Wearable Finger-Braille Interface for Navigation of Deaf-Blind in Ubiquitous Barrier-Free Space

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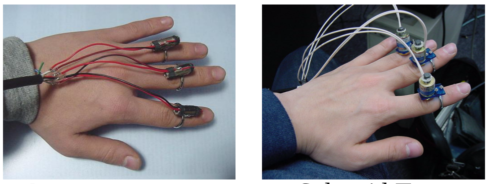
Abstract

In this paper, the implementation of Finger-Braille interfaces for navigation of Deaf-Blind people and the ubiquitous environment for barrier-free application are described. Finger-Braille is one of the commonly used communication methods among Deaf-Blind people in Japan. Two types of Finger-Braille devices, the vibration motor type and the solenoid type, are developed. Each device is connected to a wearable computer, so that Deaf-Blind people can use it in their daily life. In order to support the wearable computers with the Finger-Braille device, a ubiquitous environment is designed and developed at the Research Center for Advanced Science and Technology (RCAST), the University of Tokyo. This environment consists of wireless LAN networks, network cameras, and floor-embedded active radio frequency identification (RFID) tags. In this environment, Deaf-Blind people can be guided and can obtain various types of information by using a wearable computer equipped with the Finger-Braille device and an RFID tag reader.

1 Introduction

According to the report of Ministry of Health, Labour and Welfare of Japan, there are over twenty thousand Deaf-Blind people in Japan. In order to support their mobility, the use of guide dogs, the long white cane and leading blocks for the Blind, which are route finders of the footpaths, has spread widely. However conventional leading blocks for the Blind have a weakness of unexpected change of environment. It is one of the greatly important research topics for the authors to solve such problems and to design novel navigation system with cutting-edge technology, like wearable computer and ubiquitous computing (Amemiya et al., 2002).

Communication support technology and position identification technology are essential to support Deaf-Blind people. As communication interfaces, we proposed wearable Finger-Braille interfaces which are hands-free and can communicate with others in real-time. As positioning technology, we designed the ubiquitous environment for barrier-free applications which consists of network cameras, wireless LAN and floor-embedded RFID tags.



Vibration Motor Type　　Solenoid Type

Figure 1: Wearable Finger-Braille Interface

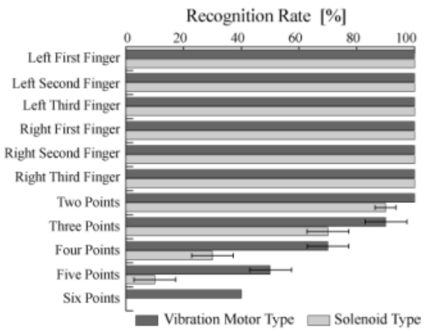


Figure 2: Recognition Rate of Each Device

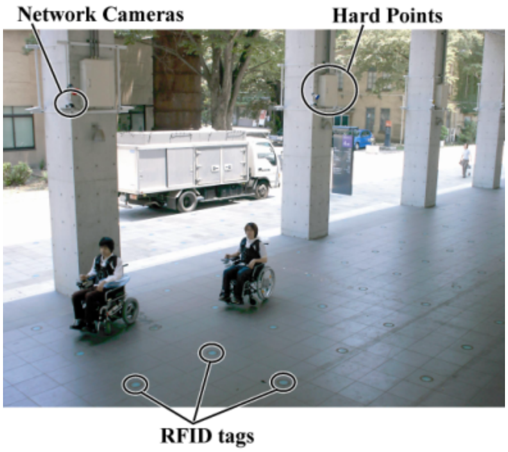


Figure 3: Outdoor Barrier-Free Experimental Environment

2 Communication Device: Finger-Braille Interface

Finger-Braille is a method of tapping Deaf-Blind person’s fingers to transmit verbal information, which are assigned to the digits of Braille. This method enables Deaf-Blind people to obtain information as if they are listening in real-time.

Glove-style interfaces seem to be the most suitable design for the Finger-Braille interface because they are easy to wear. However, they cover the palm or the fingertip which has the highest tactile sensitivity. In this work, two types of ring-shaped devices are developed; (1) vibration motor type and (2) solenoid type (Figure 1). Vibration motor type consists of six small-size, lightweight DC motors, which are currently used for vibration of cellular phones. Solenoid type consists of six tubular solenoids weighting 15 grams each. Each device is fixed onto the setting of the ring. Thereby the palm can be used freely and the device never prevents the user from obtaining original tactile sense information. The initial version of this prototype connects to a parallel port, and the improved version connects to a USB port.

The authors asked five Deaf-Blind people who usually use Finger-Braille to evaluate these interfaces. By transmitting characters or messages by using each prototype the optimum position of the interface device is examined.

In the initial experiment, the devices were firmly set to the root of the fingers. In this location, phantom sensation was experienced and some participants could not recognize the message at all. This experiment revealed that the best place to attach the device was that which is tapped in daily Finger-Braille communication. In the next experiment, the vibration motor type device was more readable than the solenoid type as shown in Figure 2. However, many Deaf-Blind people believed that, if improved, the solenoid type would be better since it is similar to the original Finger-Braille method.

3 Implementation of Barrier-Free Experiment Space

In order to support the wearable computers with the Finger-Braille device, the authors designed and implemented the outdoor ubiquitous experimental environment for barrier-free applications in May 2002 (Figure 3). This environment consists of wireless LAN networks to support communication links among wearable computers, access boxes called hard-points to support network connection and power supply, network cameras to observe users' behavior and floor-embedded active RFID tags to detect the users' position. In the following section, details of the positioning system by using RFID technology are explained.

3.1 RFID Tag as the Position Identification Technology

Many ordinary sensor-based positioning systems, such as electromagnetic, infrared or ultrasonic systems, are assumed to be used indoors (Jeffrey and Gaetano, 2001). The U.S. military's satellite-based Global Positioning System (GPS) is one of the major positioning systems for outdoor use. GPS needs not improve infrastructure and supports users to identify their location with about ten meters resolution. Unfortunately, the satellite signal is not available when the sky is cloudy or between buildings where satellites cannot be seen. As the alternative outdoor positioning system, the positioning system based on RFID tags is proposed. Since the system based on RFID tags does not have such a constraint, it complements the GPS.

In order to obtain the position data continuously, active RFID tags, which operate by using batteries and emit RF signals autonomously, are employed (Spider Tag; RF Code, Inc.). Passive RFID tags, which are activated RF energy transferred from the reader, do not meet the requirement since they can emit very weak RF signal. Each tag periodically transmits a globally unique identifier consisting of seven alphabetical characters every 0.2 seconds. Radio frequency is 303.825 MHz. This time, the shape of the antenna is modified to make the isotropic working range about 1.2 meters.

In the ubiquitous environment, 1349 active RFID tags are embedded in the floor of this environment which is approximately 1700 m^2, and arranged in the 2D shape of a lattice with 1.2 meters spacing. The lifetime of the internal battery of the tag is about 5 years. A small container is designed to protect the tags from outdoor environmental conditions such as rain.

3.2 Position Detection by Using RFID Tags

A user's position can be identified by referring to the ID of received RFID tags. A tag reader can receive multiple signals from RFID tags located at various distances nearby. Since the probability of receiving IDs depends on the distance between the tag and the reader, the exact position can be calculated by simply averaging the known positions of the received tags. Moving average method is also effective in reducing errors caused by unexpected reception from very distant places. So the position can be obtained from the following equation, where n is number of received tags in the time between t and t-1, $\boldsymbol{u}_i$ is the known position of the received tags and $\boldsymbol{x}(t)$ is the user's position at the time t;

$$\boldsymbol{x}(t) = \frac{1}{n+1}\left\{\boldsymbol{x}(t-1) + \sum_{i=1}^{n}\boldsymbol{u}_i\right\}. \quad (1)$$

The initial position $\boldsymbol{x}(0)$ is negligible since $\boldsymbol{x}$(t) will be continuously calculated and the influence of the old data decreases exponentially with time. For evaluation of Equation 1, users walked a straight path in the environment at the constant speed and recorded their positions every

0.1 seconds. The results are shown in Figure 4. As a result of comparison of actual experimental data and calculated data, the standard deviation was determined to be about 400 mm, depending on the position where the user wore the reader. Time delay was approximately 0.1 seconds.

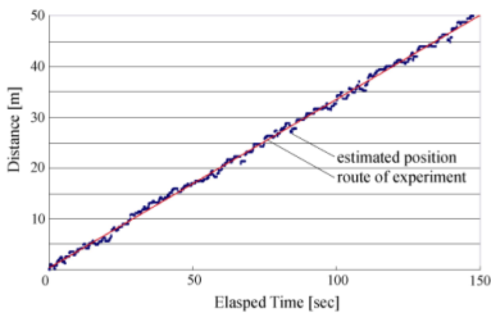


Figure 4: Comparison of Measured Location and Real Location

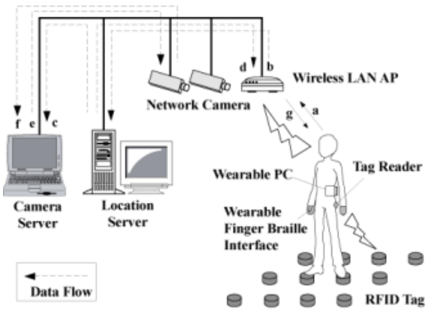


Figure 5: Block Diagram of Virtual Leading Blocks

Figure 6: Suit for Wearable Computer

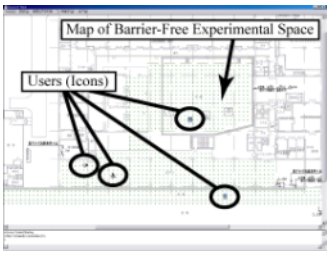


Figure 7: Server Monitor

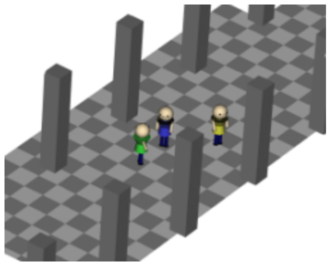


Figure 8: 3-Dimensional Monitor

3.3 Virtual Leading Blocks

To solve the problems of conventional leading blocks for the Blind people such as unexpected change of surrounding environment (for example, abandoned bicycles on these blocks), the route of the virtual leading blocks should be dynamically changed by monitoring the changes of environment. This application is called *Virtual Leading Blocks*. To develop this kind of system, images obtained from the network cameras will be useful. Figure 5 shows the block diagram of the wearable computer with the Finger-Braille device and the ubiquitous environment for the virtual leading blocks. The vest shown in Figure 6 was designed in collaboration with fashion designer Ms. Michie Sone. Unlike the former reader system that was installed in long white cane, this reader is installed in the vest apart from the cane since the cane must be light so that the user's arm does not get tired.

4 Future Works

More accurate location data is required for the practical use of this device. In addition, to improve the positioning algorithm, other positioning technology such as image processing by network cameras should be integrated. Actual experiments with people with disabilities as participants should be conducted. To realize a truly wearable interface, we plan to fabricate a wireless Finger-Braille interface.

5 Conclusion

In this paper, we presented the following. First, wearable Finger-Braille devices which enable Deaf-Blind people to obtain verbal information were described. The vibration motor type is more readable than the solenoid type however, Deaf-Blind participants believe that if improved, the solenoid type may be more effective than the vibration motor type. Second, positioning system which uses RFID tags in the ubiquitous environment has also been described. This system has a positioning ability with a margin of less than one meter. Finally, the possibility of navigation of Deaf-Blind by integrating two novel technologies, wearable computer and ubiquitous environment, has been discussed and virtual leading blocks have been proposed.

6 Other Related Applications

In this section, closely related applications other than barrier-free application that have been developed for the experimental environment will be introduced.

(1) *Server Monitor Application*. This application provides the users with a browsable model on Windows platform. We have implemented a map which is updated in real-time with location data. Many users can be viewed in the monitor at the same time over the network (Figure 7). An additional gyro sensor allows us to view the orientation of the users (Figure 8).

(2) *Music Application*. This application can change the sound parameters of software of wearable computer into various setting of volume, balance and pitch as if users are on the keyboard of a piano. This application is more closely relate to entertainment application rather than navigation application. Of course this application can be used to inform a Blind person of the existence of any near obstacles or the entrance of a route.

(3) *Camera Tag*. According to the user's position identified by RFID tags, the server can select the camera in the position from where the user can be captured most easily. The camera with recording lamp follows the user as if it is 'playing tag'. This *Camera Tag* system is based on CGI script, and the camera images can be seen through a web browser.

In addition, to support physically challenged persons, an automatic navigation and control system for electric wheelchairs is under development as an extension of the virtual blocks application.

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