International Journal of Scientific & Engineering Research, Volume 4, Issue 4, April-2013 1163
ISSN 2229-5518

Arduino Based Mobility Cane

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Abstract— Rehabilitating the handicapped by devising useful aid forms a part of portfolio for the biomedical engineers. 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. Right from the simple white cane up to the most advanced electronic stick, many designs have been proposed for the noble cause of aiding the visually impaired. But there have always been some ergonomic or financial constrains in the newer designs which have kept the white cane as the first choice for the maximum number of visually handicapped people. This project aims at the design and development 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 as well as below-knee detection. The designed mobility stick which is low cost, sturdy, and robust can be easily operated uses ultrasound sensors for detecting the obstructions before direct contact. It offers haptic feedback to the user in accordance with the position of the obstacle.

Index Terms— Arduino Board, Mobility Aid, Ultrasonic Sensor, Visually Impaired.

1 Introduction

Globally, the number of people of all ages living with sight loss is estimated to be 285 million, of who 39 million are blind according to the World Health Organization (WHO) [1]. Among many constraints faced by a blind person, the challenge of independent navigation and mobility is prominent. Generally visually impaired people 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.

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

A variety of high-tech devices, using different types of range finders are available in the market and have been widely used too, but they are discarded on the basis of cost and other factors. Some of the old devices are *Nottingham Obstacle Detector, (NOD)* [2], *Binaural Sonic Aid (Sonicguide)* [3], *Guide Cane* [4], Mowat *Sensor* [4], *C-5 Laser cane* [5]. Advancement in technology has resulted in developing the old devices into new ones with additional features.

(i) The *K-Sonar* is based on the use of ultrasound wherein the ultrasonic waves bounce off obstruction and send information about object and the location. The feedback is provided through sound signatures [6].

(ii) The *Ultracane* is employed with a sual range, narrow beam ultrasound system which helps in determining objects in the user path. The range data obtained from the sensor is delivered to the user via two small button-shaped tactile vibrators mounted in the handle of the device [7].

(iii) The *Palm Sonar* is termed as a palm-attached electronic mobility aid, when it locates object in the path o fthe ultrasonic beam. The object information is conveyed through vibrator stimuli [8].

(iv) The *Mini Guide* is a device which is a hand held device used to determine an obstacle. Ultrasonic waves are used and echo signal helps in locating the obstacle. The obstacle information is provided to user with a change in the vibrator frequency. The faster the vibratoion rate the nearer the object. Moreover, it is also consists of an earphone socket which can be used to provide sound feedback [9].

The aspiration of the research work was to design and develop 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 wirelessly. This modifies the traditional cane as it is enhanced by furnishing information about the obstacles before direct contact, as the cane does not provide information beyond its immediate length. The obstacle detection signal is transmitted to the vibrator. Four vibrators are used; the first two are for the obstruction above knew and the third one is for pothole detection or staircase detection, while fourth one is for water detection, thus enhancing thue user to get more close to real envi-

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ronment [10].

2 System Design

The arduino based mobile stick makes the visually impaired person informed about the obstructions beforehand. Such aid gives user more knowledge about the environment 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 environment may be in a park, at work, at home, and while a long journey. The designed assisted device helps a visionless person to anticipate 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.

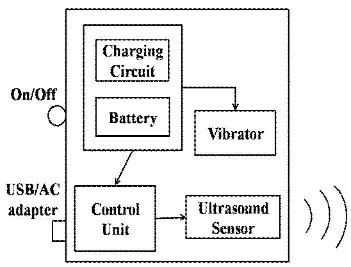

Fig.1 System block diagram of obstruction detector

A. Battery and ON/Off Switch

The system is powered from two 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 via protection circuitry. The ultrasound module is supplied with 5V power. So a total of four LI-ion batteries are required [11].

B. Charging Circuit and USB/AC Adapter

A battery charger is a device used to supply 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. USB slot is provided in case of future programming of the device.

C. Ultrasound Sensor Module

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

D. Control Unit

The control sub-system consists of an Arduino Board having an ATMEGA328P microcontroller merged in it [12]. Arduino is an open-source single board microcontroller, heir of the open-source Wiring platform, thus helping in designing electronics projects easily. 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 [13].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 for vibrators 1and 2 is generated according to the zone (Fig 2). The vibrator 3 continuously tracks the terrain and unevenness in the terrain (Fig. 3) turns the vibrator ON, thus a visionless person can walk prudent. It can be also used for staircase detection.

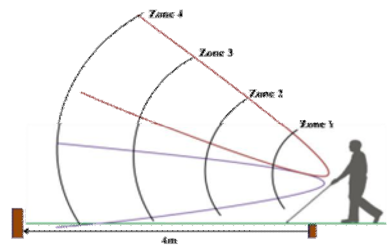

Fig.2 Angular coverage of the detection zone

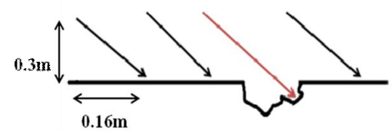

Fig.3 Pothole detection of the obstruction system. The black line shows a constant reading while the red line shows the fluctuation wherein the vibrator 3 would be turned on.

E. Vibrators

The system consists of four vibrators placed over the forearm guard (Fig.5). The vibratory pattern (Fig.4) depicts, the four patterns are for the vibrator 1 and 2 while the fifth pattern is for vibrator 3. Vibratory patterns (Fig.3) are generated by manipulating the duration, thus changing the interval between successive vibration pulses. As a result 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. When the terrain surface is uneven then the vibrator 3 provides a long pulse until the terrain surface is even. The fourth vibrator portrays presence of water and thus helping user to navigate safely.

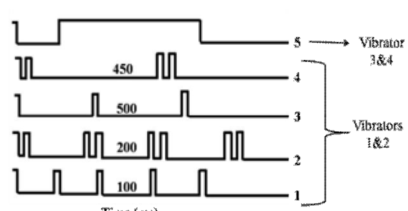

Fig.4 Pictorial representation of vibratory patterns

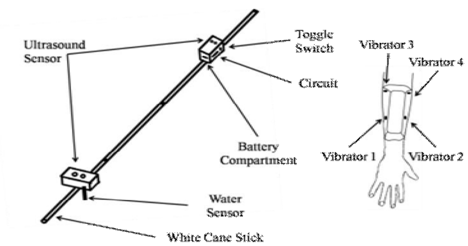

Fig.5 Prototype model of the obstruction detection system

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

The two detachable units which have been developed can be mounted on the top fold of the white cane. The upper detachable unit employs directional ultrasound based ranging to detect obstacles in front or above knee height within range of 3m. The user acquires distance information through haptic feedback. The device vibrates in distinct patterns that vary with changing obstacle distance [14].

The lower detachable unit is used for pothole detection or staircase detection. The ultrasound sensor receives a constant reading while the terrain is even, in the case of unevenness, the reading changes thus activating the vibrator and making the user walk gingerly. The detachable unit also comprise of a water sensor, which would detect presence of water and activate vibrator 4.

The system has been premeditated as an independent detachable unit so that the existing white cane does not have to be re-modelled. 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 distenace estimation device. The module runs on standard Li-ion rechargeable battery. For charging, the user connects an aAC or USB adapter (similar to charging a cell phone). This eliminates the inconvenience of opening the battery pack to replace batteries.

3 RESULTS

A distance calculated experiment was performed by placing an obstacle at a meticulous distance and calibrating. It concluded a faithful output uptil 3m. As a result the range was divided into four zones, and, each zone was specified a particular vibratory pattern.

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 1
Current consumption of the vibrator for various vibratory patterns of virators 1& 2

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 analog voltage produced at the ultrasonic sensor input.

Table 2
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	46	0.08
3	10	100	95	0.05
4	15	150	144	0.04
5	20	200	196	0.02
6	25	250	247	0.012
7	30	300	296	0.013

There is a slight difference amongst the values measured and observed as per the table. It shows that the device was not capable of showing exact values and ended in errors. The graph of the readings is plotted.

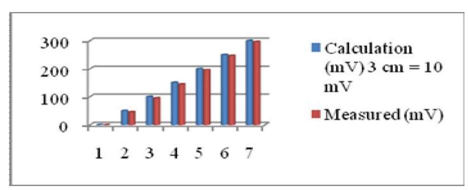

Fig.6 Difference between the calculation value and the measured value in the analysis of ultrasonic range finder

The next statistics include the calibration of pothole detection. When the unevenness in the surface was noted then the output voltage changed. The sensor is placed at 0.3m vertically from ground and 0.16m horizontally. The pothole was 0.5m deep. Whenever the surface was even the measured voltage value was recorded, as soon as the device detected unevenness in the surface, the change in the voltage value triggered vibrator 3.

Table 3
Experimental analysis of ultrasonic sensor for pothole detection

	Calculation(mV)3cm =10mV	Measured(mV)	Error:(cal-meas) / cal
Normal Values(Sensor level 0.3m from ground)	0.33 V	0.295V	0.106
Pothole Values (0.5m deep pothole)	0.495V	0.488V	0.014

4 Discussion

The discussion section is divided into three parts, the detailed analysis of the results, followed by comparison of other available devices over the assembled one, and the patient training procedure. From the above experiments, it is clear that the device provides some errors due to external factors. There is a scope to improve the accuracy. Moreover the current consumptions value helps in determining the number of Li-ion batteries and the working time of the device. In water detection system a 5V output is provided which is given to the control unit for processing and thus vibrator 4 is turned on.

A table below portrays the functional limitation of various available devices in the market and the approximate cost of those devices.

Table 4
Limitations of existing Ultrasound based Devices

Device	Limitations	Price (INR) Approx
K-Sonar	-Auditory output can interfere with environmental sounds. -Additional training is required.	31,500
Ultracane	-System is integrated with a carbon graphite cane. -Vibration is provided through two small buttons. -Attaching to existing cane is impossible.	44,000
Palm Sonar	-The device cannot be mounted on the cane. -The device is held in one hand and the stick in other hand.	24,000
Mini Guide	-Prone to breakage because of hard plastic case. -Training is necessary. -Device cannot be mounted on the cane.	25,000

The Arduino based stick tries to overcome most of the limitations. The vibrator false triggering is removed through programming. Moreover this device can be attached to existing cane. This device covers the above knee, below knee, potholes and water detection system which is superior functionality over available devices. The system cost up to 5,000 INR which is much lesser than the available devices.

The limitation of the Arduino based stick could be that the obstacle towards extreme right and left may not be detected, so pivoting a servo motor rotating through an angle of 40 degrees to 135 degrees can provide a sector scan and thus can detect moving obstacles within this beam range more effectively. A buzzer can be added so the buzzer will activate at a specific duration. Hot object Detector can also be incorporated for the detection of hot obstacles.

The training procedure initially starts with basic operating instruction further by basic training concepts, then exercise using Arduino stick. Some floor exercise followed by the exercises in landmark recognition and spatial navigation.

5 Conclusion

A low cost, sturdy and robust arduino based Mobile stick was designed and developed for Visually Impaired People with the help of ultrasound sensor. The designed prototype can be made more equipped by making the sensor rotate 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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