2013 IEEE Point-of-Care Healthcare Technologies (PHT)
Bangalore, India, 16 - 18 January, 2013

# Way-finding Electronic Bracelet for Visually Impaired People

Shripad Bhatlawande, Manjunatha Mahadevappa* and Jayanta Mukhopadhyay

*Abstract*— **Way-finding Electronic Bracelet (WEB) for visually impaired (subject) is a portable embedded system for obstacle detection and way-finding. This MSP430G2553 processor based real-time system employs single Maxbotix MB1340 ultrasonic transceiver mounted on customized circular bracelet for detecting obstacle in the range 20 to 600 centimetres. Half duplex wireless communication is used for invoking vibrotactile and audio cues at receiver side. Maintaining a safety margin distance in front, left and right direction, WEB dynamically calculates obstacle distance (if any). Using on-demand hand movements, subject can understand surrounding situations and can perform successful way-finding. WEB system is available with choice of optimum hardware as per wearable comfort and requirement of subject. Preliminary trials on blindfolded subjects, WEB demonstrated substantial potential for cost-effective wearable real-time system with minimum physical interface for mobility of visually impaired people.**

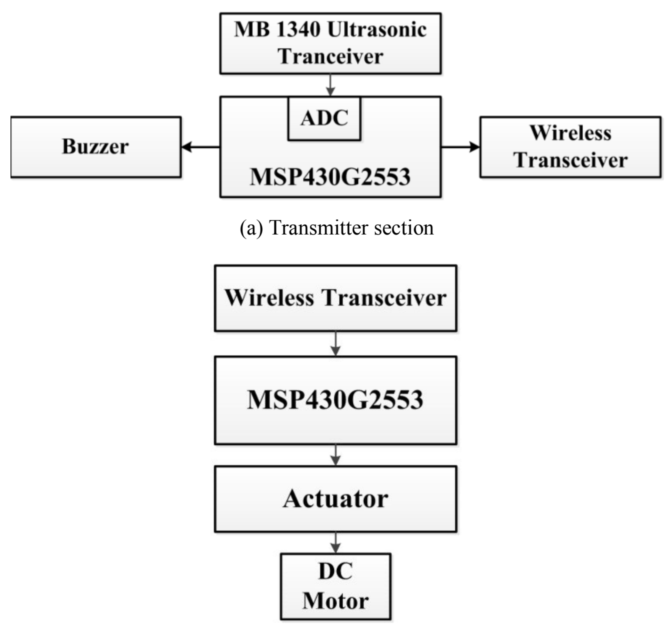
## I. INTRODUCTION

Performing routine daily-life activities without vision presents a big challenge for visually impaired people. A long white cane is the tool that most visually impaired people choose as it is the most basic, versatile and low maintenance option. Situations that require broad route planning are little difficult with white cane, as it provides tactile information of things within the reach of cane [1]. Based on ultrasonic sensors, optical sensors and vision sensors like camera, various Electronic Travel Aids (ETAs) are now available for emulating vision perception. Hand-held compact sized Mowat sensor [2] detects obstacle based on echolocation and uses vibration intensity to indicate obstacle distance. This device keeps both the hand of subject occupied holding the cane in one hand and sensor in other hand for way-finding. An obstacle distance has been related to the pitch of the generated sound and its surface texture by the timbre of the sound in sonic torch [3]. These combined sounds are quite difficult to interpret. Sonic pathfinder [4] uses head-mounted ultrasonic sensor for obstacle detection and its distance calculation. It uses different audio notes for indicating obstacle distance. GuideCane [5] introduced a robotic guiding cane for obstacle avoidance and way-finding. Wearable Navbelt [6] used ultrasonic sensors mounted on customized belt for travel direction, speed, proximity to obstacles and an acoustic panoramic image of the environment by using stereophonic effects. Three ultrasonic sensors mounted waist-belt for obstacle detection and pre-recorded short speech messages were used for alerting subject in [7]. Phase beamforming technique is exploited in [8], where ultrasonic sensor-microphone array interface is used for detection of obstacles and their direction. Camera-computer interface based ETA [9] used image to sound mapping for alerting subject.

Manuscript received September 28, 2012. *Asterisk indicates corresponding author.*
*Manjunatha Mahadevappa is with School of Medical Science and Technology, Indian Institute of Technology Kharagpur, West Bengal, India (e-mail: mmaha2@smst.iitkgp.ernet.in, mmaha2@ieee.org).
Jayant Mukhopadhyay is with the Computer Science and Engineering Department, Indian Institute of Technology Kharagpur, West Bengal, India (e-mail: jay@cse.iitkgp.ernet.in).
Shripad Bhatlawande is with School of Medical Science and Technology, Indian Institute of Technology Kharagpur, West Bengal, India (e-mail: shripad.bhatlawande@ iitkgp.ac.in).

## II. SYSTEM OVERVIEW

This paper presents echolocation based obstacle detection and avoidance system based on MSP430 LaunchPad manufactured by Texas Instruments Inc.




(a) Transmitter section

(b) Receiver section

Fig.1. Way-finding Electronic Bracelet: (a) Transmitter and (b) Receiver

This board has MSP430G2553 processor working at 16

MHz as main processor. It has 16 KB flash memory, 512 B RAM, and sixteen general purpose input–output (GPIO) pins including eight channel 10-bit analog to digital converter (ADC) [10]. Narrow beam angle and low power MaxBotix MB 1340 ultrasonic sensor having good acoustic and electrical noise resistance [11] is used on customized bracelet. A supply of 3.3V to MB 1340 gives around 3mV/cm and is fed to ADC of MSP430G2553 processor. Channel zero of ADC is used for this application. Based on real-time information collected from ultrasonic sensor, MSP430G2553 processor dynamically computes the distance of detected obstacles (if any) in the travel path of subject. As per computed distance, transmitter section of WEB shown in fig.1 conveys certain decisions to receiver section to generate variable frequency vibrotactile cues. The complete set-up of WEB is battery operated and works at 5V DC power supply. Total weight of the WEB system is 0.22Kg. Transmitter section of WEB has to be worn as bracelet on any hand and receiver section of it is recommended to carry on (waist) belt loops or in pocket for convenient walking.

## III. System Description

### A. Obstacle Detection and Way-finding

The flowchart in Fig.2 shows the overall development cycle of WEB system. Detection of obstacle-free path is essential for the subject to navigate successfully without colliding with obstacles, if any.

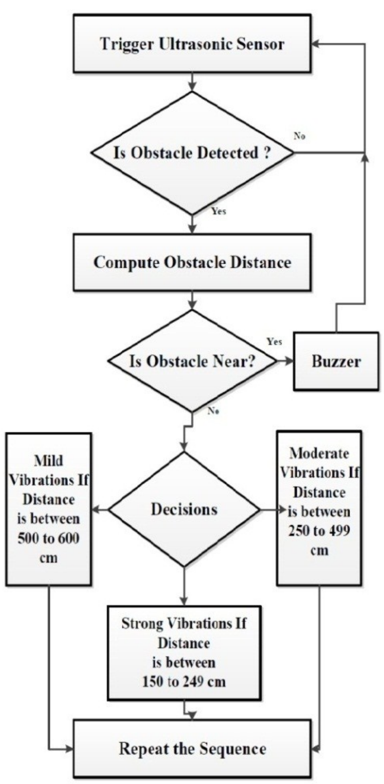



Fig.2. Overall Development Cycle of WEB system

WEB system uses single ultrasonic sensor for detection of obstacle. Ultrasonic sensor dynamically computes the obstacle distance based on echolocation principle. In this, transmitter sends out a short ultrasonic pulse which strikes the object surface and receiver observes the first echo with a threshold level. The distance ($d$) between an ultrasonic sensor and a reflecting object is calculated by multiplying the speed of sound in air ($c$) by the measured round-trip time of flight (*TOF)* when the echo amplitude first exceeds the desired threshold [12].

$$d = \frac{TOF \text{ x } c}{2} \quad \ldots (1)$$

The speed of sound ($c$) depends on medium of propagation and air temperature. An ultrasonic beam reflection depends on object attributes like surface, size, distance, and angular orientation. A large object has more surface area to reflect the incident beam. The inclination of an object's surface facing the ultrasonic sensor decides the reflections; the portion perpendicular to the sensor returns the stronger echo whereas portion with greater angle returns weak echo. Based on chosen travel direction subject can scan the surrounding environment with structured hand movement to understand presence and distance of obstacle. With imparted training, subject can realize the approximate size (width and height) of the detected obstacle as well as narrow opening with cautious hand movements. Subject can use similar principle for detection of multiple obstacles with small spacing in between. If the detected obstacle is at 20 cm to 149 cm distance, WEB activates variable frequency buzzer beeps. A buzzer is mounted with the customized bracelet. If detected obstacle is beyond 150 cm, WEB generates strong, moderate and mild vibrations indicating distance range of the obstacle. As per perceived feedback cues, subject can change the travel path and perform way-finding consequently. Fig.3 shows the actual photographs of WEB transmitter and receiver section.

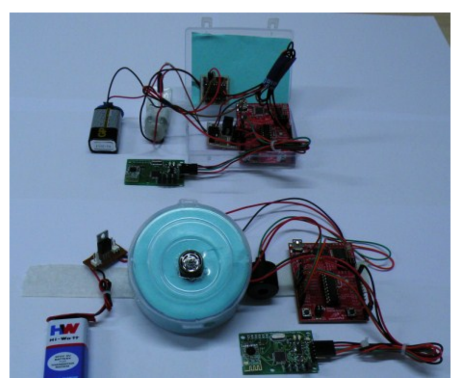


Fig.3. WEB transmitter and receiver section

### B. Optimum Hardware Selection Options

WEB system offers a broad choice for selecting optimum hardware pertaining minimum physical interface with natural sensory channels and wearable convenience of subject.

*1. WEB with wireless connectivity between transmitter and receiver (WWTR)*

In the transmitter section as shown in Fig.3 a processor board, an ultrasonic transceiver, a wireless transceiver, a buzzer and battery enabled 5V DC power supply are set within the customized circular bracelet. A flexible fabric hook-and-loop fastener (Velcro) is used to fix this bracelet on the wrist of subject. WWTR bracelet weight is 0.11 Kg. In the receiver section a processor board, a wireless transceiver, a DC motor driver, a 320 rotations per minute (rpm) DC motor and battery enabled 5V DC power supply are set within the little rectangular box. Receiver section is recommended to carry on (waist) belt loops or in pocket for convenient walking. A blindfolded subject wearing WWTR is shown in Fig.4.

Fig.4. Blindfolded subject wearing WWTR

Subject can perceive the detected obstacle distance by variable frequency vibrations at receiver section. Near obstacles are indicated by buzzer beeps. As two separate modules are used with different batteries, battery life showed extended performance as current requirements are divided.

*2. Integrated WEB (IWEB)*

In this configuration a processor board, an ultrasonic transceiver, a wireless transceiver, a buzzer, a DC motor driver, a DC motor and battery enabled 5V DC power supply are set within the customized circular bracelet.

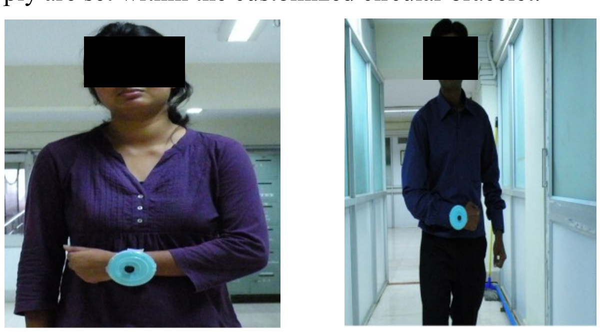


Fig.5. Blindfolded subjects wearing IWEB

Subject can perceive the detected obstacle distance by variable frequency vibrations generated near wrist. IWEB bracelet weight is 0.18 Kg. This configuration offers minimum physical interface and greater wearable comfort as compared to other proposed configurations. Blindfolded subjects wearing IWEB are shown in Fig.5. Current requirement of this configuration is relatively more than WWTR configuration. Battery life performance is also lower in this configuration.

*3. IWEB with Cane (IWEBC)*

In WWTR and IWEB, obstacle at front, left and right direction can be detected from waist-level to chest-level height. Obstacles at ground level height cannot be detected with these systems. Using IWEB system with cane, IWEBC presents a comprehensive approach for detecting obstacles from ground level to chest level height. Blindfolded subjects wearing IWEBC are shown in Fig.6.

Fig.6. Blindfolded subject wearing IWEB

Blindfolded subject performed well with this configuration. Subjects demonstrated good orientation and confident walking with this configuration. Like IWEB, current requirement of this configuration is also more than WWTR configuration. Battery life performance is also lower in this configuration.

In all configurations presented in the paper, based on collected information from ultrasonic sensor, WEB supports way-finding by avoiding obstacles. Though WEB has additional information of the surrounding, only need basis information is provided to the subject to reduce the information overload and further confusion.

### *C. Functional assessment of the system*

WEB system was subjected to one hundred tests (keeping WEB system stationary at 85 cm height from ground level) for assessing performance in terms of obstacle detection, directional sensitivity and distance measurement accuracy. A 16X2 liquid crystal display (LCD) was interfaced with microcontroller for verification of distance mapping of detected obstacle. Relevant feedback cues were also timetested throughout functional tests. In 97% cases WEB system detected the obstacle in the detection range, horizontal and vertical resolution of the MB1340 sensor. In 93% cases WEB system detected the distance of detected obstacle with 2.6% variation.

### D. Trials

For better utilization of WEB system, a training module is developed for visually impaired people. This includes usage of WEB systems, hand and overall body movements, walking orientation, correlation of feedback cues with walking speed and passing through without collision. With the said curriculum, two blindfolded subjects were trained on WEB system for three weeks. Trial environment and WEB system appearance were not shown to participated individuals for faithful assessment of the mobility system. For preliminary testing of the proposed system, two blindfolded subjects wearing WEB systems as shown in Fig. 4, 5 and 6 were asked to walk through a 20 meter controlled environment with placement of sample obstacles. Total thirty trials were conducted (ten trials for each WWTR, IWEB and IWEBC configuration) and parameters like actual no. of obstacles placed (NO), WEB detected no. of obstacles (DNO), no. of obstacles avoided (OA), no. of collisions with Obstacles (NC), actual no. turns in the environment (NT), WEB detected no. of turns (TD), no. of turns followed (TF) and Walking Speed (WS) are recorded. During initial training subjects collided with obstacles several times but after substantial training of three weeks, subjects were able to follow obstacle-free path and could detect placed obstacles, their position as well as approximate height (knee-level, waist-level and chest-level). Outcome of trial no. 10 (WWTR), 20(IWEB) and 30 (IWEBC)) with actual and approximate (calculated by WEB) measurements are shown in table I.

Table I
WEB system performance evaluation

| WEB System | WWTR | IWEB | IWEBC |
|---|---|---|---|
| NO | 05 | 05 | 05 |
| DNO | 05 | 05 | 05 |
| NT | 02 | 02 | 02 |
| TD | 02 | 01 | 02 |
| TF | 01 | 01 | 02 |
| NC | 01 | 01 | 00 |
| WS (m/s) | 0.63 | 0.60 | 0.74 |

## IV. CONCLUSION

The WEB system detects the obstacle in the travel path, compute its distance and convey optimum need basis information to the subject. It detects occluded obstacles as a single combined obstacle. Depending on the size of obstacles and path occupied, it guides the obstacle-free path way (if available). The system is independent of the type of path (road or corridor) and illumination. System successfully alerts the subject well in advance about the surrounding environment and possible obstacle. As system uses wrist-mounted electronic bracelet, it puts significant constraints on overall hand and body movement of subject and system performance in the cluttered environment. WWTR, IWEB and IWEBC configurations of WEB are portable, convenient for wearing and involves minimum physical interface with natural sensory channels of the subject. These configurations do not occlude external acoustic signals and offers good flexibility while walking. Currently trials are carried out on blindfolded subjects with static obstacles. Outcome of these trials are satisfactory and demonstrated significant potential as mobility aid for visually impaired people. Current trial outcome shows slow walking speed which can be improved with extended training and practice. Work is on for detection and recognition of dynamic obstacles as well as surrounding environment with the help of miniature camera mounted bracelet and Raspberry pi (ARM1176JZF-S) compact sized single board computer. Trials on actual visually impaired and blind people are scheduled after enhancing existing system with robust recognition and allied algorithms.

## ACKNOWLEDGMENT

The authors would like to thank all blind folded normally sighted volunteers for their participation in this study to assess usability of WEB system.

## REFERENCES

[1] http://www.livingblind.com/whitecanes.html
[2] A. Heyes, "A polaroid ultrasonic travel aid for the blind," Journal of Visual Impairment and Blindness, vol. 76, pp. 199– 201, 1982.
[3] Kay, L.: "Electronic aids for blind persons: an interdisciplinary subject". *IEE Proceedings,* 131, pp. 559–576, 1984
[4] A. Dodds, D. Clark-Carter, and C. Howarth, "The sonic PathFinder: an evaluation," Journal of Visual Impairment and Blindness, vol. 78, no. 5, pp. 206–207, 1984.
[5] Ulrich, I.; Borenstein, J.; , "The GuideCane-applying mobile robot technologies to assist the visually impaired," *Systems, Man and Cybernetics, Part A: Systems and Humans, IEEE Transactions on*, vol.31, no.2, pp.131-136, Mar 2001.
[6] Shoval, S.; Borenstein, J.; Koren, Y.;, "Auditory guidance with the Navbelt-a computerized travel aid for the blind," *Systems, Man, and Cybernetics, Part C: Applications and Reviews, IEEE Transactions on* , vol.28, no.3, pp.459-467, Aug 1998.
[7] Bhatlawande, S.S.; Mukhopadhyay, J.; Mahadevappa, M.; , "Ultrasonic spectacles and waist-belt for visually impaired and blind person," *Communications (NCC), 2012 National Conference on* , vol., no., pp.1-4, 3-5 Feb. 2012.
[8] Strakowski, M.R.; Kosmowski, B.B.; Kowalik, R.; Wierzba, P.; , "An ultrasonic obstacle detector based on phase beamforming principles," *Sensors Journal, IEEE* , vol.6, no.1, pp. 179- 186, Feb. 2006.
[9] Meijer, P.B.L.;, "An experimental system for auditory image representations," *Biomedical Engineering, IEEE Transactions on* , vol.39, no.2, pp.112-121, Feb. 1992.
[10] http://www.ti.com
[11] http://www.maxbotix.com
[12] Kuc, R.; , "Binaural sonar electronic travel aid provides vibrotactile cues for landmark, reflector motion and surface texture classification," *Biomedical Engineering, IEEE Transactions on* , vol.49, no.10, pp.1173-1180, Oct. 2002.