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Assessment of a simple obstacle detection device for the visually impaired

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ABSTRACT

A simple obstacle detection device, based upon an automobile parking sensor, was assessed as a mobility aid for the visually impaired. A questionnaire survey for mobility needs was performed at the start of this study. After the detector was developed, five blindfolded sighted and 15 visually impaired participants were invited to conduct travel experiments under three test conditions: (1) using a white cane only, (2) using the obstacle detector only and (3) using both devices. A post-experiment interview regarding the usefulness of the obstacle detector for the visually impaired participants was performed. The results showed that the obstacle detector could augment mobility performance with the white cane. The obstacle detection device should be used in conjunction with the white cane to achieve the best mobility speed and body protection.

1. Introduction

Mobility refers to one's ability to identify the relation between their position and the objects in the environment and then move independently, safely and efficiently (Kuyk et al., 2010). The most obvious problem faced by blind persons is moving around in their environment without bumping into unexpected obstacles (Molton et al., 1998). Obstacle detection is thus one of the major problems to be solved to ensure safe navigation. The white cane is the most popular and traditional navigation aid for the visually impaired (Molton et al., 1998; Snaith et al., 1998; Dakopoulos and Bourbakis, 2010) in spite of modern technology-based devices (Clark-Carter et al., 1986; Schellingerhout et al., 2001). The white cane is the simplest, cheapest and most reliable device thus far. It can be generally applied to detect static obstacles on the ground, uneven surfaces, holes and stairs (Cardin et al., 2007). However, the reach of the cane is limited (Yasumuro et al., 2003) and obstacles not located on the ground are hardly detected.

A number of electronic travel aids (ETAs) for the visually impaired have been developed for navigation and obstacle detection/avoidance. Dakopoulos and Bourbakis (2010) presented a comparative survey among portable/wearable obstacle detection/avoidance systems for the visually impaired. Cardin et al. (2007) also reviewed several obstacle detection devices developed in the literature.

The common ETA features based upon new technologies in the literature may conclude that information was gathered from the environment using sonar, laser scanner or stereo camera vision. The user was generally informed through auditory and/or tactile sense (Cardin et al., 2007; Dakopoulos and Bourbakis, 2010). Other features and disadvantages of ETAs are briefly summarized as follows. The signal processing of many novel ETAs usually required complicated computer algorithms to provide more complete information about nearby obstacles (Cardin et al., 2007; Sainarayanan et al., 2007). The sensors in some ETAs could only detect obstacles on the ground just like the white cane. Other ETAs had more functional body protection capabilities (e.g., shoulder protection, Cardin et al., 2007). Some ETAs were small, light and handheld, e.g., Miniguide (Phillips, 1998), while other ETAs were bulky, e.g., Navbelt (Shoval et al., 1994) and GuideCane (Ulrich and Borenstein, 2001), making them difficult to hold or carry when needed. Although some aids were portable, they still required manual operation (e.g. Ghiani et al., 2009), making co-incident use of conventional aids difficult or impossible (e.g., white canes). One or more cameras in some ETAs required mounting on headgear (Sainarayanan et al., 2007) or the frame of eyeglasses for obstacle capture (Meers and Ward, 2005 cited in Dakopoulos and Bourbakis, 2010). Such devices may be not accepted by some visually impaired individuals because they may feel cumbersome or embarrassed to wear in public places. Some ETAs required extensive training

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periods (Snaith et al., 1998). The relatively high cost of ETAs available in the market is a discouraging feature.

To fill the detection gaps in the white cane and overcome the disadvantages of ETAs, a compact size, lightweight, low-cost and simple detection feedback obstacle detection device was developed and explored in this study. The prototype of this detector was developed and evaluated using blindfolded sighted and visually impaired participants in travel experiments. This study hypothesized that different travel aid devices would alter walking efficiency and obstacle detection for visually impaired persons. The aims of this study were to compare ETA walking efficiency and obstacle detection capability using both blindfolded sighted and visually impaired participants under three test conditions.

2. Method

2.1. Survey of mobility needs

At the start of obstacle detector development a survey of visually impaired students was conducted to determine their mobility needs in daily life. Participants were interviewed individually using a constructed questionnaire. The data were then recorded by researchers. The first part of the questionnaire contained the participant's personal data which included name, gender, age, educational level, blind or visually impaired condition, peripheral (side) vision, awareness of light, colour vision and any other impairment. The second part asked for travel experiences including daily activities, use of travel aids and obstacle collision experiences in the environment. Several discussions were held with teachers, who were blind and teaching in the school, to modify the questions before the interview was performed. The purpose of this study was clearly explained to the participants prior to the interview. Informed consent to participate was obtained from the participants in this study.

Thirty-one participants were junior high and senior high students from a school for the visually impaired in Central Taiwan. The students had received at least six-month training in orientation and mobility before joining this study. During the interview one student was determined to have a learning disability, and thus, was eliminated from the study. A total of 30 valid participants included 15 junior high school students (aged 13–15, 9 males and 6 females) and 15 senior high school students (aged 16–19, 9 males and 6 females). As self-reported during the interview, 25 students (83.3%) said they were blind and 5 classified themselves as having low vision, 27 (90.0%) with congenital impairment and 3 with acquired impairment.

All interviewed participants lived at school during the weekdays and could choose to return home or stay at school during weekends and holidays. This study (including a survey and an obstacle detection experiment) was approved by the Institutional Review Board for Ergonomics Experiment of Chaoyang University of Technology.

2.2. Travel aid development

2.2.1. Obstacle detector

The obstacle detector developed in this study was based upon an automobile parking sensor, consisting of 3 main modules; a sensing module with transmitting and receiving functions, a processing module and a warning module. Table 1 shows the dimensions and photos of the ultrasonic obstacle detector modules. The detector architecture is illustrated in Fig. 1. The detection system works by sending out ultrasonic pulses that are reflected back to the sensor by obstacles within the sensor detection envelope. The reflected signals are processed by the processing module, which in turn activates the warning buzzer to alert the user that there is an obstacle in the travel path.

The three detector modules were commercial electronic parts packed as a set used for obstacle detection while car-parking. The default distance sensitivity setting of the sensor was adjusted to a lower level for this study. Another detection system modification was made for the detector power connection. A 12 V dry battery was sufficient for detector use by an individual. A 12 V battery with 2 Ah capacity was used to supply the experiment with sufficient operational time during a day. The obstacle detector was small and lightweight, as shown in Table 1. One sensing module was mounted on the participant's body with the other two modules placed in a small bag on a belt worn on the waist or in a pocket. Two sensors were attached to the participant's chest and waist, respectively, during the experiment. The reason for this arrangement was to test if the detector could effectively detect obstacles not located on the ground.

The sensor detection envelope was investigated in the laboratory before the detector was assessed in the field. A high flat wooden board (height 245.4 cm, width 32.5 cm) and three university students were employed to move around as targets for detection envelope measurements. The mean age of these students was 27.0 yr/SD 2.6 yr; mean body height 165.6 cm/SD 4.6 cm; and mean body weight 60.3 kg/SD 10.8 kg. The test direction was varied every 5° from the mid–saggital plane to the right and left sides. Each angle for each target was tested twice. Another test for detection distance was performed at the university campus after the laboratory test. The obstacles on the campus included the iron railings outside a building and in an athletic field, the net in a volleyball court, the bonnet of sedans and the stairways. An individual (stature 163.3 cm and body weight 68.4 kg) was asked to wear a sensor on his chest (120.4 cm) in the test. A parking lot gate arm (7.5 cm in width) was also tested in a parking lot by the individual with a sensor worn on his waist.

2.2.2. Evaluation of the electronic obstacle detector

Two experimental stages were performed for obstacle detection evaluation in this study. Five blindfolded sighted participants (4 males and 1 female) who were graduate students at the university were recruited to detect obstacles in a simulated environment. Fifteen visually impaired participants (10 males and 5 females) were then invited to travel a real world mobility route. The visually impaired participants included 5 junior high school students, 6 senior high school students and 4 teachers from a visually impaired school in Central Taiwan. These participants were totally blind with no residual vision. Thirteen suffered from congenital visual impairment. All visually impaired participants had received at least six-month training in orientation and mobility prior to this study. Table 2 shows the participants' personal data and anthropometric measurements.

A corridor 30 m long outside the laboratory at the university was used as a simulated route for the first experimental stage. Nine obstacles existed in the corridor, including 5 purposefully placed obstacles (1 bicycle, 2 chairs, and 2 overhanging cardboard boxes) arranged in the middle of the corridor and 4 natural obstacles (2 shoe cabinets and 2 shelves) situated against the corridor walls. The positions of the purposefully placed obstacles were changed for each test and each participant. No arrival time was recorded at each checkpoint (i.e., the obstacle location) in this experimental stage and only the total time for each test was recorded.

The route around the school campus travelled by visually impaired participants was used for the second-stage test. The route shown in Fig. 2 was determined based upon the concern for the participant's transportation safety when the experiment was proposed and discussed with the school staff. Eight obstacles were