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Wearable Haptic Device as Mobility Aid for Blind People: Electronic Cane

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Abstract

Purpose: The conventional long cane, largely used for mobility of visually impaired people, presents some limitations, such as the short-range detection of obstacles and the inability to protect against head-level obstacles. The purpose of this study was to develop and test a wearable haptic interface system attachable to a long cane in order to detect obstacles and provide notification to the user.

Methods: The components used for the system were: three hook and loop wristbands containing three vibrating motors each (haptic interface), three HC-SR04 ultrasonic sensors (obstacle detection and direction), an Arduino® microcontroller board (control of all system components), a long cane with a roller tip, and a portable power bank.

Results: During the test phase, the system detected obstacles, such as steps, unevenness/holes on the ground, bushes, and tactile floor markings.

Conclusions: The wearable haptic interface adapted to a long cane developed and tested in this study proved to be viable and a valuable asset as a mobility aid for visually impaired individuals.

Keywords: Visual impairment; Blindness; Mobility; Electronic cane; Assistive technology; Wearable; Haptic; Development

Introduction

The World Health Organization estimates that two billion people worldwide have visual impairment or blindness. Visual impairment dramatically affects the quality of life, impacts mobility, compromises autonomy and the performance of daily life activities, leisure, and access to education and work [1-6]. Assistive technologies are used in the rehabilitation process. The purpose is to improve the functionality that is being disrupted by the disability, thus increasing autonomy, improving quality of life, and promoting social inclusion. Assistive technology can become an indispensable tool for individuals with disabilities, but there are some difficulties related to the acquisition and maintenance of such technology. The cost, maintenance service availability, design, and ergonomics can become a challenge. The availability of assistive technologies is an important factor that defines if the individual with disabilities will resume some of their daily activities [7].

The white or long cane is the most widely used assistive technology for the mobility of people with visual impairment. It enables the detection of obstacles ahead of the user through the touch of its tip on the ground, providing information about its contact area. The long cane can either have a regular tip or a roller one. The roller is ideal for scanning the surface by the roller movement; the regular tip is for recognizing the surface type [8-11].

Although the long cane is considered the most effective and used assistive technology by individuals with visual impairment, it has some limitations, such as the short range of obstacle detection (less than two steps or at a distance equal to the cane length) and the inability to detect obstacles at head level [8,9]. Because of these limitations, many efforts have been made to develop and commercialize products to supply the existing demand in the mobility field. Some examples are bracelets and other wearable devices, systems attachable to long canes, and electronic canes; all of them with the primary purpose of identifying or detecting the presence of obstacles in the user's route and notifying them, either by sound or vibration feedback (classified as mobility aids). Some of these provide location information by GPS (Global Positioning System), which is classified as an aid to navigation [8,9,12].

Currently, five models of electronic canes are sold worldwide, and all of them are manufactured outside of Brazil: SmartCane™, India; UltraCane, UK; Safe Walk, Italy; WeWALK, England; BAWA Cane, Malaysia. The main characteristics of each cane are presented in table 1 [13-17]. Despite the proposal of solving important mobility and accessibility problems that are common among individuals with visual impairment, these devices can be economically unavailable for most of these individuals due to the cost of acquisition, import and export taxes (in case of maintenance needs), and the monthly income of these individuals [18].

Table 1: Characteristics of the electronic canes currently on the market.

Cane	Obstacle Detection (Sensor)	Sensor Position	Sensor Reading Range	User Feedback	Adapted to Long Cane	Selling Price
SmartCane™	Ultrasonic	Upper	Up to 3m	Handle vibration	Yes	None*
Ultra-Cane	Ultrasonic	Upper	Up to 4m	Handle vibration	No	US$ 807
Safe Walk	Ultrasonic	Lower	None*	Handle vibration	No	None*
WeWALK	Ultrasonic	Upper	80 to 250cm	Handle vibration	Yes	US$ 599
BAWA Cane	Ultrasonic	Upper	Up to 4.5m	Handle vibration and audio	Yes	US$ 579

*None = Information not provided by the manufacturer.

The development of a wearable haptic interface system that notifies the presence and direction of ground and air obstacles and can be attached to a long cane may significantly improve the mobility and navigation of individuals with visual impairment. This study's purpose is to develop and test a wearable haptic interface system attachable to a long cane for obstacle presence and direction notification.

Methods

Design

The purpose of the wearable haptic interface adapted to a long cane is to notify its user about the detection and direction of obstacles through the vibration of its wristbands. This system is composed of three hook and loop wristbands containing three vibration motors each (haptic interface), three HC-SR04 ultrasonic sensors (obstacle detection and direction), an Arduino® microcontroller board (control of all system components), a long cane with a roller tip, and a portable power bank (Figure 1). The obstacle detection of this prototype was programmed to be up to one meter away. Since the system was designed to be attached to a long cane, parts were produced to protect its components using additive manufacturing.

Results

Figure 2 shows the wearable haptic interface attached to a long cane, highlighting its components and wristbands. The test was carried out in an urban environment to simulate its application in a real setting where mobility is required. Two blindfolded study team members performed the test wearing the interface system. They were instructed to move around a block where the Nestor Schor Research Building is located, at the Federal University of São Paulo, guided by the vibratory feedback provided by the system. These tests were performed in order to verify the performance of the haptic interface in situations such as slopes, steps, bushes, or water puddles. Figure 3 demonstrates the detection of urban obstacles by the wearable haptic interface system during the test.

Discussion

During the tests, the system demonstrated the ability to identify barriers and provide feedback to the user. The wearable haptic interface enabled the distinction between the vibrations resulting from the friction of the cane's tip with the ground and the vibration of the motors used in the system's wristbands, proving to be essential for reliability and safety while using the cane.

Most of the currently available electronic canes use vibratory feedback in their handles, not in a wearable system. Depending on the shape of the handle and the position in which it's held by the user, there may be a change or absence of feedback perception. A wearable system can help attenuate the effects of this variability and avoid the perception variation of this type of feedback. Although there is no significant difference in the auditory feedback (in terms of performance), vibratory feedback is more advantageous outdoors, so that the user can stay alert to ambient noises which are essential for safe mobility [12,13,17-25].

The ultrasonic sensors, commonly employed in the electronic canes marketed today for obstacle detection, proved effective

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feedback within the predefined range in the wearable haptic interface system. It was possible to detect obstacles up to three steps away from the user. Furthermore, this type of sensor proved advantageous due to its ability to detect slopes, steps, bushes, overhead trash cans, solid and overground obstacles such as poles, newsstands, and walls. This indicates that the prototype can solve an important issue concerning this population's mobility, which is the detection of obstacles on their route, in agreement with the previous findings of Kim et al. [22]. Massive obstacles - such as stair steps - and non-massive - such as bushes - were successfully detected. It is worth noting that this type of sensor's accuracy is related to the obstacle's nature [22]. The prototype had its sensor at the tip of the cane, enabling the detection of obstacles without the need for the tip to actually touch the obstacle. This further helps solve some usability challenges related to the use of electronic and long canes [13-17,22].

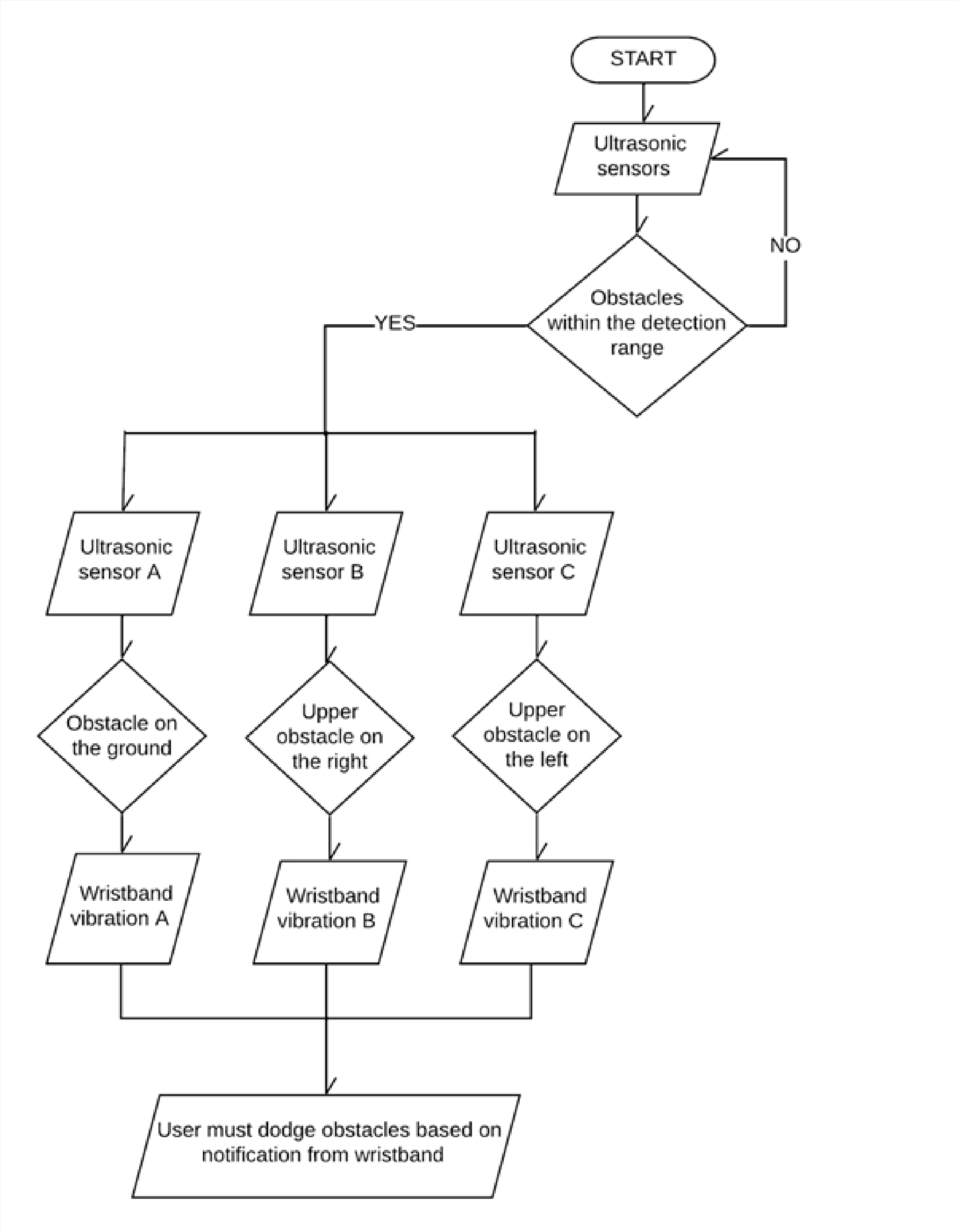

Figure 1: Schematic of the operation of the haptic interface.

Note: The upper obstacle was located above the body's midline.

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Figure 2: Wearable haptic interface attached to a long cane.

Note: 1 - Wristband A: notifies the presence of obstacles on the ground; 2 - Wristband B: notifies the presence of obstacles higher to the right; 3 - Wristband C: notifies the presence of obstacles higher to the left; 4 - Sensor A: detects obstacles on the ground; 5 - Sensor B: detects obstacles higher to the right; 6 - Sensor C: detects obstacles higher to the left; 7 - Portable power bank.

Figure 3: Urban obstacle detection by the wearable haptics interface system during the test.

Note: 1 - Step detection: sensor A; 2 - Detection of unevenness/hole in the ground: sensor A; 3 - Detection of side bushes: upper sensor C; 4 - Detection of the tactile floor marking: sensor A.

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Our prototype was adapted to the long cane because, according to the literature, this is the cane widely used by individuals with visual impairments. The roller tip was chosen because of its ability to cover a larger area in its sweep over the ground, being more advantageous than the dry tip. Comparing the models of canes currently marketed, only the WeWALK and SmartCane™ are adapted to the roller tip [9,19,25]. Besides facilitating the system's adaptation to a long cane, the design materialized by additive manufacturing (3D printing) facilitates the production and customization of the system. Any necessary changes can be done in the three-dimensional drawing and subsequently printed to match the idealized design [20,21].

A recent study by Rodrigues et al. [26] found that implementing technological items would be a positive differential in the development of assistive technologies and that mobility is the greatest daily life difficulty faced by individuals with visual impairment. In a study with ten volunteers with visual impairment who used the long cane as an assistive technology for mobility, all of them showed interest in learning new assistive technologies for mobility; seven of them justified their choice due to the curiosity and the opportunity to improve their navigation skills [26,27].

The rehabilitation of individuals with visual impairments also depends on the provision of assistive technologies. Therefore, the development of this type of technology is essential. However, considering the current costs and importation taxes, this should be developed nationally [6,13-18,28,29]. The marketing of a system such as the one proposed in this study will likely contribute to the improvement of mobility and autonomy of this population, positively affecting their inclusion in society.

Conclusion

The present study enabled the development and testing of a wearable haptic interface system for the detection of obstacles and their direction through its bracelets. The wearable haptic interface adapted to a long cane proved viable to be used as a mobility aid for individuals with visual impairment.

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Conflict of Interest

All authors declare that there is no conflict of interest in this work.

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