Belt-Based Haptic Device for Representing Scene Depth Information

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Abstract

This paper aims to demonstrate the usage of haptic device for helping the navigation task in a virtual environment. We developed a belt-shaped interface with a matrix of 35 (7x5) vibrotactile actuators attached to the users' abdomen. Tests demonstrated that the device can help users perceive the movement of objects, as well as allow them to move in environments containing obstacles without using vision.

Keywords: Tactile display, depth to haptic convertion.

Index Terms: Virtual reality, haptic interfaces.

1 Introduction

In this study, a prototype consisting of software and hardware was developed, which captures three-dimensional images from both a virtual environment and converts this information into a haptic device. Based on vibratory motors, this device is attached to the abdomen of the user and informs, in real time, the geometry of the environment in front of him, as well as the movement of objects.

The apparatus developed was evaluated in order to measure its capacity to inform users about existing obstacles in front of them.

2 Prototype

The prototype has two different input modules, one for real, and another for virtual environments.

On virtual environments the depth buffer of the image generated from the user's point of view is captured and serve as the input for the system.

On real environments, the system uses a Microsoft Kinect device to get the scene in front of the user. Each pixel acquired by the Kinect sensor represents the distance between the object and the camera plane, in a range between 100 cm and 300 cm.

On the output side, the haptic display developed in this project is composed by a matrix of 7x5 tactors that covers the abdomen area. The region of the abdomen was chosen mainly because the researches by Van Erp [2] and Barros [1] demonstrated that it is possible to express distance and direction in this area of the body. The spacing between tactors used to compose the matrix was five centimeters in the horizontal direction and four centimeters in the vertical direction, because of the area available in this region and the size of the tactors available.

An odd number of rows and columns in the matrix was selected to ensure a central position in the display. The existence of a central point in the display made it possible to represent the presence of objects exactly in front of the user.

The arrangement of the tactors on the waist line was determined to cover the abdomen area to the greatest possible extent, in a tactile area of 30 centimeters wide and 16 centimeters high (Figure 1).

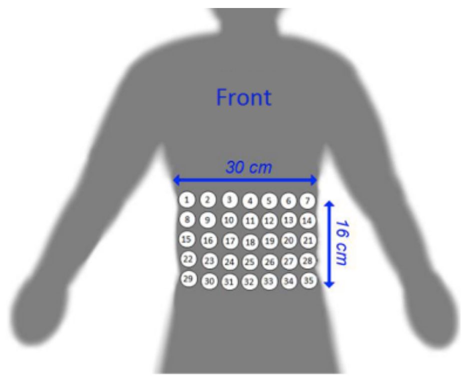

Figure 1: Position of the Tactors in the Torso Region

Figure 2 presents the haptic display developed in this project, composed by (A) microcontroller and (B) belt with tactors. The belt is made of Neoprene, on which a layer of Velcro was sewn in order to facilitate the attachment of the tactors.In the haptic display developed, each tactor is a DC motor that produces vibration through Eccentric Rotating Mass (ERM) technique.

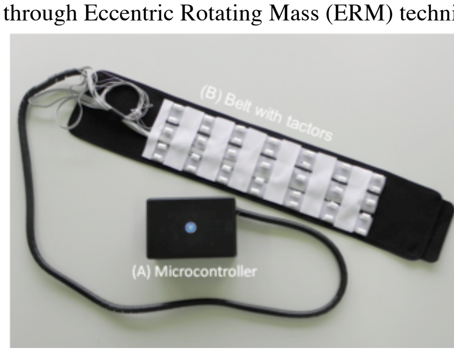

Figure 2: Haptic Belt

The motors used in this project were taken from cell phone devices. Each motor received a Polyacetal (Tecaform) machined encapsulation in order to isolate its axis and eccentric mass from body contact (Figure 3). This adjustment was necessary because these motors do not have any original shield.

Figure 3 – Eccentric Rotating Mass Based Tactor

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The matrix of tactors of the haptic display is controlled by an Arduino ATmega1280 microcontroller (http://www.arduino.cc/). An auxiliary electronic circuit was developed to supply the necessary power to the matrix. As the Arduino microcontroller used does not have enough analog ports to control the 35 motors, the Pulse Width Modulation technique (PWM) was applied, using the digital ports of this microcontroller only. In this technique, a digital signal controls the frequency with which the power of the motor is on or off, over time, rather than the intensity of this power. This produces a controllable variation in speed vibration of the motors.

2.1 Software

The process of converting the depth image data into the tactile information shown in the haptic display was carried out by a C++ program running on a portable computer with the Microsoft Windows operating system. In this process, the depth frames are resized to a 7x5 matrix and the software maps the distances into an intensity for each tactor.

2.2 Demo Description

The demonstration runs on a PC. During the interaction, the user wears the belt developed in the project and should close his eyes during the session.

For the virtual environment version the goal is to navigate through a virtual room using a joystick or a keyboard. The room has a couch that should be avoided during the navigation. In this room there is also an block that moves around the user, so he can also feel the presence of moving objects.

Figure 4 shows two different images of the the virtual room. On both images, on the felt-lower corner is shown the zbuffer downsampled to a 7x5 matrix.

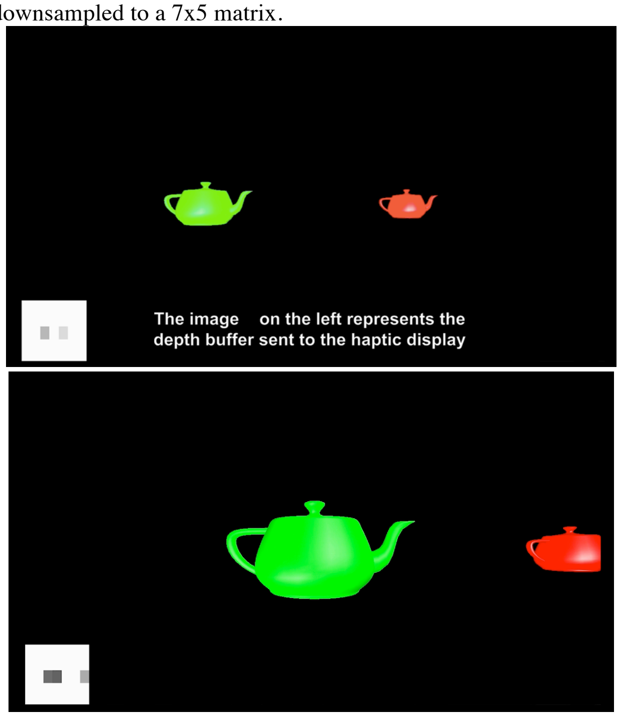

Figure 4: Virtual Environment

The video available at https://youtu.be/ovlNxU1tkak shows how the depth buffer of a virtual environment changes while the user and the object move, and how reduce its resolution, in order to use it in the haptic device.

In order to make this demostrantion more interesting for the audience, we also use the haptic interface in a real environment. For this setup, we place a Kinect sensor in front of the user and he will be able to feel people moving around. Figure 5 shows a sample depth frame of a person moving to the user. Figure 6 shows a user wearing the belt, standing behind a Kinect sensor. The video available at https://youtu.be/6ZqBpztFltQ shows an user interacting with the haptic device.

Figure 5: User moving in front of a Kinect device

Figure 6: User wearing the haptic display behind the Kinect device

3 Acknowledgements

Our research is funded by the National Institute of Science and Technology in Medicine Assisted by Scientific Computing(MACC) (Grant CNPq 181813/2010-6 and FAPERJ E-26/170.030/2008).

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