developed to test both modes. Results are then presented in section 3 for the Augmented Reality environment. The Virtual Reality experiment we describe is still under development.

2.1 Hardware

The hardware consists of a HMD *i-glasses SVGA Pro* with resolution of 800x600 pixels, an orientation sensor (tracker) *InterTrax 2* from *InterSense* with three degrees of freedom (yaw, pitch and roll) (Figure 1).

For the Augmented Reality environment, the Virtual Reality hardware was adapted by simply adding a camera to the system. The use of a HMD with a micro camera mounted on it prefigures video see-through Augmented Reality applications.

The camera used is a wireless analog micro-camera with a CMOS sensor of approximately 330 lines, working at 1.2GHz. Given the small dimensions and weight of the camera, it was possible to mount it directly at eye-level on the HMD and power it from a 9V battery.

Figure 1: HMD with tracker and micro-camera

2.2 Augmented Reality

Augmented Reality (AR) environments combine real scenes with scenes generated by the computer, making possible the visualization of data, models and meta-information [Pan05]. The AR setting used in this work is the most common one: Video See-Through, which uses a conventional HMD to render Virtual elements on the images captured by a camera.

Our experiment consists in showing to different users data from their own field of expertise within an Augmented Reality environment. Two different configurations are used: in the first one, called AR (Augmented Reality), the user sees, through the HMD, virtual models or data aligned with a real marker (a black square with known geometry) captured by the camera. In the second one, called AD (Augmented Desktop), the same augmented models or data are shown in a desktop display and the view is updated according to a hand-held video camera the user can move around the markers.

Our Augmented Reality prototype uses the ARToolkit [Billinghurst99]: a graphical toolkit capable of detecting the orientation of markers in a scene and render virtual objects according to the orientation and position of the markers. The orientation of the camera is also extracted directly from the analysis of the known markers. For the processing and representation of different types of 3D data available, since ARToolkit only provides rendering of VRML models, we use The Visualization Toolkit (VTK) [Schroeder98]. This toolkit is useful since it offers hundreds of classes for the manipulation and visualization of 3D data, import of models and interaction with devices. Basically, we used ARtoolkit only to extract the camera pose from the images and render the object correctly according to the marker in VTK. This configuration provides much more flexibility and allows testing several different datasets and visualization methods with minimal effort.

2.3 Virtual Reality

The VR test environment is an immersive game, which consists of corridors defining a maze in which the player has to navigate. In order to complete the game, the users have to get 21 objects in a pre-defined period of time, which is 5 minutes. The Virtual Reality environment (VR) uses a HMD for display, mouse buttons and orientation sensors for interaction. The environment that is going to be compared with the virtual environment is a traditional desktop environment (VD), where the user plays the same game using mouse and keyboard as interaction devices and the desktop display.

Regarding the VR software, most of the programming was done in C++ using OGRE [OGRE], a well-known open-source rendering engine. Some additional code was written to perform collision detection and counting/recording of events within the game. The user interface is similar in both Desktop and Virtual Environments. The mouse/tracker is used for the orientation of the head (where the player is looking at), whereas the mouse buttons/arrows of the keyboard are used for the movements inside the maze (where the user goes). This experiment is still under development.

3. USABILITY STUDY

3.1 Experiment Description

The first experiment consists in the visualization of data from a mechanical model of water flow around a ship hull. The pressure at each point is mapped through colour, and arrows are used to represent the velocity of the water around the ship hull (see Figure 2).

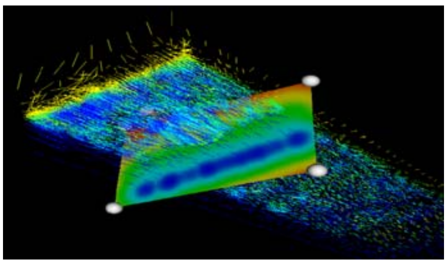

Figure 2: The water-flow data set.

We use four different representations of the same data to provide the users with several viewpoints and scaling factors to make visualization easier:

- The complete data viewed from above;
- A scaled version of a sub-set viewed from the side (corresponding only to the main area of interest);
- The same sub-set viewed from above;
- The sub-set without any marker and camera image, having a totally black background.

Those four different representations were visualized in the Augmented Reality (AR) and in the Augmented Desktop (AD), in order to compare the differences between these two environments and assess which one provides better manipulation, orientation and/or image visualization for the users.
The eight stages of the experiment are presented in Table 1.

1.	AR with complete data viewed from above
2.	AR with sub-set data viewed from the side
3.	AR with sub-set data viewed from above
4.	AR without markers (only data was represented)
5.	AD with complete data viewed from above
6.	AD with sub-set data viewed from the side
7.	AD with sub-set data viewed from above
8.	AD without markers

Table 1: Different conditions of the experiment

The experiment started with the AR environment and then proceeded to AD, since we expected users would prefer the AD due to the better image resolution and contrast of the desktop display.

The AR experiment is presented in Figure 3. The user sees the model lying on the marker and can interact easily by moving the head as well as the marker to change the viewpoint. Figure 4 is a screenshot of the monitor in AD mode. In this experiment, the user holds a camera in his hand and moves it around the marker to change the viewpoint while observing the updated image in the monitor.

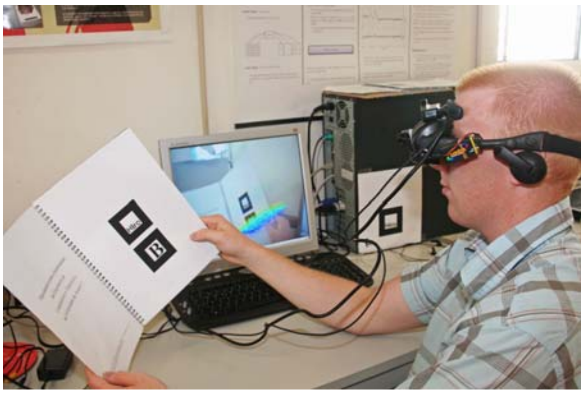

Figure 3: The AR experiment with a clone copy of the image seen by the user on the monitor.

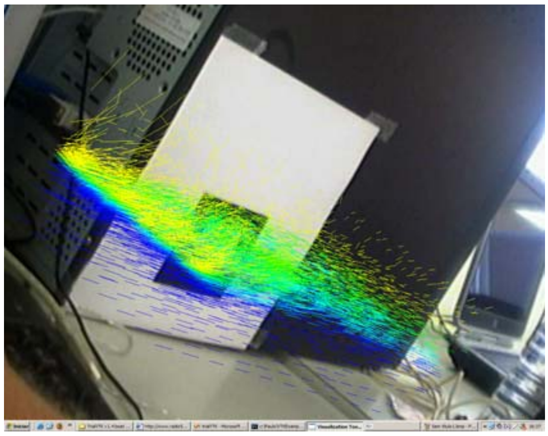

Figure 4: The AD experiment: image captured by the hand-held camera and projected on the monitor.

3.2 Evaluation Methods

In this experiment, we used a qualitative evaluation: users were asked to use the application and then express their opinions by talking to the evaluator while or after they are performing the tasks. The evaluator can comment and counterargument, but at the end users state their overall preferences.

3.3 Participants

Two application domain users were invited to test the eight situations listed above. One is a Professor at the Department of Mechanical Engineering at the University of Aveiro, and the other is a doctoral student. They are both male and it was their first contact with a virtual environment.

3.4 Results

First of all, we were surprised with the positive response of the participants perhaps this was due to the enthusiasm of using a new and attractive form of visualization. Users showed great interest in the application, suggested some improvements and proposed future work with other kinds of data sets.

When the experiment was designed, we expected the users could get lost on the fourth and eighth experimental condition (with no background), since there are no markers to guide them, which was not the case since users found that manipulation of the marker was intuitive enough.

Concerning manipulation and orientation issues, both users concluded that the Augmented Reality environment (AR) with HMD was more intuitive than the Augmented Desktop (AD).

On the other hand, AD was found better than AR regarding the data visualization, due to better resolution and contrast, a result that we already expected.

To conclude the experiment we asked the user suggestions on how to improve the system. The more relevant are:

1. The possibility to navigate inside the model in a totally immersive Virtual environment;
2. A pointer to indicate specific data features to other users;
3. An option/button that would allow the user to zoom in or out the data;
4. Although they did not get lost on the fourth and eighth experiments, they suggested displaying a thin square representing the border of the marker to help its localization without disturbing the viewing of the data.

Their overall conclusions were that for short periods of time, as when somebody wants to show something to a user that is not used to this kind of data/systems, the Augmented Reality (AR) makes data manipulation easier since the HMD interaction is more intuitive. However, for long periods of work the Augmented Desktop (AD) environment could be better than the Augmented Reality (AR), because the visualization is more precise and less tiring.

As a consequence of users suggestions, two additional experimental conditions were implemented. One adds a virtual thin white line around the marker in the fourth and eighth experimental condition. The other shows the camera image instead of the black background, when the user loses sight of the marker. Finally we also added stereoscopic vision.

These modifications were presented to the same users. The results were that the thin square does help to manipulate the object without losing sight of the marker, but when it disappears from the camera field of view, seeing the real image helps to find the marker faster. So the users preferred to combine the two suggested situations.

Regarding stereoscopic vision, although the users think it can add interesting information, it does not produce a significant improvement in this particular data set (probably because it was a vector dataset). The setting of the distance between eyes was relevant since one of the users had great difficulties to sense depth until this distance was set to a smaller value [Ware00].

4. CONCLUSIONS AND FUTURE WORK

The technology of Virtual Reality is still a challenge to outdo. The image contrast and resolution are still much better in a desktop display, which is also less tiring compared with the HMD. The main advantage of the Augmented Reality in our experiment was the natural and easy interaction when compared with the hand held camera: the user looses sight of the marker more often in this latter configuration.

Even though this work is still in an early stage, some additional experiments involving brain and lung data and domain expert users have been conducted with similar results to the ones described before.

In the VR case, some tests comparing the virtual and desktop environment have been performed. The evaluation methods used were a combination of qualitative and quantitative studies. On the qualitative study, as in the Augmented Reality experiments, the evaluator asked the user's opinion, while the quantitative study measured variables, such as time, number of collisions and falls, speed, distance covered, and objects caught.

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