Design and Implementation of Virtual Environments for Training of the Visually Impaire

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ABSTRACT

This paper presents the virtual reality applications developed for the feasibility study tests of the EU funded IST project ENORASI. ENORASI aims at developing a highly interactive and extensible haptic VR training system that allows visually impaired people, especially those blind from birth, to study and interact with various virtual objects. A number of custom applications have been developed based on the interface provided by the CyberGrasp haptic device. Eight test categories were identified and corresponding tests were developed for each category. Twenty-six blind persons conducted the tests and the evaluation results have shown the degree of acceptance of the technology and the feasibility of the proposed approach.

Keywords

Virtual environments; training; haptics; visually impaired;

INTRODUCTION

In recent years there has been a growing interest in developing force feedback interfaces that allow blind people to access not only two-dimensional graphic information, but also information presented in 3D virtual reality environments (VEs). It is anticipated that the latter will be the most widely accepted, natural form of information interchange in the near future [1].

The greatest potential benefits from VEs, built into current virtual reality (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].

This paper presents the virtual reality applications developed for the feasibility study (FS) tests performed in the Informatics and Telematics Institute for the project ENORASI. The main objective of this project is to develop a complete training system for the blind and visually impaired based on techniques for haptic interaction in simulated virtual reality environments [7], [8]. 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 innovative ways, in order to improve the possibilities for a blind person to extract rich and educative information from artificially controlled, simulated VEs. By using the computer and 3D computer generated digital worlds it is possible to dynamically link the sense of touch with that of hearing in ways, which are difficult/impossible with real world models [5], [6].

The purpose of this paper is to develop specialised VR setups and to conduct extensive tests with blind users in order to obtain measurable results and derive qualitative and quantitative conclusions on the added value of an integrated system aiming to train the visually impaired with the use of virtual reality. The CyberGrasp haptic device [9] (shown in Figure 1) was selected, based on its commercial availability and maturity of technology. In this paper we have developed a number of custom applications (the FS tests) and specific software to support the communication of the applications with the peripheral devices and we have also integrated a new optimised collision detection algorithm (based on RAPID [3] and PQP [4]) in the VHS software library [10] for the CyberGrasp haptic device, in order to improve the performance of the whole system.

Figure 1 : CyberGrasp haptic device.

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The steps above were required in order to develop and provide a pilot environment, which offers adequate functionality for end users to familiarize themselves with the technology and also to enable them to judge its potential and usefulness. Eight test categories were identified and corresponding tests were developed for each category.

SYSTEM PROTOTYPE DEVELOPMENT

The architecture of the ENORASI system is presented in Figure 2.

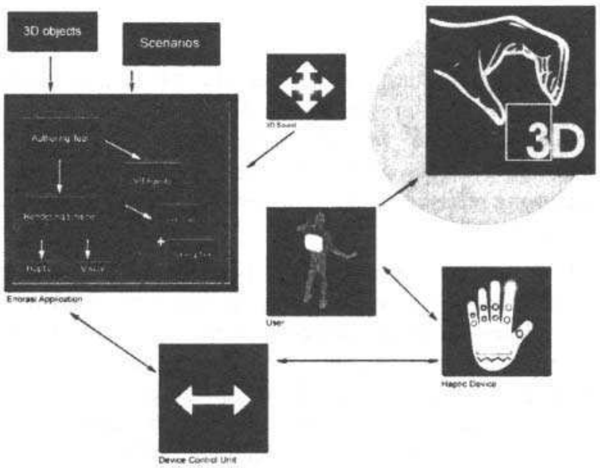

Figure 2 : ENORASI system overview.

The system comprises mainly a powerful personal computer running the ENORASI software application and a haptic device along with the units that control it. A 3D position and orientation-tracking device is optional for navigation applications of the ENORASI training system. The ENORASI software application will include an authoring environment for developing scenarios and training cases, the haptic and visual rendering modules (visual rendering is needed for monitoring the performance of haptic rendering) and the ENORASI intelligent agents implementing the guidance and help tools of the system. The ENORASI software application will be connected to a database of virtual objects, scenarios and training cases, especially designed for ease of use and adding value in the procedure of training visually impaired persons.

ENORASI Prototype

The ENORASI Prototype shown in Figure 3, supports both authoring and simulation functionalities.

A user can use the prototype to import objects in VRML (Virtual Reality Modeling Language) format, place them in an new or existing scene, set their properties and navigate through the scene by starting the simulation. The edited scene can be saved for later use. In general the first ENORASI prototype has the following features :

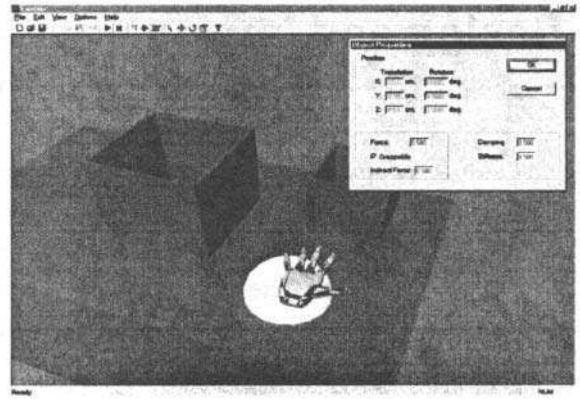

Figure 3 : Enorasi prototype snapshot.

- Supports the use and full control of more than one force feedback haptic devices simultaneously.
- Provides visual output to be used by the (sighted) training test leader.
- Provides an authoring environment for designing virtual environments optimized for the blind.
- Supports more than one collision detection algorithm (Rapid, PQP, V-CLIP, SOLID).
- Supports change of object haptic properties (stiffness, dumbing, graspable/non-graspable, etc.).
- Supports operations such as translation, rotation and scaling. Scaling, in particular, can be used to interactively decrease the size of the object to be examined (i.e. an aircraft or a building), in order to allow the user to get an overview of it and interact with it dynamically. The object can then be scaled back to the real size to allow realistic investigation of the details.

System Requirements

In terms of hardware and software requirements the system is comprised of the following core units:

- *Hardware:* The ENORASI system consists of the CyberGrasp haptic device, a powerful personal computer with a video card with 3D acceleration, input devices (primarily mouse and keyboard) and output devices other than the haptic device (primarily loudspeakers and if necessary a braille display).
- *Software:* The software system consists of drivers for the haptic device and a 3D modeling system for the creation of VR worlds.

Collision Detection

Collision detection is a core part of the control system that ensures the smooth, effective and precise synchronization between the artificial digital world and the haptic hardware device.

In the FS applications we have evaluated the Rapid[3] and the PQP [4] collision detection algorithms. In Rapid, hierarchical representation is based on Oriented Bounding Box (OBB)-trees. This algorithm is applicable to all general polygonal and curved models. It pre-computes a hierarchical representation of models using tight-fitting oriented bounding box trees. It can accurately detect all the contacts between large complex geometries composed of hundreds of thousands of polygons at very good rates. PQP is a library (based on Rapid) for performing three types of proximity queries on a pair of geometric models composed of triangles: collision detection - detecting whether the two models overlap, and optionally, all of the triangles that overlap, distance computation - computing the minimum distance between a pair of models, i.e., the distance between the closest pair of points and tolerance verification - determining whether two models are closer or farther than a tolerance distance.

It was concluded that PQP is more suitable for use with the CyberGrasp, which works significantly better when distance information is available. A customised version of that algorithm was developed to optimise the performance of the system.

Desk Setup Applications Development

The desk set applications implemented and tested in the ENORASI prototype consist of object recognition, map navigation, target shooting emulation, flexible object squeezing simulation and 2D mathematic curve recognition. More specifically:

- Object recognition/manipulation and map access simulation cases provide to the user force feedback when his/her fingertips collide with the objects. Force feedback is send to the user when the distance between a fingertip and an object is smaller than a threshold (0.5cm) The amplitude of the force is maximum when the fingertips are in contact with the object and linearly decreases to zero as the distance reaches the threshold.
- In the target shooting applications, force feedback follows the same rules for all fingers but the index. The index finger, which is pulling the trigger, receives a pulse force effect when the trigger is pulled simulating the realistic feeling.
- Flecible object squeezing is using stiffness and damping properties to emulate different types of objects (soft, hard).
- Mathematic curves recognition applies forces to user fingers proportional to the value of their 2D function.

In some of the tests force feedback was accompanied by acoustic feedback in order to help the user to understand the VE.

Cane Simulation Applications Development

Cane simulation, has been used for performing realistic navigation tasks with the use of CyberGrasp, which in combination with the Ascension MotionStar wireless tracker leads to a significant workspace (up to 7 meters). These simulations include indoors and outdoors environments such as navigation in the interior of a bank or a public building, traffic light crossing, etc.

The cane was simulated to be an "extension" of the users index finger. The relative position between the index finger and the top of the cane is as shown in Figure 4.

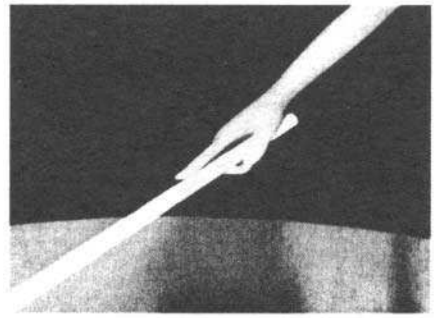

Figure 4: Cane grasping simulation.

The force feedback applied to the hand of the user depends on the orientation of the cane relatively to the object that collides with, in the virtual environment. When the cane hits on the ground, force feedback is send to the index finger of the user (shown in Figure 5).

Figure 5: Simulation of cane collision with the ground.

Force feedback is applied to the thumb when the cane collides with an object laying on its right side (shown in Figure 6).

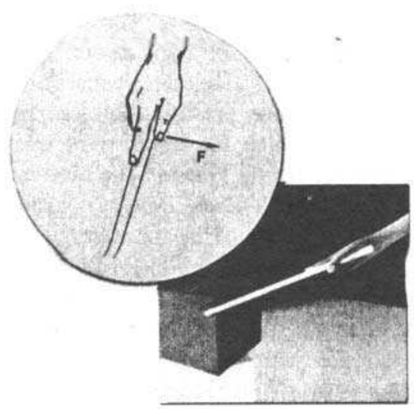

Figure 6: Simulation of cane collision with an object on the right hand side of the user.

Force feedback is applied to the middle ring and pinky fingers when the cane collides with an object being on its left side (Figure 7).

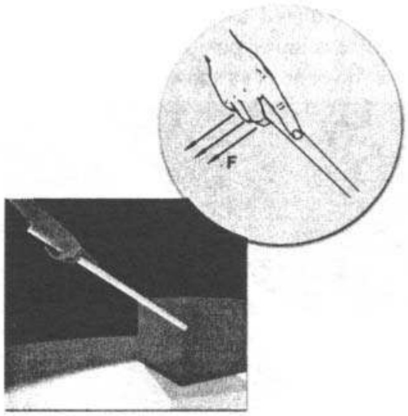

Figure 7: Simulation of cane collision with an object on the left hand side of the user.

The forces applied to the user are: a constant continuous force that emulates the force provided by grasping a real cane, a cosine force effect (buzzing) provided to the user when the cane is penetrating an object and a Jolt force effect is send to the user when the cane hits an object or the ground.Cosine force effect is described by the equation

$$F=a(1+\cos(2\pi\omega t))$$

the Jolt force effect by the equation

$$F=de^{-kt}.$$

The cane simulation application is adjustable in terms of:

- the cane length,
- the grasping force, the floor hit force and the wall hit force and
- the level of buzzing (force when cane is penetrating an object),

in order for the test leader to be able to modify the simulation parameters online, based on the user requirements.

FEASIBILITY STUDY TESTS

The FS included twenty-six blind users. Each test took approximately two 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 FS 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 in advance with blind users. The majority of the tests in the FS 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 to use the results of the FS in order to gather information useful in the design of the final system. For example, a test could consist of an easy task, a middle level task and a complicated task. In the beginning the test sets were designed on this line, but due to time constraints some test tasks were removed after the pilot tests.

Test setup

Figures 8a and 8b depict the layouts of the test equipment used for the CyberGrasp tests.

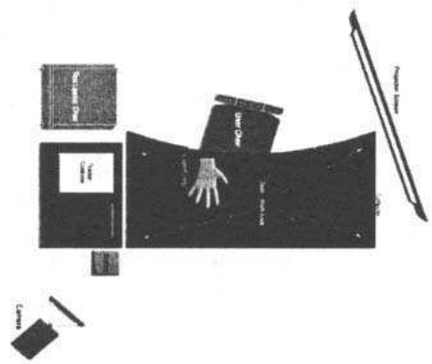

Figure 8a : The desk setup used for the tests.

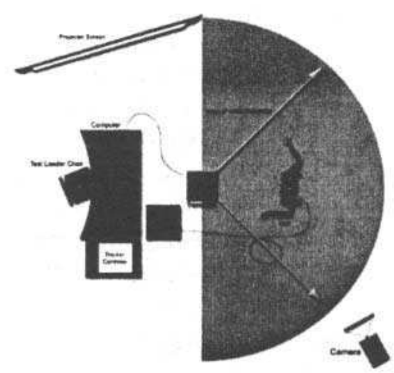

Figure 8b : The cane simulation setup used for the tests.

Aside from the material shown in Figures 8, 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 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 virtual geometrical objects of different shapes placed in a pattern on a virtual table. On the adjacent desk, there is a 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 9). Then, the user is informed of the correct placement of the objects.

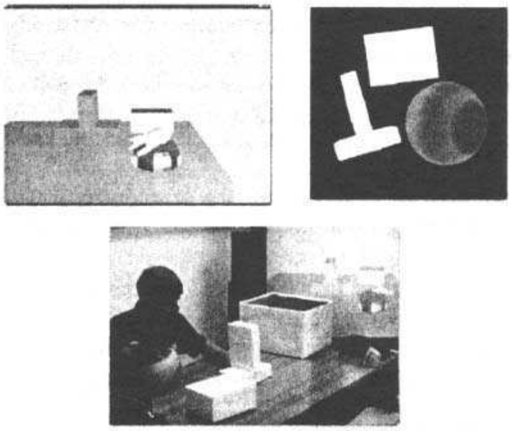

Figure 9 : Geometrical objects in a pattern test, a) setup, b) real objects, c) a user performing the test.

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-defined object and move it to a specific position. FS goals include recognition of shape, object manipulation into virtual environments, understanding scale and knowledge transfer.

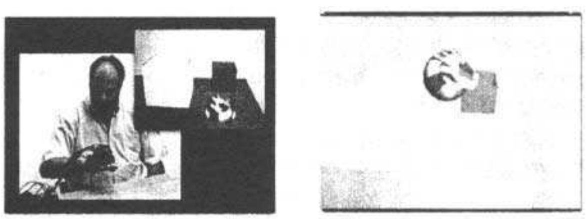

Figure 10 : a) a user exploring the VE of Test 2 (object grasping and manipulation), b) the same user snaps the ball into the basket.

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 10).

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. FS goals include navigating in complex environments, knowledge transfer, understanding scale and interacting with haptic user interface components.

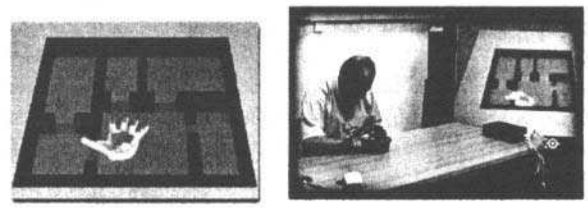

Figure 11 : Map test: a) setup, b) a user performing the map test.

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 11). 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. FS goals include edutainment – use a mathematical educational system and knowledge transfer.

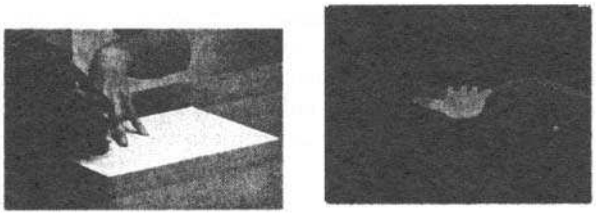

Figure 12 : A user plotting the curve in the mathematics test.

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 12). 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 flexible 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. FS goals include interacting with virtual objects and understanding their physical properties and knowledge transfer.

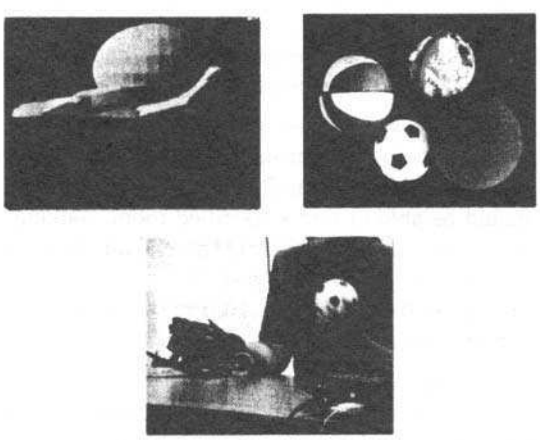

Figure 13 : A user performing the object squeezing test.

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 13). Ball 1 is a well-inflated small ball; ball 2 is a less inflated plastic ball; ball 3 is a deflated small 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. FS goals include, edutainment – participation into a virtual athletic event, interacting with haptic user interface components and knowledge transfer.

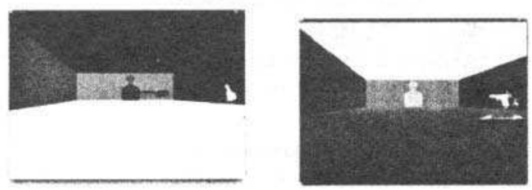

Figure 14 : Target shooting-tests : a) 6.1, b) 6.2.

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 14). 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. The objective for the user is to find out how to shoot correctly and then shoot as many targets as possible.

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 14). 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. The objective for the user is to shoot as many targets as possible.

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. FS 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 15). 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.

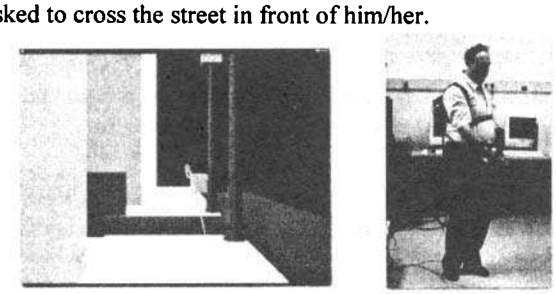

Figure 15 : Cane simulation – Outdoors test – a) setup, b) a user performing the test.

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. FS goals include navigating in complex environments, cane simulation, edutainment, knowledge transfer and interacting with haptic user interface components.

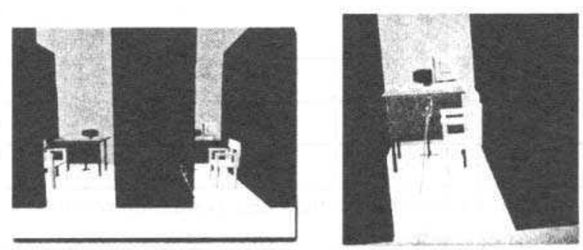

Figure 16 : Cane simulation – Indoors test : setup.

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 16). 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.

FEASIBILITY STUDY TEST RESULTS

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.

The accompanying video shows some representative users performing the ENORASI FS tests. Table 1 shows some of the parameters used for the evaluation of the prototype, such as time of completion/test, success ratio, percentage of users needing guidance and degree of challenge (set by the users).

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

Table 1 : Feasibility study test evaluation results.

Note also that a percentage ranging from 90-100% of the users have characterised all tests as useful or very useful.

FEASIBILITY STUDY CONCLUSIONS

Upon completion of the tests 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.
- 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.

ACKNOWLEDGMENTS

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REFERENCES

1. Burdea, G. C., "Force and touch feedback for virtual reality", *Wiley-Interscience Publication*, 1994.
2. Colwell, C., Petrie, H., Kornbrot, D., Hardwick, A. and Furner, S., "Haptic Virtual Reality for Blind Computer Users", *Proc. of ASSETS '98*, pp 92-99.
3. Gottschalk, S., Lin, M. C., Manocha, D., "OBBTree: A Hierarchical Structure for Rapid Interface Detection", Proc. Of ACM Siggraph 1996 http://www.cs.unc.edu/~geom/OBB/OBBT.html, RAPID.
4. Larsen, E., Gottschalk, S., Ming, C., Lin, D. Manocha "Fast Proximity Queries with Swept Sphere Volumes", Technical report TR99-018, Department of Computer Science, UNC Chapel Hill, http://www.cs.unc.edu/~geom/SSV/, PQP.
5. McLaughlin, M. L., Sukhatme, G., Hespanha, J., "Touch in Immersive Environments", In Proc. of the EVA 2000 *Scotland Conf. on Electronic Imaging and the Visual Arts*, July 2000.
6. Scoy, V., Kawai, I., Darrah, S., Rash, F., "Haptic display of mathematical functions for teaching mathematics to students with vision disabilities", *Haptic Human-Computer Interaction Workshop*, 2000.
7. Sjostrom, C. "Touch Access for People With Disabilities", licentiate thesis, in CERTEC, Sweden, (http://www.certec.lth.se/doc/touchaccess).
8. Yu, I., Ramloll, L., Brewster, J., "Haptic graphs for blind computer users", *Haptic Human-Computer Interaction Workshop*, 2000.
9. http://www.virtex.com/products/hw_products/cybergrasp.html, CyberGrasp Haptic Device, Virtual Technologies Inc.
10. http://www.virtex.com/products/sw_products/VHS2000.html, Virtual Hand Suite 2000, Virtual Technologies Inc.