

OBJECT RECOGNITION FOR THE BLIND

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ABSTRACT

This document describes a haptic application that allows blind people recognize three-dimensional (3D) objects that exist in virtual environment. The system allows blind people to touch, grasp and manipulate objects that exist in the haptic enabled VE. The system is designed in order to provide an alternative way of human computer interaction to blind users.

1. INTRODUCTION

The most commonly used interface for providing information to a computer user is the screen, display. Unfortunately, the screen is completely useless when the user is a blind person. In this case, the most common interfaces utilize the audio channel to provide information to the blind user.

The greatest potential benefits from virtual environments can be found in applications concerning areas such as education, training, and communication of general ideas and concepts [3]. The technical trade-offs and limitations of the currently developed virtual reality (VR) systems are related to the visual complexity of a virtual environment and its degree of interactivity [4], [5]. Hitherto, several research projects have been conducted to assist visually impaired to understand 3D objects, scientific data and mathematical functions, by using force feedback devices [6-10].

Nowadays, research groups typically make use of PHANToM™ (Sensable Technologies Inc.) [13] [14] and/or the CyberGrasp™ data glove (Immersion Corp.) [12]. 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. CyberGrasp™ is another haptic device with force feedback rapidly incorporated to research lines. Cybergrasp devive has 5 points of contact with one degree of freedom for each case.

The proposed paper focuses on the development of a highly interactive haptic system that combines benefits from both CyberGrasp and PHANToM™ devices. More specifically, the main objective of this work is to develop specialized VR set-ups with full five-finger haptic feedback. A number of custom applications have been developed in order to test the performance of the whole system. The advantages of the proposed method over existing VR methods are the improvements this approach offers in terms of usability and accessibility in applications such as training of the blind and the visually impaired using virtual reality.

2. APPLICATION DESCRIPTION

The system is a tool that enables blind people to access a VE through haptic interface. There exist three different setups for the application depending on the devices used: a) “haptic glove setup” which utilizes the Cybergrasp device, b) “haptic probe setup” which utilizes the Phantom device and c) “haptic combo setup” which utilizes a combination of both haptic devices to provide force feedback.

Three different scenarios were developed in order to evaluate the prototype system:

- Object recognition scenario,
- Object manipulation scenario and
- Audio-haptic interactive scenario.

In the object recognition scenario, it is expected that the use of the integrated device will reduce the overall time needed to understand the shape of objects and provide better immersion to the virtual environment. In this scenario both devices are expected to contribute equally. The PHANToM device will allow the user to explore details of the object, while the CyberGrasp device will help the user perceive the general shape and size of the object.

In the case of the object manipulation scenario, the use of the integrated device is expected to facilitate the grasping of objects in the virtual environment. The CyberGrasp device is expected to have a more important role in this case, since it allows the users to grasp objects in a natural way.

Finally, in the audio-haptic interactive scenario, the integrated device is expected to reduce the time needed by the user to explore the 3D environment. The PHANToM device in this case is considered more important since all the actions are triggered by the index finger. The CyberGrasp device will assist the user to find objects that are close to the index finger area.

The main goal of the described application is to introduce an innovative virtual reality system in order to provide an interface to 3D virtual environments that is accessible to blind and visually impaired users. The application will allow blind people understand and interact with objects in a virtual environment get used with new technologies and thus introduce new opportunities for training, entertainment and work.

Figure 4-1 presents schematically the test setup for the object recognition application test case. The user wears the CyberGrasp, while the Force Control Unit (FCU) for the

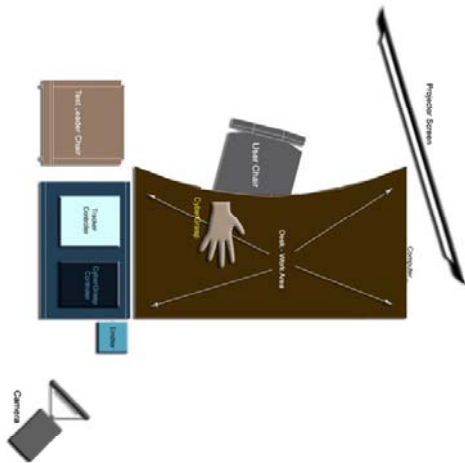


Figure 1 Object recognition application setup.

CyberGrasp lies on a table on the right side of the user. Alternatively the Phantom device lies on the desk so that the user can use the combination of the devices. Both, sound and haptic feedback are provided while interacting with the virtual objects.

The object recognition supports loading 3D shapes from VRML files in the virtual environment (Figure 8). The user is allowed to explore the 3D objects in order to recognize their shape. It is possible for an expert user to change the physical properties of the objects in order to make force feedback more realistic. It is also possible to insert multiple objects in the scene and inquire from the user to recognize each one of them.

Object manipulation scenario supports loading one object at a time and manipulating it. The user can enable or disable object grasping by pressing a toggle button that resides on CyberGlove. When the button state is on, the user can grasp and move the object in the virtual environment (Figure 8). When the button is off, the user can examine the shape of the object. In order to grasp an object, the thumb and two more fingers must be in contact with the object. In order to release the object, the user must release two of the grasping fingers by opening his/her hand.

This scenario supports navigation through an audio-haptic menu. A menu assists the user to select a 3D object shape and explore it while listening to information about it. The last part of this scenario is similar to the object recognition scenario; however, the user selects the object to explore in order to gain access to an audio description of information relative to the object.

This is a more complex scenario where the user has to perform specific actions in the scene and receives both haptic force feedback and audio feedback. In this scenario the user has to use the index finger in order to select an object.

Selection of an object is performed with the following procedure: Initially the user has to use the index finger and touch a selection object (Figure 8). The selection object declaims itself. If the user wants to select this object he/she pushes the object (in the same way like pushing a button on the keyboard).

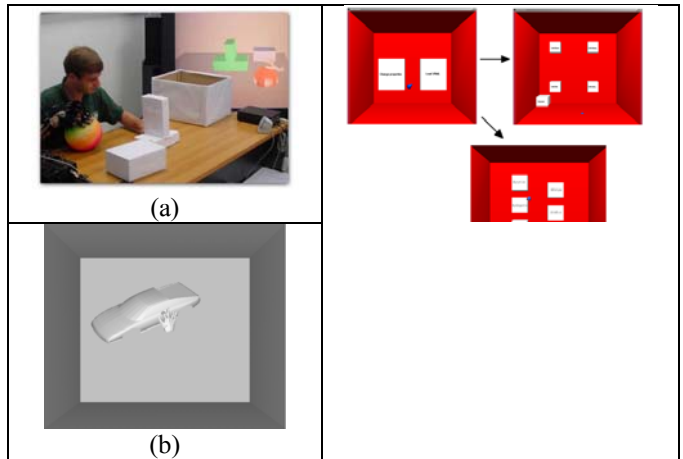


Figure 2. Object recognition application scenarios– a) object recognition, b) object recognition and manipulation and c) audio-haptic interactive environment.

The users had to select a category of objects and in the following, a specific object. After that, they could explore the object using the haptic devices while listening to audio information about the object.

The object recognition scenario allows the user to import one or more objects in the scene and explore them using the available device or devices. Collision detection is performed between the fingertips of the users' hand, the Phantom probe (which corresponds to the index digit) and the objects in the VE. Force feedback is applied to the fingers that collide with objects in the scene allowing thus the user to estimate the shape and size of objects in the VE.

The object recognition and manipulation allows the user to explore with his/her hand over the desk as in the first case. Furthermore, the user can grasp and move an object in the VE and explore it from various "viewing" angles. Force feedback is also applied to the user when he/she grasps and moves an object in the scene.

The audio haptic interactive scenario supports navigation through an audio-haptic menu. The menu assists the user to select a 3D object shape and explore it while listening to information about it. The last part of this scenario is similar to the object recognition scenario; however, the user selects the object to explore in order to gain access to an audio description of information relative to the object. Selection of an object is performed with the following procedure: Initially the user has to use the index finger and touch a selection object. The selection object declaims itself. If the user wants to select this object he/she pushes the object (in the same way like pushing a button on the keyboard).

3. SYSTEM ARCHITECTURE

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



Figure 3. CyberGrasp, Phantom Combination.

The application consists of the CyberGlove™, CyberGrasp™ and the PHANToM™ devices, a powerful workstation with specialized 3D graphics acceleration, conventional input devices (primarily mouse and keyboard) and output devices other than the haptic device (primarily speakers). The Phantom device is connected to the application PC via a parallel port. CyberGlove and CyberGrasp are connected to the CyberGrasp main unit via the Device Control Unit (DCU) and the Force Control Unit (FCU), respectively. Finally, the CyberGrasp main unit and the application PC are connected together using a 100Mbps Ethernet line.

Alternatively for the setup without the Phantom device, Flock of birds™ Tracker device is used for tracking the position of the users hand.

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 or the PHANToM device), reads the scene (models and sounds), initializes the collision detection algorithm and starts the haptic and visual loops (Figure 2-1).

The haptic loop updates the scene using data from the devices, checks for collisions between hand and scene objects, checks conditions for object grasping, sets the new position of any translated object, sends feedback forces and enables sound playback (Figure 2-2).

There are two input devices, the glove and PHANToM™ Desktop device and two output devices, CyberGrasp™ and PHANToM™ Desktop. CyberGrasp™ device, which provides the force feedback to the four fingers, runs its own control loop (on the device control unit) on 1 KHz. The update rate (input and output) for the PHANToM device is also 1 KHz 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 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™ and PHANToM™ devices. Collision detection is performed only for the fingertips. The overall delay produced by the input devices equals to the delay caused by the device with the lowest update rate.

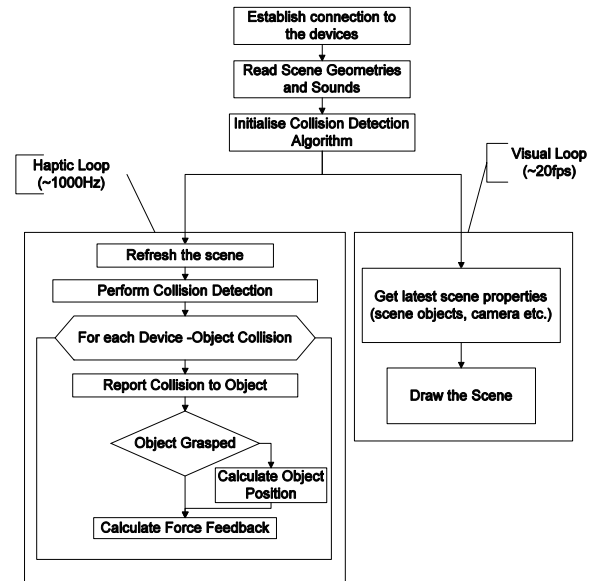


Figure 4. General flow chart of the object recognition system.

Thus, the system has an overall delay of 4 msec due to the delay in receiving data from CyberGlove (250 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.

In the case that Phantom device is not used the flock of birds motion tracker with an ERT is used to track the position of the hand and thus allow the interaction in the VE.

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

The present work described the combination of two haptic devices in order to provide an enhanced haptic virtual environment for blind people training.

Both blind and non-blind users have evaluated the presented work in the laboratory. The non-blind users were blindfolded and tested the three applications using the integrated device, the PHANToM and the CyberGrasp.

The main advantages of using the combination of the two devices over using only one of them are:

- The index finger receives realistic touch feedback from the PHANToM device, i.e. the user can explore details of the object.
- All the fingers receive force feedback increasing the immersion of the environment. In this case the user can touch the object as a whole and get information on its global properties
- The users cannot penetrate the objects in the scene.
- The users can grasp and move objects in the virtual environment in a more realistic manner.

However, there are also some drawbacks in using the integrated device:

- The workspace of the CyberGrasp device is limited to the workspace of PHANTOM.
- Each user has to perform a calibration procedure for the CyberGrasp device, which is not necessary when utilizing PHANTOM™.

The results show that the combination of the devices can improve the performance in a variety of applications. However, one has to take in account the complexity of the hardware system, the complexity of the 3D environment and the task the user is asked to perform in order to decide whether it would be more efficient to use the combination of the devices or one of them.

5. CONCLUSIONS

A haptic application that allows blind people recognize 3D objects in virtual environments has been presented. The system utilizes haptic devices to allow blind people touch, grasp and manipulate objects that exist in the haptic enabled VE.

The use of CyberGrasp device enable interaction with objects in the scene providing force feedback to the users fingertip. However, the device is not mounted and thus cannot prevent the users hand from penetrating objects in the VE. The use of PHANTOM desktop device, which is mounted to the desktop, is preventing the user from penetrating object in the VE, however the workspace in this case is limited to a square of approximately 12cm x 12cm x 16 cm.

In all cases the following conclusions can be drawn from the evaluation in terms of system usability:

- Most of the participants were very positive about beginning with simple objects and then proceeding to more and more complex ones. Some of them would have liked to deal with more complex scenarios.
- All people tested had no problems with the system after an explanation of the technology and some exercises to practice the application.
- They enjoyed completing their tasks, showed a lot of commitment and were very enthusiastic about being able to have this experience.
- 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.

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. ACKNOWLEDGMENTS

This work has been conducted in conjunction with the “SIMILAR” European Network of Excellence on Multimodal Interfaces of the IST Programme of the European Union (www.similar.cc).

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