A Wearable Haptic Navigation Guidance System

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Abstract

This paper describes a wearable navigation system based on a haptic directional display embedded in the back of a vest. The system consists of a 4-by-4 array of micromotors for delivering haptic navigational signals to the user's back, an infrared-based input system for locating the user in an environment, and a wearable computer for route planning. User testing was conducted to evaluate the effectiveness of this system as a navigation guide for sighted users in an unfamiliar lab area. It is hoped that such a system can be a useful navigation guide for individuals with severe visual impairments in an unfamiliar environment. Future work will address the specific issues concerning blind navigation.

1. Introduction

This work was motivated by our desire to develop a haptic navigation guidance system for the blind. Current work on blind navigation focuses on auditory displays of visual information [1] [2][3]. These systems convert processed information from cameras or ultrasonic sensors to sounds. The design of a sonification system often requires judicial selection of auditory events in order to minimize interference with a blind traveler's perception of environmental sounds. In this paper, we propose that the sense of touch be used as an additional or alternative channel for navigation display to ease the demand on auditory attention.

Our system is based on a sparse 4-by-4 stimulator array that delivers directional cues exploiting the sensory saltation phenomenon [4]. An earlier work has indicated that such stimulation elicits vivid movement sensations that are intuitive for even first time users [5]. The goal of the current work is to implement a wearable navigation display and test it in the field. Through field testing, much can be learned about the specific needs of users when navigating through an unfamiliar space.

In addition to the haptic display, the navigation system also requires a method for determining the user's location and route planning. Because global positioning system (GPS) signals are not easily received indoors, a ceiling-mounted infrared transceiver system that had been previously developed for other projects in the MIT Media Lab was used instead. A simple map of the lab area was created and stored on a wearable computer for route planning and directional signal generation.

2. System Construction and Design

The navigation system is comprised of three main units: infrared transmitters and receivers, a wearable computer, and a haptic display.

<u>Infrared Transceivers</u>. Each transmitter and receiver used for position sensing is built around the iRX 2.0 printed circuit board [6]. Each transmitter continuously broadcasts a unique ID number to the environment. The IR is emitted in a cone shaped region that covers an area of about two to three feet in diameter at the floor level. For consistent IR detection, the transmitters must be mounted such that they cover the whole path on the floor where the user walks on. Additionally, the IR receiver should be mounted or held up high so that the IR signals can be easily detected. More detailed information concerning the IR transceiver system can be found on the web at "http://lcs.media.mit.edu/projects/wearables/locust/".

<u>The Wearable Comouter</u>. As the user moves through a space populated with infrared transmitters, the infrared receiver picks up the IDs from the IR transmitters. This information is sent to the wearable computer via its serial port and is used to determine the current location of the user within the context of an internal map of the area. The map is represented with a binary two-dimensional array. Given two points A and B, a search algorithm finds all routes connecting A to B and selects one with the shortest distance. As the user moves through the space, one of the four cardinal directions (forward, backward, left, and right) or stop is generated and sent to the parallel port of the

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the wearable as a five bit word. The same directional signal is repeated until a new transmitter ID is received, at which point the navigation direction is re-computed.

The Haptic Display and its Controller Board. The haptic display is a 4-by-4 array of micromotors (MicroMo, 06A3-1) that vibrate when excited with a 5-volt D.C. voltage. These motors are mounted in the back of a vest specifically designed to optimize the effectiveness of the stimulators. The vest is designed to be adjustable in size, tight in fit, and protective of its electronics components. It consists of a corset-like inner lining that uses Velcro straps as adjustable fasteners, and an outer layer to create a loosely fit appearance. To protect the motors from being caught in fabrics, each motor is mounted inside a plastic tubing that is snugly fit into a pouch sewn into the back of the inner lining. Several channels are sewn down the side of the vest to provide conduits for wires. In addition to the vest, a backpack is used to carry the wearable computer and control electronics.

The directional output from the wearable is sent to the vest controller board, which drives the motors of the grid in the desired pattern. There are five possible instructions: the four cardinal directions and stop. The cardinal directions are indicated by successively turning on rows or columns of motors in the direction that the user should move. For example, the right signal is generated by pulsing the first column of motors three times, the second column three times, the the third column three times, and finally the fourth column three times. The stop signal is a circular pattern.

3. User Testing

The goals of user testing were to (1) assess the feasibility of using a haptic display for navigation guidance, (2) establish performance measures such as total travel time that can be compared with results from future implementations, and (3) identify issues that need to be resolved in future work.

Twelve MIT students, aged 19 to 30, participated in the experiment. Each subject was asked to use the system to navigate four different paths within the lab. The lengths of the paths were 50 ft, 63 ft, 67 ft, and 71 ft for paths a, b, c, and d, respectively. All paths started at the same location, with two possible destinations, and two ways to reach each destination. Each subject was shown the directional patterns of the vest and instructed to follow the signals they felt, pausing briefly under each transmitter to receive the next signal. Total time of travel and number of errors were recorded for each path. An error was noted when the subject walked off course, and therefore had to restart the trial. Cases where the subject took a wrong turn but was corrected by the system were not counted as errors.

On average, each path took about 1.5 minutes to navigate. The number of errors for each subject and path varied from 0 to 3. The average error rate was 0.5 for paths a and c, and 1.2 for paths b and d. The main cause of error was timing: if the subject passed the location underneath a transmitter too fast, the infrared signal from that transmitter may not register on the receiver correctly. In general, subjects found that the directional signals were comfortable and easy to interpret. Several subjects commented that the vibrations felt like a soothing massage. One problem is the infrared transceiver setup. Since the new signal could be the same as the previous one, subjects had no feedback on when the signal from a transmitter had been correctly registered on the receiver.

4. Summary

We have described the implementation of a wearable haptic navigation guidance system for navigation through unfamiliar spaces. User testing confirmed the feasibility of using a haptic display for navigation guidance. One problem that needs to be addressed is position sensing. In order for the user to walk freely through a space, a position sensor that continuously reports the user's current location is needed. Future work will focus on the incorporation of GPS for position sensing, and then field testing of blindfolded and visually impaired individuals.

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