Chapter 15

Virtual Environments for the Training of Visually Impaired

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15.1. Introduction

In recent years researchers have started developing force feedback interfaces, which permit blind people not only to access bi-dimensional graphic interfaces (as was the case until now), but in addition to access information present on 3D Virtual Reality interfaces anticipating that the latter will be the natural form of information interchange in the very near future [1].

The greatest potential benefits from virtual environments (VE) built into current VR systems, are in such applications as education, training, and communication of general ideas and concepts. The technical trade-offs and limitations of the currently developed VR systems are related to the visual complexity of a VE and its degree of interactivity [1,2].

The present paper presents the applications developed for the feasibility study test developed in the Informatics and Telematics Institute for the EU IST project ENORASI. The main objective of the ENORASI project is to develop a complete training system for the blind and visually impaired based on haptic virtual reality (VR) techniques [3,4] the challenging aspect of the proposed VR system is that of addressing realistic virtual representation without any visual information.

In ENORASI our intention is to combine haptic and sound information in such a way as to improve the possibilities for a blind person to obtain overview. By using the computer (and a 3D computer generated world) we may dynamically link the sensation of feeling with sound in ways, which are difficult/impossible with real world models [5,6].

The purpose of this paper is to present measurable results and derive qualitative and quantitative conclusions on the added value of an integrated system aiming to train the blind with the use of virtual reality, based on the CyberGrasp haptic device. The CyberGrasp haptic device [7] was selected, based on its commercial availability and maturity of technology. In this paper we have developed a number of custom applications (the Feasibility Study tests) and specific software to support the communication of the applications with the peripheral devices and also integrated a new collision detection algorithm (based on RAPID [8] and PQP [9]) in the VHS software library [10] for the CyberGrasp haptic device, in order to improve the performance of the whole system.

Figure 15.1.1 : CyberGrasp haptic device.

The above steps were deemed to be sufficient in order to develop and provide a pilot environment which offers adequate functionality for end users to familiarize themselves with the technology and being able to judge its potential and usefulness. Eight test categories were identified and corresponding tests developed for each category.

15.2. Feasibility Study Tests

The CyberGrasp feasibility study included 26 users from Greece. Each test took approximately 2 hours (including pauses). The test was preceded by a one-hour pre-test that was held the day before the test, in which the users were allowed to get acquainted with the haptic system. The motivation for this pre-test was that the ENORASI system is expected to be a system used more than once by the users. The purpose of the feasibility study was not to test the initial reaction of a user to a haptic system. Rather, the idea was to try to obtain information about the use of such a system by a user who is somewhat familiar with the use of haptics. The pre-test consisted of simple shape recognition tasks, manipulation of simple objects and navigation in the haptic virtual environment using cane simulation.

The tests were implemented by developing custom software applications and their parameters were tuned in two pilot tests performed with users. The majority of the tests in the feasibility study were divided into parts. Those subtests were chosen to include tests on similar tasks but with varying expected level of difficulty into the study. The reason for this design approach was that we wanted to use the work put into the feasibility study not only to show that the ENORASI system is feasible, but also to gather information useful in the design of the final system. E.g. a test could consist of an easy task, a middle level task and a complicated task. In the beginning the test sets (below) were designed on this line, but due to time constraints some test tasks were removed after the pilot tests.

Test setup

These are the layouts of the test equipment used for the CyberGrasp tests.

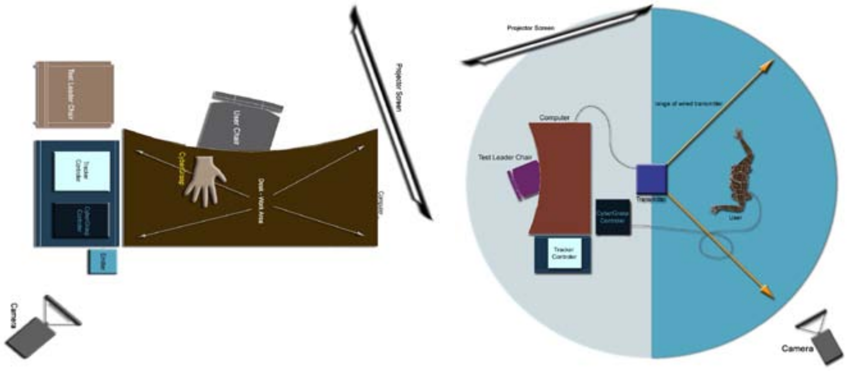

Figure 15.5.2 : Desk and cane simulation setup

Aside from the material shown in Figures 2, tests 1 and 5 used physical models as will be seen in the test descriptions. The backpack for the CyberGrasp haptic device has also been used for tests 7 and 8.

Test 1 : Simple objects test

The user is navigating in a constrained virtual environment (VE) containing geometrical objects. The goal for the user is to recognise the objects and reconstruct the VE using real geometrical objects. FS goals include recognition of shape, knowledge transfer and understanding scale.

Specifically, the VE consists of a table with a number of geometrical objects of different shapes placed in a pattern on a virtual table. On the adjacent desk, there is one box with a number of physical representations of different geometrical objects. The user should feel the virtual environment and try to reconstruct it using the physical models. After completion, the test leader takes a picture of the result, for later analysis (Figure 3). Then, the user is informed of the correct placement of the objects.

Figure 15.2.3 : Geometrical objects in a pattern test.

Test 2 : Object grasping and manipulation test
The user should explore the VE, find the number of objects in it, recognise them and then grasp a pre-selected object and move it to a specific position. Feasibility study goals include recognition of shape, object manipulation into virtual environments, understanding scale and knowledge transfer.

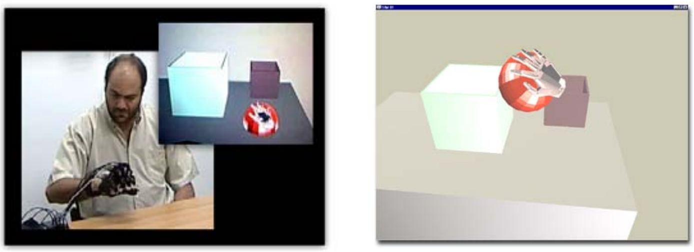

Figure 15.2.4 : A user exploring the VE of Test 2 (Object grasping and manipulation)

The VE consists of a table with three objects (a ball and two empty baskets of different size). One of the baskets is two times bigger than the other. The goal of the user is to find the ball, grasp it and put it into the bigger basket on the table (Figure 4).

During the test, the user is asked to feel the virtual models and recognize the ball and the two baskets. He/she should understand the size of the objects and also be able to tell how many times one of the baskets is bigger than the other. This is important, in order to show that scale estimation is possible in virtual environments and also that users can estimate size and scale using only one hand. Finally, he/she should grasp the virtual ball and put it in the bigger of the virtual baskets.

Test 3 : Map test
The maps are representations of house floor plans. The user has to explore them and find certain rooms. Sound feedback is provided when the user presses the floor of each room. Feasibility study goals include navigating in complex environments, knowledge transfer, understanding scale and interacting with haptic user interface components.

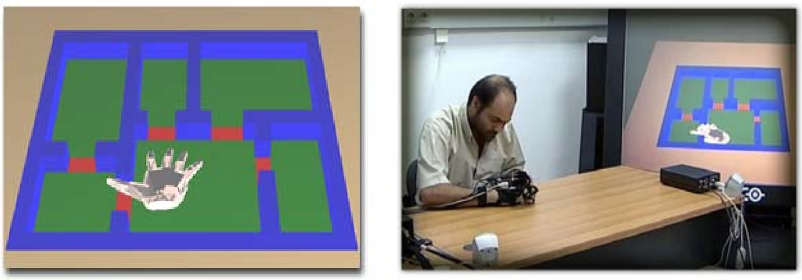

Figure 15.2.5 : A user performing the map test.

Test 3.1- Flat with 4 rooms, kitchen and hall

The virtual environment consists of a map placed on the floor. The walls are thick and high enough so that the user can identify the difference between the wall and the floor. In the door openings, there is a very thin ridge a lot lower than the walls, to enable the user to feel the difference between walls and doors (Figure 5). When the user presses the floor of a room, he/she hears an audible message informing him/her in which room he/she is at the moment. When the user presses the floor again he/she will not hear anything until he/she enters another room.

The user should use a maximum of 7 minutes to explore the map. When the user feels to have an “overview” of the flat, he/she should state the number of rooms that he/she thinks there are in the flat. Following that, the user should use a maximum of 7 minutes to show to the test leaders the relative position of the rooms in the flat and additionally find and accurately follow the walls and the doors.

Test 3.2 – Flat with 4 rooms, find a specified room

If the user needs to walk through the flat again, he/she may explore the flat for less than 2 minutes. When finished, the user should be able to find a specified room, walking from the hall to the room directly. He/she should show this by pressing the floor in the hall, and then go to the specified room and press the floor there. He/she should not press the floors on the way to the room.

Test 4 : Mathematics test

The user works with an illustrative mathematics example designed to teach students mathematical graphs in 2 dimensions. Feasibility study goals include edutainment – use a mathematical educational system and knowledge transfer.

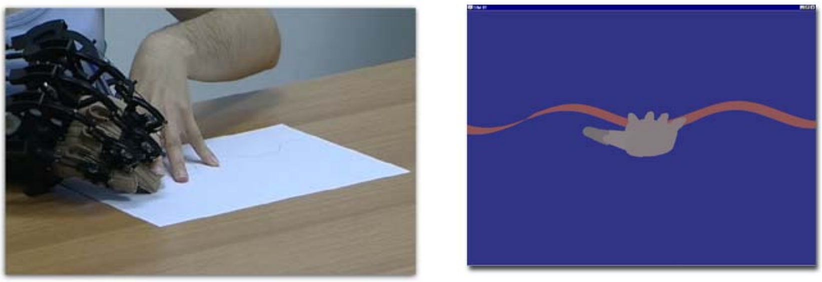

Figure 15.2.6 : A user plotting the curve in the mathematics test

Test 4.1- A sinusoid

The user rests his/her hand on a box located in front of him/her on the test table and the geometrical shape of a specific waveform is passing under his/her fingers (vertical forces are applied to each finger based on the shape of the waveform). A sine of a specific frequency is first simulated by the system (Figure 6). The user is asked to leave his/her fingers relaxed and let the device control his/her fingers without applying any resistance to it. Based on the movement of the fingers the user is asked to guess the shape of the waveform.

The user should use a maximum of 3 minutes to feel/recognise the curve that is transferred to his/her fingertips by the system. When the user feels that he/she has understood the shape of the curve, he/she should describe it and try to plot it on a white paper.

Test 4.2 – A sinusoid with lower frequency

The frequency by which the sinusoid waveform passes under the user's fingertips decreases and the user is asked if he/she felt any change and what could this change be. The user is again asked to plot the curve.

Test 5 : Object Squeezing Test

The user should examine a ball in the virtual space, understand its physical characteristics – specifically, its elasticity and stiffness - and correspond each of the states of the ball with a real object. Feasibility study goals include interacting with virtual objects and understanding their physical properties and knowledge transfer.

Figure 15.2.7 : A user performing the object squeezing test.

The user grasps a virtual ball and squeezes it. The physical characteristics of the virtual ball can be modified, by changing its stiffness and dumping parameters. This is controlled by the test leader, with the press of a button. Initially the ball is very soft (state 3) and the user can squeeze it until a specific point, then it becomes harder to squeeze (state 2) and finally it becomes almost impossible to squeeze (state 1). The four real balls are in a box on the desk (Figure 7). Ball 1 is a well-inflated small basket-ball; ball 2 is a less inflated plastic ball; ball 3 is a deflated small soccer ball, and ball 4 is a ball made of sponge.

The user should use a maximum of 4 minutes to examine the virtual ball in all different states. The test leader then changes the characteristics of the ball and the user is asked to describe in detail what does he/she think the ball is made of. Finally, he/she is asked to match each virtual ball with its corresponding real ball lying on the desk.

Test 6 : Athletic Event Simulation – Target Shooting

A game-like program has been developed for simulating the participation of a user into an athletic event. Two versions of target shooting for the blind were simulated and evaluated by the users. Feasibility study goals include, edutainment – participation into a virtual athletic event, interacting with haptic user interface components and knowledge transfer.

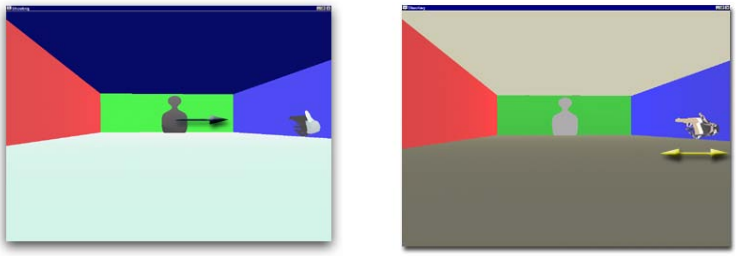

Figure 15.2.8 : Target Shooting-Tests 6.1, 6.2

Test 6.1- Target shooting using 3D sound

The user grasps a virtual gun, which fires when you pull its virtual trigger. The virtual gun is supposed to be grounded, i.e. changes in the position and orientation of the hand of the user do not affect the position and orientation of the virtual gun (Figure 8). The user can move his/her arm freely, but only grasping and finger movements are affecting the operation of the system. The goal for the user is to shoot the target, which comes from left to right. A 3D sound is attached to the target, which indicates the correct timing for shooting the target (i.e. the sound comes from left to right and the user should fire when the sound approaches the center).

A shot is considered successful by the system if the user pulls the trigger at an instance differing by less than ±7% from the optimal position. The user is asked to shoot 10 targets and the score is recorded. The objective of this test is to show that 3D sound can be used as an accurate positioning and orientation cue for visually impaired people while force feedback can effectively assist user immersion into the virtual environment. The score of the task is recorded by the system.

Test 6.2- Target Shooting for the Blind (Simulation of "Special Olympics" Target Shooting Event)

The user grasps a gun, which fires when he/she pulls its virtual trigger. The user cannot move the virtual gun but he/she can rotate it around an axis perpendicular to the floor, passing from his/her wrist. In this test, changes in the position and orientation of the hand of the user affect only the orientation of the virtual gun (Figure 8). The orientation of the virtual gun is converted to a sound frequency, which increases as the gun approaches the direction of the target. Again the sound indicates the correct rotation angle for shooting the target.

A shot is considered successful by the system if the user pulls the trigger at an instance differing by less than ±7% from the optimal position. The user is asked to shoot 10 targets and the score is recorded. The objective of this test is to show that sound frequency can be used as an accurate positioning and orientation cue for visually impaired people, while force feedback can effectively assist user immersion into the virtual environment.

Test 7 : Cane simulation test – Outdoor environment

The user is asked to cross a traffic light crossing using a virtual cane. Sound and haptic feedback are provided by the system upon collision of the cane with the virtual objects. Feasibility study goals include navigating in complex environments, cane simulation, edutainment, knowledge transfer and interacting with haptic user interface components.

The user is standing at the beginning of the test room wearing the CyberGrasp and a waistcoat for carrying the Force Control Unit (FCU) for the CyberGrasp. When the test starts, the user is asked to grasp the virtual cane. The parameters of the virtual cane (size, grasping forces, collision forces) are adjusted so that the user feels that it is similar to the real one. After grasping the cane the user is informed that he is standing in the corner of a pavement (Figure 9). There are two perpendicular streets, one on his/her left side and the other in his/her front. Then he/she is asked to cross the street in front of him/her.

Figure 15.2.9 : Cane simulation - Outdoors (user wearing the CyberGrasp back-pack).

The user should walk ahead and find the traffic light located at about one meter on his left side. A realistic 3D sound is attached to the traffic light informing the user about the condition of the light. The user should then wait close to it until the sound informs him/her to cross the street passage (green traffic light for pedestrians). When the traffic lights turn to green the user must cross the two meters wide passage until he/she finds the pavement at the other side of the street. It is also desirable that the user finds the traffic light at the other side of the street.

Test 8 : Cane simulation test – Indoors environment

The user is asked to navigate into an indoor environment using a virtual cane. Sound and haptic feedback are provided by the system upon collision of the cane with the virtual objects. Feasibility study goals include navigating in complex environments, cane simulation, edutainment, knowledge transfer and interacting with haptic user interface components.

Figure 15.2.10 : Cane simulation – Indoors (user wearing the CyberGrasp back-pack)..

The user is standing at the beginning of the test room wearing the CyberGrasp and a waistcoat for carrying the Force Control Unit (FCU) for the CyberGrasp. When the test starts, the user is asked to grasp the virtual cane. The parameters of the virtual cane (size, grasping forces, collision forces) are adjusted according to the characteristics of his/her cane. The goal for the user is to find the second door on his/her left side and enter the room (Figure 10). There he/she should find a chair. During his/her walk the user should find successively the wall on his left side, the first door where he/she is not supposed to enter, the wall of the second room and the door where he/she is supposed to enter. After entering the room he/she should find the chair located in his right side. We have also performed the same test without sound feedback.

15.3. Results and Feasibility Study Conclusions

Twenty-six persons participated in the tests from the Local Union of the Panhellenic Accosiation for the Blind in Greece. The users were selected so as to represent the following groups: blind from birth, blind at a later age, adults, and children.

Test	1.1	1.2	2.1	3.1	3.2	4.1	4.2	5.1	6.1	6.2	7.1	8.1	8.2
Av. Time (min)	4,6	12,8	8,8	10,69	1,26	-	-	5,88	-	-	2	1,96	1,9
Success Ratio(%)	100	92,30	100	96,20	100	100	100	100	100	100	100	96	96,20
Percentage of users needing guidance (%)	7,70	26,90	15,38	15,38	3,80	-	-	-	-	-	-	3,80	3,80
Difficulty 1=very easy 5=very dif.	1,9	2,8	2,1	2,15	2,15	-	1,5	1,38	-	1,7	2,4	2,69	2,88

Table 15.3.1. Feasibility study test evaluation results.

According to the test evaluation results shown in Table 1 the following conclusions were drawn:

- End users participating in the tests faced no general usability difficulty to the pilot system; particularly, when they were introduced with an explanation of the technology and after running some exercises to practice the new software. Little or no guidance at all was needed by the participants, i.e. the users had no difficulties to handle the software and the devices. On the contrary, they enjoyed completing their tasks, showed a lot of commitment and were very enthusiastic.
- The overall result has unanimously been that the prototype introduced was considered very promising and useful, whereas that still leaves a lot of potential for improvement and supplement.
- Provided that further development is carried out, the system has the fundamental characteristics and capabilities to incorporate many requests of the users for a very large pool of applications. The approach chosen for the ENORASI project fully describes the belief of blind people to facilitate and improve training practices, and to offer access to new employment opportunities.
- The most important areas, according to the participants, which can be addressed through the approach of the ENORASI project are: a) mobility and orientation training, b) shape recognition, c) teaching mathematics, d) simulating athletic events and e) map and cane simulation.

15.4. Acknowledgement

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