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Smart Cane Assisted Mobility for the Visually Impaired

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***Abstract*—**An efficient reintegration of the disabled people in the family and society should be fulfilled; hence it is strongly needful to assist their diminished functions or to replace the totally lost functions. Assistive technology helps in neutralizing the impairment. Recent advancements in embedded systems have opened up a vast area of research and development for affordable and portable assistive devices for the visually impaired. Granted there are many assistive devices on the market that are able to detect obstacles, and numerous research and development currently in process to alleviate the cause, unfortunately the cost of devices, size of devices, intrusiveness and higher learning curve prevents the visually impaired from taking advantage of available devices. This project aims at the design and implementation of a detachable unit which is robust, low cost and user friendly, thus, trying to aggrandize the functionality of the existing white cane, to concede above-knee obstacle detection. The designed obstruction detector uses ultrasound sensors for detecting the obstructions before direct contact. It bestows haptic feedback to the user in accordance with the position of the obstacle.

***Keywords*—**Visually impaired, Ultrasonic sensors, Obstruction detector, Mobility aid

I. INTRODUCTION

ACCORDING to the World Health Organization (WHO), there are approximately 285 million people who are visually impaired worldwide: 39 million are blind and 246 have low vision [1]. Among many constraints faced by a blind person, the challenge of independent mobility and navigation is eminent. Mobility of blind and low vision individuals is a combination of two related techniques: local navigation and global way finding. Local navigation is about sensing with white canes, relying on surrounding sounds, tactile clues from the ground surface and the use of guide dogs. Way finding is a matter of experience and/or training.

Mostly visually impaired people must rely on assistance of sighted persons to find their way or need an accompanying person to follow; at least during a training period. This means that the majority of visually impaired people cannot find their way autonomously in an unknown area. Generally visionless persons use a white cane or walking cane.

It is a pure mechanical device dedicated to detect static obstacles on the ground, holes, uneven surfaces, steps and other hazards via simple tactile-force feedback.

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Its light weightiness and the capability to be folded into a small piece can be advantageous to carry around when not required. These simply designed canes are only capable of detecting below waistline obstacles like street curves, steps and staircases and simple guidance between distances. Although these canes are capable of detecting obstacles, receiving feedback is very low. Therefore visually impaired individuals still find it difficult to navigate especially in unknown environments. More high-tech devices, using different types of range finders, have been in the market and have been widely used too but they are discarded on the basis of cost and other factors.

Some of them are:

- The *Guide Cane* provided aid for obstacle detection and navigation which used an ultrasound sensor. The sensor head is mounted on a steerable axel to detect obstacles and steer the device around it. Its drawback was that it required GPS system for navigation [3].
- The *Mowat Sensor* is employed with a pulsed ultrasound which is ordained with an analogue vibratory feedback operating over two ranges of distance: up to one meter and up to four meters. The vibration frequency is inversely proportional to the distance between the sensor and the object [2].
- The *C-5 Laser cane* is embedded with a laser beam which is aimed above and ahead. After collision with the obstacle the laser beam is reflected back, which is acquired by three photodiodes as receivers [4].
- The *Binaural Sonic Aid (Sonicguide)* is a device which furnishes much information about aspects of the milieu which lies outside the immediate path of the user. The device is incorporated in the pair of spectacle with two receivers mounted on left and right side, while, the transmitter faces straight piercing the environment via pulsed ultrasound. An obstruction visualised on the left side is detected by the receiver, which, will provide a signal to left ear and similarly for right ear. Hence, allowing the user to determine the direction of obstacle [2].
- The *Path Sounder* was developed by Russell [1966], as the *Lindsay Russell Path Sounder*. The crux of the whole concept was that, the blind person shall not have to deal with complex auditory stimuli from the mobility aid while navigating through milieu. The device used single pulse ultrasound to connote the presence, absence of an object in the travel path and to indicate its relative distance [7].
- The *Nottingham Obstacle Detector (NOD)* is a hand held device subsumed with ultrasound. The device provides feedback as a unique note on the musical scale which is audible, and depicts the distance of the obstacle [6].

The aim of the research work was to design and implement a device for sensing the surrounding environment using ultrasonic sensors and sending the feedback to the user of the position of the closest obstacle in sensor's range. In a way, the traditional cane is enhanced by furnishing information about the obstacles before direct contact, as the cane does not provide any information beyond its immediate length. In addition, when the user is in motion, they cannot detect obstacles on the ground and above the waist simultaneously. The designed system has the ability to detect above-knee obstacles within 3 meters and alert the user in real-time with a combination of vibration motors mounted on the cane grip or on a sweat band.

II. System Design

The main reason for designing the Obstacle Detector Systems is to make the visually impaired person acknowledged about the obstructions beforehand. Such aid gives user more knowledge about the milieu and enables them to make decisions much more quickly, thus allowing them to move around more confidently and effectively. The cane may be used in the nearby milieu may be in a park, at work, at home, and while a long peregrination. The designed assisted device helps a visionless person to visualize the surrounding using the sensor and vibrations.

The following block diagram describes the prototype model of obstruction detector system. An Arduino is used as system controller. The various components of the system are discussed below.

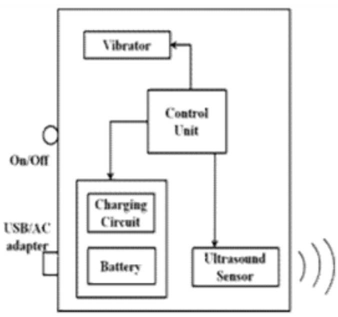

Fig. 1 System Block Diagram of the Prototype Model of Obstruction Detector

A. Battery and ON/Off Switch

The system is supplied power from two Li-ion (Lithium-Ion) rechargeable batteries summing up to 7.4V. The regulated supply of 7V is given to the Arduino Board through a toggle switch operated by the user. The supply voltage of around 5V is given to two vibrator motors which bestows haptic feedback to the user in accordance with the position of the obstacle.

B. Charging Circuit and USB/AC Adapter

A battery charger is a device used to put energy into a secondary cell or rechargeable battery by forcing an electric current through it. The charging protocol depends on the size and type of the battery being charged.

A battery charger can be a simple Nokia charger or an AC adapter [8]. USB slot is provided in case of future programming of the device.

C. Ultrasound Sensor Module

The reason behind using the Ultrasonic sensor over other available sources is, it is less affected by target materials or by colour, it is capable of detecting objects within a meter. These ultrasonic sensors are designed to resist external disturbances such as vibration, infrared radiation, ambient noise, and EMI radiation.

Ultrasonic waves are emitted from the module and bounce back when hits an objects and obstructions in the path of the user is determined. The output of the sensor provides change in voltage with respect to the distance of the obstacle. The sensor used is a SRF-04 which is equivalent to a Polaroid sensor and easy to use. It requires a short trigger pulse and it provides an echo pulse.

D. Control Unit

The control sub-system consists of an Arduino Board having an ATMEGA328P microcontroller merged in it [9]. Arduino is an open-source single board microcontroller, heir of the open-source Wiring platform, thus helping in designing electronics projects easily [10].

The hardware consists of a simple open hardware design for the Arduino board with an Atmel AVR processor and on-board input/output support. The software consists of a standard programming language compiler and the boot loader that runs on the board [11].

The sensor output is provided to an Arduino which calculates the distance based on the program. The obtained value is compared with the fixed value and a vibratory pattern is generated according to the zone. The zones are shown below.

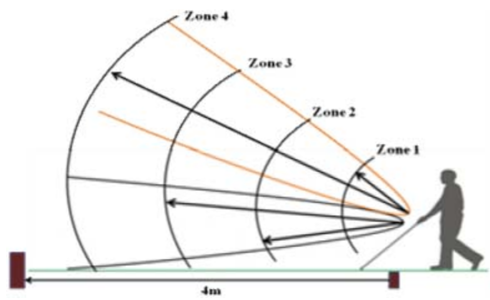

Fig. 2 Angular coverage of the detection zone

E. Vibrators

The system comprise of two vibrators placed over a sweat band. Vibratory patterns (Fig.3) are produced by manipulating the duration while the vibrator is running and the interval between successive vibration pulses. Thus, by recognizing the vibratory pattern the user can infer the obstacle distance. When the obstacle is in Zone 1(Fig.2) then vibratory pattern 1 (Fig.3) is experienced. Vibrator frequency is inversely proportional to obstacle distance.

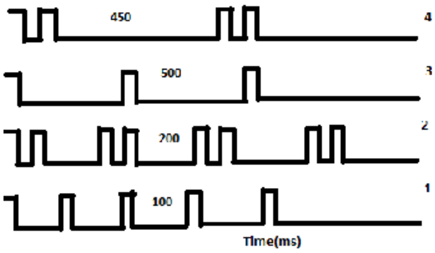

Fig. 3 Pictorial representation of vibratory patterns

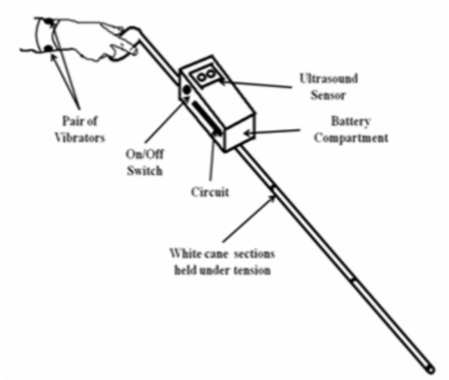

Fig. 4 Prototype Model of the Obstruction Detection System

The working of the designed cane is described in the following sections.

A detachable unit has been developed that can be mounted on the top fold of the white cane. The device employs directional ultrasound based ranging to detect obstacles in front or above knee height within a range of 3m. The user obtains distance information through vibratory stimuli which supplement the auditory cues emanating from the environment and those produced by tapping the cane.

The device vibrates in distinct patterns that vary with changing obstacle distance. The vibration frequency increases incrementally according to changing obstacle distances [12].

The system has been designed as an independent detachable unit that the existing white cane does not have to be re-modeled. An attachment mechanism has been developed so that the user can attach the device on the cane without sighted assistance.

The unit can also be used as a general purpose distance estimation device. The module runs on a standard Li-ion rechargeable battery. For charging the user connects an AC or USB adapter (similar to charging a cell phone). This eliminates the inconvenience of opening the battery pack to replace batteries.

III. Results

Initially distance calculation experiment was performed by placing an obstacle at a particular distance and calibrating the device. It was found that the range of the device which provides faithful output corresponds to 3m. Thus range of the device was divided into 4 zones, and, each zone was specified a particular vibratory pattern (Figure2, 3).

The experiments regarding the current consumption of vibrator were performed.

The Arduino drives the vibration motor by supplying a known amount of current for different patterns. Since pattern 1 corresponds to the obstacle being closest, the frequency of vibration is the highest. Consequently, maximum current is required for pattern 1. This current has a specific rise and fall time depending upon the pattern of vibration given to the user i.e. it would not remain constant for a pattern. The current supplied to the vibrator for each delivered pattern are recorded by connecting a digital multimeter into the circuit. The evaluation of the experiment is shown in the following figure:

TABLE I
Current Consumptions of the Vibrator for Various Vibratory Patterns

Vibratory Pattern	Detection Range (cm)	Current Consumption(mA)
1	1-75	28.9
2	75-150	19.6
3	150-250	15.3
4	250-350	11.1

The other experiment includes the calibration of the ultrasound sensor. The table shows calculated and measured values of the analog voltage produced at the ultrasonic sensor output.

TABLE II
Performance Analysis of Ultrasonic Sensor in Obstacle Detection

No	Range (cm)	Calculation (mV)3cm= 10 mV	Measured (mV)	Error: (cal - meas)/ cal
1	0	0	0	0
2	5	50	45	0.1
3	10	100	97	0.03
4	15	150	142	0.05
5	20	200	193	0.035
6	25	250	245	0.02
7	30	300	29	0.01
8	35	350	340	0.02

The voltage values obtained from the test are slightly different from the values shown in the ultrasonic sensor data sheet. It shows that there were errors with the ultrasonic analog output. The graph of the same is shown below.

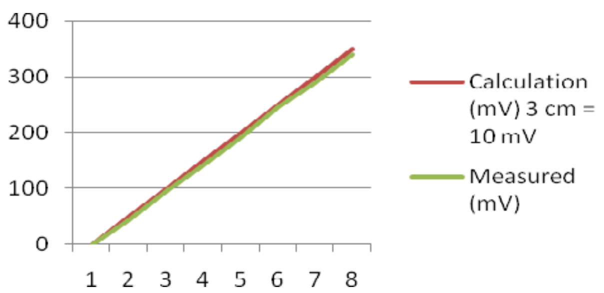

Fig. 5 Difference between the calculation value and the measured value in the analysis of ultrasonic range finder

IV. Conclusion

The basic aim of the design was to develop and implement an Obstruction Detection System for Visually Impaired People with the help of ultrasound sensor. The smart cane is an inexpensive alternative way of identifying assistive devices to develop and build a smart cane for the visually impaired to detect obstacles. The designed prototype can be made more equipped by other sensors to make it a perfect device for a visually impaired person. Future work will concentrate on improving the performance of the prototype model.

The system was developed in close association with potential users. Feedback was taken during the problem formulation, concept design and prototype evaluation stages which were critical for achieving our objectives. Initial experiments with the target group demonstrated their utility in real life scenarios Users were able to detect raised obstacles like side of a truck, horizontal bar and the edge of a table much before coming in contact with them.

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