CANE SIMULATION FOR THE BLIND

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ABSTRACT

This paper describes a haptic application for the training of blind people in the use of the white cane. The application enables the emulation of real world areas and emulates the use of cane in a safe environment for the blind user. The system allows blind people to interact in a haptic enabled VE and use a virtual white cane. The system is designed to provide an alternative way in training blind users to use the cane. The main added value of the system compared to existing training systems is that the users can study various cases in a safe and controlled environment prior to practicing in the real world.

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].

Researchers at Stanford University, work on the research field of bringing the domestic computer world to people with disabilities. The result is an interface (Moose, [2]) that supports blind people in using the MS Windows¨ operating system. Nowadays, their research is focused on modifying Moose's interface for its use in Internet navigators.

A considerably affordable mouse with force feedback is FEELit, produced by Immersion Corp. [3]. Although the cost of the device is low, it has a restricted area of use, mainly due to its low-bandwidth force feedback. Nowadays, research groups typically make use of PHANToM™ (Sensable Technologies Inc.) [4] [5] and/or the CyberGrasp™ data glove (Immersion Corp.) [3].

PHANToM™ is the most commonly used force feedback device; it is regarded as one of the best on the market. Due its hardware design, only one point of contact at a time is supported. This is very different from the way that we usually interact with surroundings and thus, the amount of information that can be transmitted through this haptic channel at a given time is very limited. However, research has shown that this form of exploration, although time consuming, allows users to recognize simple 3D objects. The PHANToM™ device has the advantage to provide the sense of touch along with the feeling of force feedback at the fingertip. Its main disadvantage is broad when identifying small objects. In these cases, people tend to use both their hands and all their fingers; it is proven that object identification with only one finger is difficult [6]. Many research groups study methods of texture and geometry refinement in order to improve the sense of touch for texture [7], [8] and surface curvature [9] identification when using PHANToM™.

CyberGrasp™ is another haptic device with force feedback rapidly incorporated to research lines. A research group working with CyberGrasp™ is led by Sukhatme and Hespanha at the University of Southern California. They focus on helping blind children to learn words, sounds and object forms, through this force feedback data glove [10]. Others include Schettino, Adamovich and Poizner, researchers in the Rutgers University of New Jersey, working on a project, which deals with the ability of people to adjust their hands and fingers to object forms that they have seen before [11].

The main goal of the described application is to introduce an innovative virtual reality system in order to improve the training of blind and visually impaired people. The goals of the virtual reality training case studies (complete pilot training scenarios for injury-less and strain-less training) include: a) facilitating the participation of the visually impaired users in an educational or entertainment environment and b) navigating into complex virtual environments based on haptic information and guidance from virtual guides.

The paper is organized as follows. Section 2 desribes the cane simulation application. Section 3 identifies the systems requirements and describes the architecture of the proposed system. Section 4 states evaluation procedure and results form that procedure. Finally, Section 5 draws the conclusions.

2. APPLICATION DESCRIPTION

Cane Simulation environment allows the user to use a white cane in order to navigate in the virtual environment. The cane was designed to be an "extensionÓof the user's index finger. The force feedback applied to the user's hand, depends on the orientation of the cane relatively to the virtual object that it collides with. Specifically, when the cane hits the ground, force feedback is sent to the index finger of the user. Force feedback is applied to the thumb when the cane collides with an object laying on its right side and force feedback is applied to the middle ring and pinky fingers

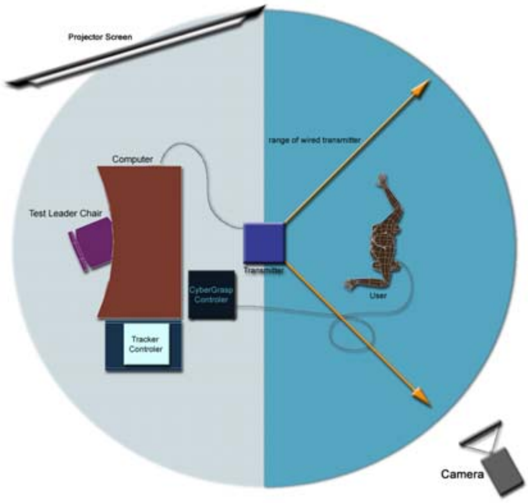

Figure 1 Cane simulation setup

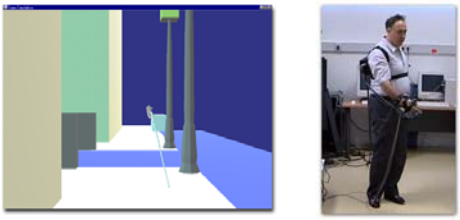

Figure 2. Cane Simulation – Outdoors test.

simultaneously, when the cane collides with an object being on its left side.

A three state force model was used: a) the cane does not collide with any object, b) the cane hits on an object in the scene and c) the cane is colliding continuously with an object in the scene (e.g. penetrates an object in the scene). The corresponding forces applied to the users are: a) a constant continuous force that simulates the force provided by grasping a real cane, b) a jolt effect force and c) buzzing.

Figure 1 presents schematically the test setup for the cane simulation test case. The user wears the CyberGrasp and a waistcoat for carrying the Force Control Unit (FCU) for the CyberGrasp (Figure 2). Sound and haptic feedback are provided by the system upon collision of the cane with the virtual objects. 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. Environmental sounds can be assigned to objects in the scene (e.g. realistic traffic lights sound is assigned to traffic lights in the virtual scene) [15].

There are two test cases implemented an outdoor test case and an indoors test case. In the outdoors test case the user is informed that he is standing in the corner of a pavement (Figure 2). 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.

The user should walk ahead and find the traffic light located at about one meter on his left side. Realistic 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

Figure 3 Cane Simulation - Indoor test.

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.

In the indoor test case the user is asked to navigate into an indoor environment using the virtual cane. When the test starts, the user is asked to grasp the virtual cane. The goal for the user is to find the second door on his/her left side and enter the room (Figure 3). There he/she should find a chair. During his/her walk the user should find successively the wall on the 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.

3. REQUIREMENTS AND SYSTEM ARCHITECTURE

This section describes technical aspects of the training environment for the blind in terms of platform, hardware requirements, implementation language and architecture.

3.1 Requirements

The cane simulation system for blind people runs on a Windows NT, 2000 and XP platforms. The application requires a powerful computer with a minimum of 256MB RAM and a graphics card that supports 3D graphics. The white cane simulation application requires additionally the CyberGrasp™, CyberGlove™, the Ascension Flock of Birds™ with the Extended Range Transmitter (ERT), a serial port and a network connection at 100Mbps.

The implementation language used in the development of the training system for blind people is C++ (MSVC). The applications are developed using the drivers and libraries provided by the hardware manufacturers.

3.2 System Requirements

The application consists of the following three main parts: a) initialization part, b) haptic loop and c) visual loop [14].

The initialization part establishes connection with the devices (CyberGrasp™ - Glove¨ , Flock of birds™ Tracker), reads the scene (models and sounds), initializes the collision detection algorithm and starts the haptic and visual loops.

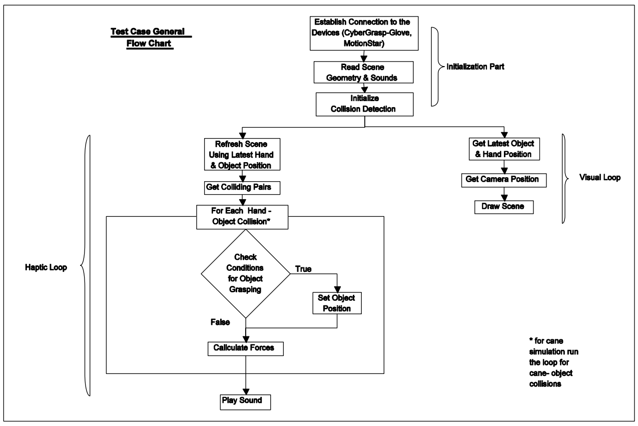

Figure 4 General flow chart of the cane simulation environment.

The haptic loop updates the scene using data from the devices, checks for collisions between the virtual cane and scene objects, sets the new position of the cane, triggers feedback forces and enables sound playback (Figure 4).

The cane simulation application utilizes two input devices, the glove and the motion tracker and one output device, CyberGrasp™. This device, which provides the force feedback, runs its own control loop (on the device control unit) on 1 KHz. The update rate of the motion tracker is 100 Hz and the update rate of the 22-sensor CyberGlove¨ connected at 115.2 Kbaud is close to 250 Hz. In order to update feedback data to the CyberGrasp™ device using 1 KHz, we calculate intermediate position values for the motion tracker and the fingers using linear interpolation. The position values are then sent to the collision detection algorithm and feedback forces are calculated and transmitted to the CyberGrasp™ device. Collision detection is performed only between the virtual cane and objects in the 3D environment. The overall delay produced by the input devices equals to the delay caused by the device with the lowest update rate. Thus, the system has an overall delay of 10 msec due to the delay in receiving data from the tracker (100 Hz). Because of this overall delay and in order to perceive realistic haptic feedback, users were asked to move relatively slow when interacting with the system.

Correspondingly, the visual loop receives as input the latest camera, hand and scene object positions and draws the scene. The update rate is approximately 20 Hz (20 frames/sec).

4. SYSTEM EVALUATION

Initial versions of the applications have been evaluated with blind and visually impaired users. Specifically the white cane simulation has been tested with blind and visually impaired users from the Thessaloniki Blind School and the Pan-Hellenic Blind association.

Twenty-six persons participated in the tests from the Thessaloniki 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 evaluation consisted of three phases. In the first phase the users were introduced to the system and were alloud to use it for a while in order to get used to the device and to calculate the most confortable parameters for the cane (i.e. length, force amplitude)[16].

In the second phase the users performed the tasks. The total time to complete the task, alloud comments and success or failure in performing the task were recorded for each user. In the third face the users answered to questionaire, about the performance and the usability of the system.

According to the comments of the users during the tests and the questionnaires filled by the users after the tests, the following conclusions can be drawn: It was deemed very important to utilize both acoustic and haptic feedback, as they are indispensable for the orientation. It is also important to note that a percentage ranging from 90-100% of the users have characterized the tests as useful or very useful.

5. CONCLUSIONS

In terms of usability, we can conclude that the system can be used for educational purposes, mobility, orientation training and exploration / navigation in 3D spaces.

In the case of the cane simulation technical limitations constrain its applicability. Specifically, the system cannot prevent the user from penetrating objects in the virtual environment. The maximum workspace is limited to a 7 m - diameter hemisphere around the tracker transmitter (the 1 m limitation, caused by the CyberGrasp™ device is solved by using a backpack so that the user can carry the CyberGrasp™ actuator enclosure). The maximum force that can be applied is limited to 12N per finger and the feedback update rate is 1KHz.

The following conclusions can be drawn from the evaluation of the Feasibility Study tests in terms of system usability:

- It was deemed very important to utilize both acoustic and haptic feedbacks, as they are indispensable for the orientation. The majority of the participants preferred to have both feedbacks.
- All people tested had no problems with the system after an explanation of the technology and some exercises to practice the application.
- The participants needed little or no guidance at all, i.e. the users had no difficulties to handle the software and the devices. On the contrary, they enjoyed completing the tasks, showed a lot of commitment and were very enthusiastic about being able to have this experience.
- No connection was found between the age that blindness occurred and the test results.
- All participants emphasized their demand to use these programs in the future.
- All the users stated that they would like to participate in future tests.

Concluding, the result has unanimously been that the application introduced was considered very promising and useful, whereas it still leaves a lot of room 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, fully describes the belief of blind people to facilitate and improve training practices, and to offer access to new employment opportunities. It represents an improvement of life for the blind and the visually impaired people when connected to reality training. These facts are evident from the participant's statements.

Besides the direct benefits of the proposed system, as many of the users mentioned, technology based on virtual environments can eventually provide new training and job opportunities to people with visual disabilities.

6. ACKNOLEDGMENTS

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