

Haptic based walking stick for visually impaired people

M. P. Menikdiwela¹, K.M.I.S.Dharmasena², A.M. Harsha S. Abeykoon³

Department of Electrical Engineering, University of Moratuwa
Katubedda, Moratuwa, Sri Lanka

¹menikdiwelamedhani@ymail.com

²ireshashamini88@gmail.com

³harsha@elect.mrt.ac.lk

Abstract— This paper proposes a new product concept of an electronic travelling aid with haptic perception for the visually impaired people. The device is much similar to the conventional white cane in appearance and it is fabricated using ultrasonic sensors, a vibrator motor scheme, a controller and a power unit inside the walking stick. The sensor system comprises of three ultrasonic sensors to acquire obstacle distance measurements and the user can interpret the distance information as a tactile sensation. The sonar sensors are fired with a sequential firing mechanism to avoid crosstalk. Distance is felt by the user in terms of the vibration intensity change. This device was tested with blind school students and results are presented.

Keywords— haptic sensation, vibration feedback, walking stick, navigational aids

I. INTRODUCTION

Each individual should have the ability to move independently and safely around the environment. The visually impaired people lack the ability of independently walking without a special aid. Thus, the electronic travelling aids (ETA) [1] have been developed to provide the necessary support for visually impaired individuals. Most commonly used methods of supporting the visually impaired people are employing animals such as guard dogs, sighted souls and devices. Because of the technological improvements, these conventional methods are being replaced with much more sophisticated electronic based equipment.

Different detection principles are used to detect obstacles. Sometimes a laser or ultrasonic beams are used in order to detect the obstacles. For instance the “Navbelt” which is a guidance system developed by Borenstein et al. in University of Michigan, uses ultrasonic range sensors [2]. With the help of eight sensors the system manages to create a map of the angles and the distance of any object at a certain angle [3]. Stereo vision cameras and complex image processing mechanisms have been used to identify obstacles [4][5][6]. The “voice” system implemented by the Meijer et al. [7], which is based on one-to-one image-to-sound mapping, uses digital cameras and headphones to capture images and interpret them as rapidly changing sound patterns. The “NAVI” system intended to assist blind people for obstacle identification during navigation [8].

The captured video frames are analyzed using ‘fuzzy learning vector quantization’ neural network to classify the pixels either as background or objects. The scientist of Wright State University has developed a 2D vibration array used as a major component of an assistive wearable navigation device for visual impaired people [9].

Auditory way of giving a feedback regarding the environment is widely used and is being used in “navi” and “voice” [10]. Use of auditory feedback has both advantages as well as disadvantages. It is clear that interference of hearing process makes the visually impaired person auditory impaired as well. Auditory based navigation system sometimes creates a nuisance to the user. But on the other hand with the use of auditory data, more precise and a higher range can be achieved as different sequences and loudness options can be chosen. It is well understood that human’s hearing system is quite capable of learning to process and interpret extremely complicated and rapidly changing sound patterns.

In contrast, haptic based systems provide more convenient solutions. There are numerous ways of providing haptic feedback. The electron-neural vision system (ENVS) by Meer et al. of University of Wollongong [11] exercise this method where it uses transcutaneous electrical nerve stimulation (TENS) unit and the TENS gloves. The information is transformed via TENS to electrical pulses that stimulate the nerves in the skin via electrodes located in the TENS data gloves [12]. Here the amount of stimulation is directly proportional to the distance to the objects. Other methods such as Tactile handle which typically employs a tactile array, where each actuator matches one finger phalanx. All the above mentioned methods are having common demerits. NAVI belts, TENS gloves, stereovision cameras [13][14] etc handling is harder than the traditional white cane for which visually impaired people are used to. Because these instruments are giving extra weight to the person and consume high power. Users usually had to carry big batteries as well. Proposed product is developed using the traditional white cane and it’s just below 2kg. If the device fails due to battery exhausting, still it could be used as the traditional white cane. Therefore this product was widely accepted by the blind community because of its ease of use.

II. SYSTEM CONFIGURATION

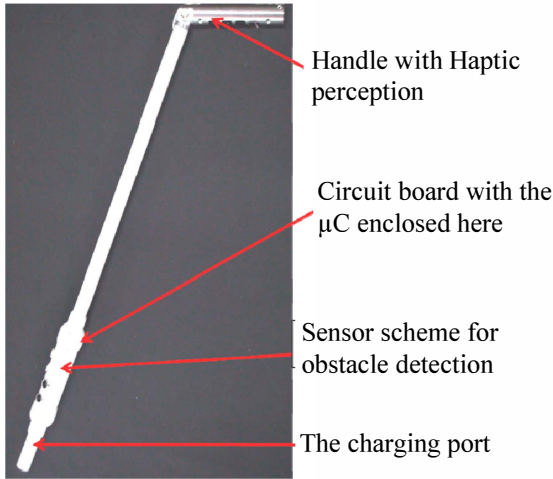


Fig. 1 Overview of the walking stick

Figure 1 shows the overview of the proposed walking stick which is similar in appearance to the traditional white cane. The system consists of a sensor panel for obstacle detection and a set of vibrator motors were positioned inside the handle to alert about the obstacles. The sensor signal was processed by the controller to feel the vibration intensity variation which is proportional to the distance to the obstacle.

A. Recreating Human Visual Field

Normally, the human visual field covers an area of 180 degrees horizontally and vertically. In the proposed design, the visual field was selected horizontally up to 150 degree and vertically up to 60 degrees and is adequate when walking.

B. Sensor System

There were two options when choosing the sensors for data acquiring, either Sonar sensors or IR sensors. Sonar sensors had been chosen because it is the most effective sensor type to detect obstacles in an area. Then a test was carried out to measure the compatibility of the sensor with the design requirements. The sensor readings had been taken by varying the distance to the obstacle. Figure 2

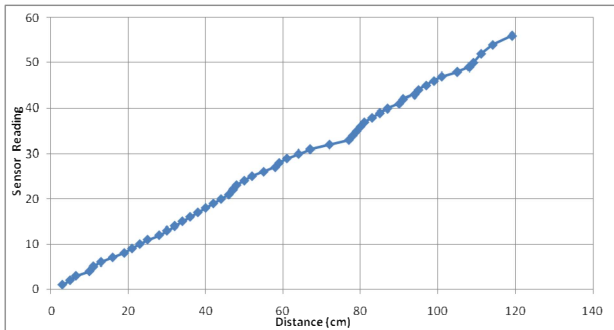


Fig. 2 Sensor reading vs Distance of sonar sensor

shows the variation of the sensor reading with the distance.

The angle of coverage for a single sensor was approximated as 50 degrees. Therefore three sonar sensors were sufficient to fulfill the requirement of obtaining the visual field. According to the design, incoming environment had been divided into three areas and the obstacles in each area were conveyed to the operator in a form of vibration.

When positioning the sonar sensors their fields of view should not overlap with each other. If they do, there will be a significant decrement in accuracy. If there are gaps between sonar areas, the obstacles in that gap will not be detected. As the obstacles may have a certain thickness the small gap is should be there. The selected sonar sensor has a wider range in short distance and a narrow range in long distance. Therefore the sensor positioning test was carried out to find the optimum situation by considering gaps and intersections. Table 1 displays the test results for sensor positioning. The plus mark indicates the intersections and the minus mark indicates the gaps. 45 degrees was selected as the mounting angle between two sensors.

TABLE 1
TEST RESULTS FOR SENSOR POSITIONING

Angle between two sensors (ϕ)	30 ⁰	35 ⁰	40 ⁰	45 ⁰	50 ⁰	55 ⁰
Intersecting angle in short distance	+18 ⁰	+13 ⁰	+9 ⁰	+3 ⁰	-2 ⁰	-8 ⁰
Intersecting angle in long distance	+14 ⁰	+9 ⁰	+3 ⁰	-3 ⁰	-8 ⁰	-14 ⁰

Three sonar sensors were vertically mounted on the stick keeping an angle of 45 degrees between them. Sonar system was tested by keeping objects in different heights and the maximum height that could be detected was around 1 m from the ground level. The maximum distance to the object detection was limited up to 1.2m.

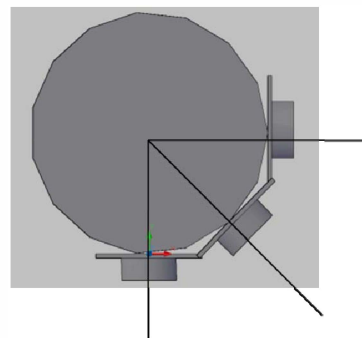


Fig. 3 Horizontal mounting of sonar sensors

C. Haptic Based System

The data that acquired from each sensor was processed by a microcontroller and then transferred to the haptic

based system. Received signals were transferred to the person in a form of vibration.

After compromising between the advantages and disadvantages, haptic perception was selected as the medium of data transferring. Solenoids valves and vibrator motors can be used to generate the haptic sense. Among them vibrator motor was the most feasible option.

According to the design every vibrator motor was assigned to a separate sonar sensor. The sensor signals were transformed to a PWM based signal. The PWM duty is inversely proportional to the distance. The distance to the obstacle could be identified by the changing intensity of the vibration.

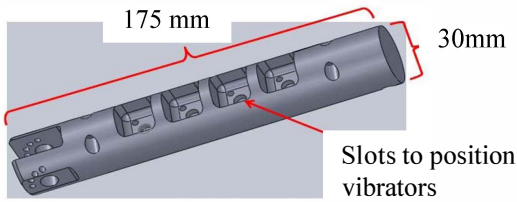


Fig. 4 Side view showing the joint and the slots

As shown in figure 4, three slots were allocated for vibration and one as a power switch. The vibrators were positioned inside the cavity with a rubber enclosure layer to avoid the spread out of the vibration to the handle. If not such vibrations could easily mislead the operator.

III. CONTROLLER DESIGN

Two major controlling parts included in this design are eliminating the cross talk and signal processing for the vibrators.

A. Eliminating the Crosstalk

Three sonar sensors were operated with the sequential firing method. This firing method was selected to avoid the occurrence of crosstalk. Operating cycle of a single sensor would take less than 40 ms so that, to start the next triggering cycle it would take a maximum of 120ms. Therefore it does not affect to the speed of the process. This process was continued by triggering each sensor one after the other.

Figure 5 shows the functional block diagram of the data acquisition system.

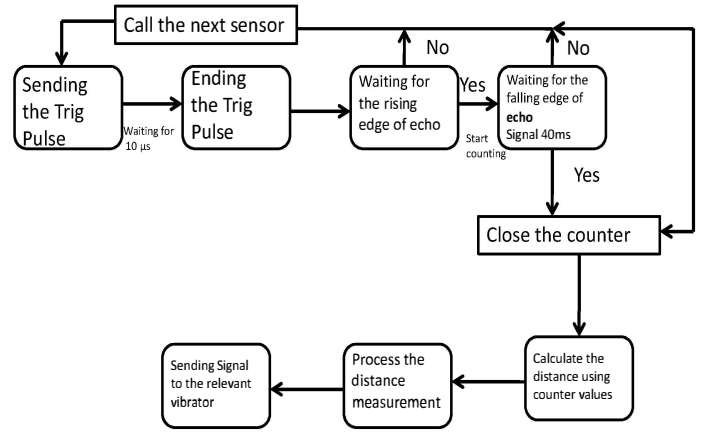


Fig. 5 The functional block diagram – algorithm for data acquisition

B. Signal Processing for the Vibrators

Visually impaired person should be able to discriminate the distance to the obstacle. Walking stick was designed, such that the proximity to the obstacle was represented as the vibration intensity. Vibration intensity was controlled using the PWM duty fed to the vibrator motors.

IV. HARDWARE IMPLEMENTATION

A. Fabrication of the Circuit Board

This circuit was included with two voltage regulator ICs which supply power to the microcontroller and the vibrator arrangement separately. 7V was supplied to the voltage regulator to get the required output of 5V. The IC can withstand high power dissipation related effects and handle output current up to 1.5A.

Vibrator motors were fed power through an integrated circuit that consists of high current Darlington arrays. It provides protection to the microcontroller from the draining high currents of vibratos motors.

B. Microcontroller

Mbed microcontroller was used as the main controller because it has a high processing speed, easy programming capability with C/C+ languages and the user friendly interface for testing. The design required several PWM ports and that was fulfilled by the mbed.

C. Power Supply Unit

The maximum power usage of the system was 1.27W. The system should be able to operate at least six hours continuously without recharging. Therefore, it required a battery with 1500 mAh.

The battery was charged with a 12V DC power supply. A power supply unit which has 300 mA capacity transformer was designed to recharge the battery pack. The charging port of the stick was designed with an easy plugging mechanism.

V. RESULTS

Several tests conducted to check the usability of haptic based walking stick. A group of blind students from Ratmalana blind school, Sri Lanka were selected. Their response of using the walking stick was recorded and presented here in the result section. The selected group was in the age range of 13-16 years who are fully blind.

The identification of the obstacle through vibration mechanism was a new experience to them. They were used to walk with the traditional white cane for years. Several experiments were conducted to test them with haptic based walking stick.

A. Test 1- Human - Device Interaction

Six students participated to the test of obstacle identification. The path created with 10 obstacles and they requested to find their way by avoiding those obstacles. Figure 6 shows the top view of the obstacles and how student "E" (As shown in figure 7) had identified his way. According to the diagram the student's obstacle identification ability is 70 percent. Figure 7 shows the identification ability of each student. On average students obstacle identification ability is around 74 percent in the initial attempt. Consequently they were allowed to use the walking stick for 15 minutes and the obstacle identification ability rose up to 80 percent.

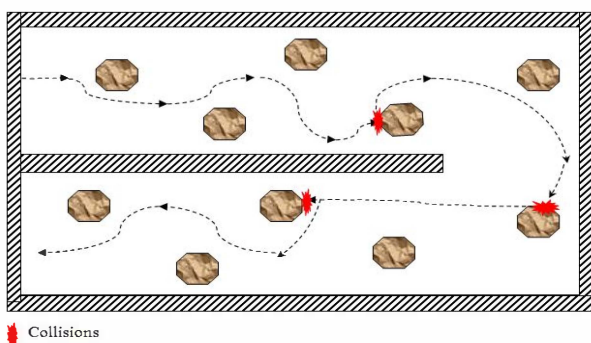


Fig. 6 Test arena

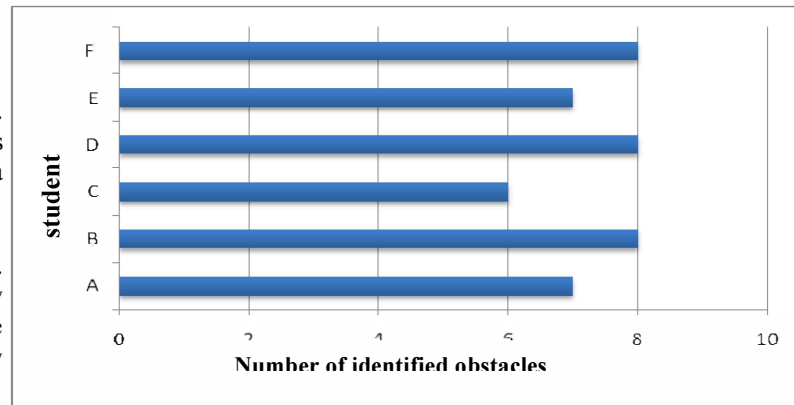


Fig. 7 Device interaction

B. Test 2 – Learnability

A new student was selected randomly for this experiment and he was requested to navigate through the obstacles in 5 consecutive attempts. Some of them were unable to identify the obstacle in their first attempt but after several attempts they used to familiar with the stick. Figure 8 shows the test result and it shows the learnability.

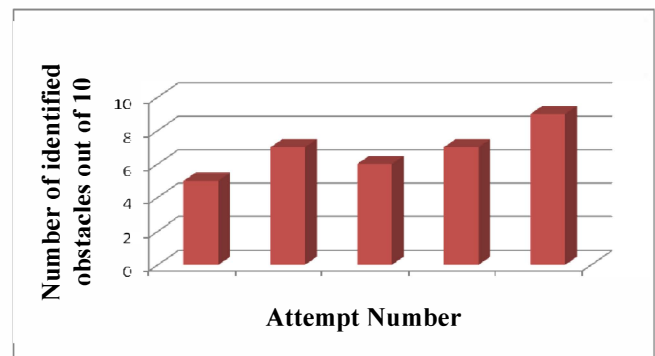


Fig. 8 learning ability measurement

C. Test 3-Walking Between Two Obstacles.

The distance was reduced between two obstacles and checked how the space was identified. Figure 9 shows testing arena and "d" is the varied distance. For this test another 8 students were selected and they were allowed to use the walking stick for 10 minutes each. Figure 10 shows the gap identification capability. In large distances most of the students were able to identify the space, but in small distance only a few numbers of students had identified the space. On average, the identification of gaps (distance) is less than 0.4m.

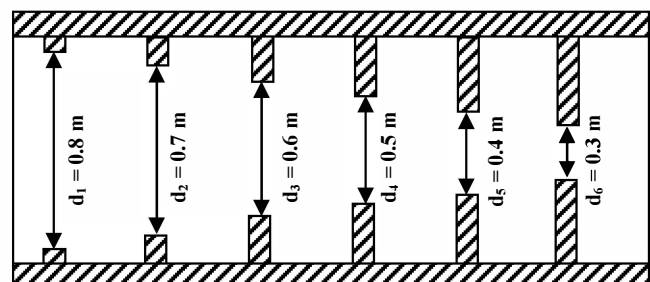


Fig. 9 Test arena 2

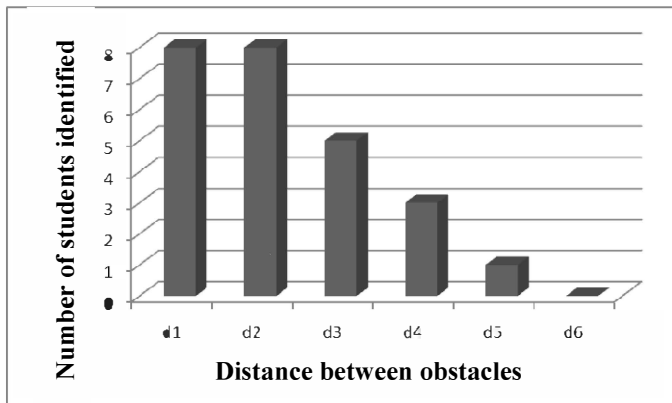


Fig. 10 Walking between two obstacles.

D. Test 4- Changing Obstacles Height.

When visually impaired people walk along an uneven ground, there are obstacles on their way with various heights. A test was carried out with varying the height and students were asked to identify the obstacles at a distance of 1m. Eight students were participated to this test. Object detection capability was as shown in figure 11. Device is capable of detecting obstacles which are greater than 0.1m.

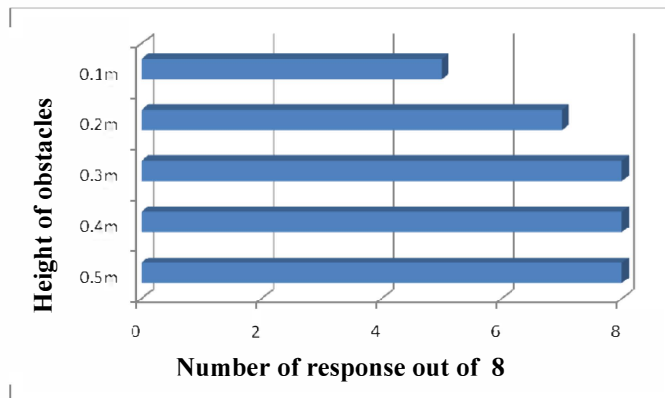


Fig. 11 Obstacle detection with various heights

E. Test 5 – Identification of the Distance Variance

The walking stick was designed such that when obstacles are nearby the vibration frequency gets higher. This experiment was done to verify the accuracy of the distance variance.

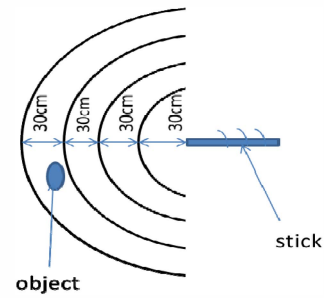


Fig. 12 Distance variance identification diagram

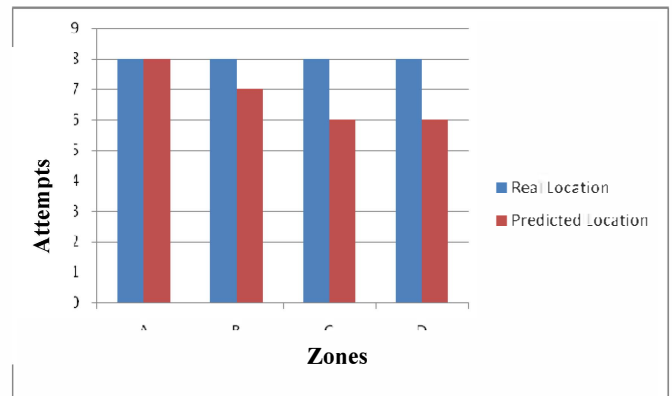


Fig. 13 Identification of the distance variance

The experiment was carried out with one person who had a good practice with the walking stick. The area was divided into four main zones and each zone had different vibration intensity (figure 12). Then the person was allowed to identify the vibration differences according to the location. The person was practiced several times to identify the object locations before starting the test. The object was randomly kept 8 times in each zone and asked him to guess the zone as for the vibration. According to the figure13 his object location identification accuracy was 84%.

VI. CONCLUSION

In this paper haptic based walking stick for visually impaired people was proposed, modeled and successfully tested. The new concept of haptic vibration sensation was tested with the proposed walking stick. Initially only a lesser number of objects were identified. But after the completion of several tests, results become better. This haptic stick detects obstacles with the height of 0.1m to 1 m which is sufficient for effective walking. When using the stick the handle should be adjusted so that the angle between the stick and the ground is around 60° with a maximum possible error of 10% (54°- 66°). This proposed stick is not capable of detecting the pits on the ground. The test result shows that this device can be used successfully for visually impaired people in navigation. Application

video of the device is available online from the following youtube link.

<http://www.youtube.com/watch?v=16GnoQ5f9WQ>

VII. ACKNOWLEDGMENT

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