JOURNAL OF SOFTWARE ENGINEERING & INTELLIGENT SYSTEMS
ISSN 2518-8739
31st August 2017, Volume 2, Issue 2, JSEIS, CADMEI Copyright © 2016-2017
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A low-cost arduino-based smart obstacle (LASO) sensing cane for visually impaired people

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ABSTRACT

Humans are blessed in all aspects if they have no disability. Despite that some are not as fortunate as they are having some disability by some disease or by any mishap. Blindness being one of them and is very common. The surveys by the World Health Organization say that the developing countries have 90% of the cases of visually impaired persons. The visual impairment is related directly to navigation. The movements and the motion of the movements are due to visual sight. We take care of and avoid the coming obstacles in our way. One more factor is the liquid on the surface that could be water or anything. As technological developments have grown Information and Communication Technology is vast spread and electronics have led to low-cost components. These advantages have made possible for researchers to work on several projects for the betterment of humanity. This paper is based on Low-cost Arduino-based Smart Obstacle (LASO) Sensing Cane hardware aimed for visually impaired people. This proposed hardware is developed locally and can be made in any environment in a very low amount. Arduino has been used in this hardware which is a good enhancement and easy-to-use component making the proposed system useful.

Keywords: visual impairment; information and communication; arduino; disability; low-cost; obstacle sensing;

1. INTRODUCTION

According to the World Health Organization (WHO) there are 285 million persons in the world who are visually impaired either totally blind or have vision problems [1]. This could happen by a result of any disease or from any mishap or accident. The vision has high impact on the person's movements and avoiding of any obstacle or to take proper action in any mishap. Developing countries have majority of visually impaired persons (90%) out of which 65% lie in the age group of 50 or above [2]. For several years it has been witnessed that visually impaired persons use a white cane for supporting and aiding in their daily life. This cane can be used by the impaired person to touch the surface of the ground and then walk. It is also used for detecting any obstacle. This is done by moving or rotating the cane by the blind person. The obstacle detected is only up to its length not more than that which makes the walking speed very slow. It means that the cane or the stick itself cannot detect the obstacle itself. In terms of mobility there are two factors involved first is obstacle avoidance and second is navigation [3].

Information and Communication Technology (ICT) is playing a vital role in different sectors and has made progress in all aspects of life like education, health and others [4]. A lot of research is being carried towards the betterment of humanity [5, 6]. People can get advantage of the ICT aided tools [7]. Efforts have been taken to help and to assist these visually impaired persons in their daily routine [8]. A lot of research is carried out in the field of ICT towards visually impaired people which as a proof is illustrated in Table 1. The world's recognized four databases IEEE, ACM, Springer and Science Direct (Elsevier) were searched for researches on ICT and visually impaired persons from years 2013 to 2017. The total number of publications in these four years is about 3178 as given in Table 1.

Table 1: ICT and visually impaired researches being carried out from 2013 to 2017

Publisher	Content Type	Number of Publications
IEEE	Journals / Conferences / Proceedings	76
ACM	Journals / Conferences / Proceedings	2673
Springer	Journals / Conferences / Proceedings	249
Science Direct	Journals / Conferences / Proceedings	180

This paper aims towards the development of a cane that is a low cost and light weight focusing on the obstacle avoidance for the visually impaired persons. The proposed design aims towards a smart cane that is able to detect obstacle below and above knee height. The idea of involving a liquid identification system is also included and has been taken from monsoon season. Heavy rains cause water staying on roads or streets thus if a blind person is moving through that road or street then that might cause problems. Person can slip or fall in it. During the process of this manuscript preparation there has been an incident in Ahmedpur East a city of Pakistan. A truck carrying approximately 25,000 liters (5500 gallons) got an accident and oil came out covering road and the surrounding areas and then burst killing at least 150 people [BBC, 17]. Thus, this addition is also very much helpful in assisting the visually handicapped persons.

The rest of the paper is structured as follows: Section 2 explains related work and the previous works carried out, Section 3 discusses the proposed methodology, hardware components are discussed in Section in 4, Section 5 discusses performance analysis of proposed hardware and finally, Section 6 concludes the paper.

2. RELATED WORK

In this section, the literature review of the existing research studies is discussed. In a research study [9] a navigational system design has been proposed for visually impaired people. Their proposed architecture allowed the impaired person to behave as independent regardless of home or work. In their system, the person who wants to use this system has to have a smart phone which he or she has to hold when the desired displacement is required. In research study [10] a prototype device which is wearable has been presented. Images were captured by the device which was having two cameras and vest which contained vibrators. Computer vision technology is used which detects the object that are moving and their distance from the two cameras. Pyramidal reduction technique reduces the resolutions of these images. After that the images are mapped on the vibrators so that a vibrational sensing is produced. This vibration assists the visually impaired person to sense the route in a collision free manner.

In research study [11] a virtual white cane has been developed which is combination of a smartphone and a laser pointer having an objective to assist virtually impaired people. The smartphone camera captures the laser pointer beam. Active triangulation is used for the purpose of computing distance which is from white cane to the reflection. There is a vibration in the smartphone which is customized and based on the value of the distance is generated. This gives the user the sense to prevent obstacles. In research study [12] vision-based way finding system is proposed which supports the visually impaired persons in an indoor environment. They adopted outdoor visual odometry technique. This technique is used in an indoor environment by placing stickers or markers on the ground. This system is to be deployed on a robot so that it can assist visual impairments. Moreover, smartphone is also used which has a convenient interface to interact with users. The research has been carried in three indoor scenarios.

The authors in [13] proposed an assistive system that is based on a mobile Kinect and matrix of electrode. This system is for visually impaired people and acts as mobility aid. It is able to perform obstacle detection. This system is divided into two main sections that are: (i) environment information acquisition and analysis (ii) information representation. A broad summary of the research based on the current techniques used for visually impaired persons is provided in [14]. According to the research the reasons which have caused navigational systems not able to achieve advantages on large scale are: (i) high-cost (ii) usability and (iii) accuracy. The authors suggest that the installation of the components may be reduced in order to make a low-cost system so that the users or the consumers may be able to afford it.

Microsoft Kinect is used for real time face recognition system by [15]. The proposed system targets visually impaired persons. Kinect performs face recognition / detection. The Kinect generates sound by using temporal coherence in combination with biometric system. The sound generated is associated with the person who is identified by 3D system. The study carried out in [16] focuses on the evaluation of accessibility of university website by the students who are visually impaired. Websites have now become a common source of information sharing. People with visual impairments face difficulties in accessing website and are not given much importance. The study was carried on visually impaired students.

In [17] research study has been carried out on features that an iPhone and iPad have for visually impaired persons. These gadgets have low-vision accessibility features which may be divided into two categories as represented in Table 2. In the study thirty-three (33) patients with low-vision participated. 20/119 and 20/133 were the average values of

visual acuity of the patients in right eye and left eye respectively. The studied concluded that Large Text and Zoom Magnification were the two features in entire features which were most commonly used.

Table 2: Accessibility features of iPad / iPhone

Features	Option
Siri Voice Assistant	Audio
Voice Over Screen Reader	
Speech Selection	
Invert Colours	Visual
Large Text	
Zoom Magnification	

Context-aware smartphone based obstacle detecting has been developed in [18]. This system provides visual aid to visually impaired persons to navigate in indoor environment. The proposed algorithm combines point track algorithms and optical flow for improving obstacle detection and assisting users. A study in [19] has been carried out to provide three dimensional (3D) audio signals and cues to guide visually impaired persons in terms of providing them directions and distance information. They used magneto metric sensor and a computer. The computer is used in their proposed system for Binaural Simulation (BS) and the magneto metric sensor is used for Head tracking (HT). First the magneto metric sensor obtains the direction and the position of the subject (visually impaired person). Then Head-Related Transfer Function (HRTF) responds to the position of the head and a 3D audio is generated.

3. PROPOSED METHODOLOGY

The proposed cane architecture is shown in Figure 1. It is based on the objectives of detecting any sort of obstacle that can cause any type of harm or make his walk slow. When the cane is operated its ultrasonic sensors send the ultrasonic waves to the environment. If there is no obstacle then it will continue to operate without disturbing the visually impaired person. If an obstacle is detected then the Arduino send an alarm signal which turns ON the alarm 1. There are two types of alarms used. Alarm 1 is for the obstacle and alarm 2 is for water on the surface found. If the water is on the walking surface of the user then the electrodes detect it and inform the Arduino which in return generates an alarm that is alarm 2. With dual alarm system, this gives advantage to the visually impaired person to understand the type of the obstacle and then to react it.

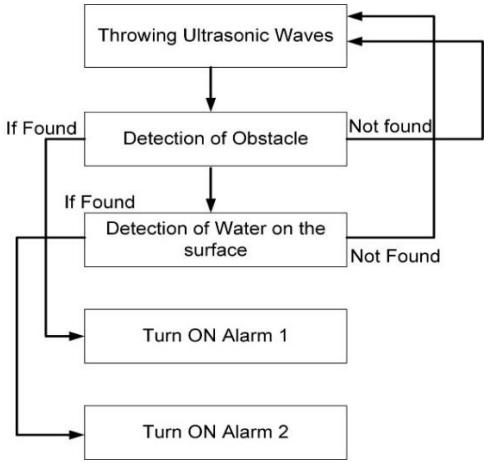

Figure. 1 Architecture of the proposed smart cane

The working scenarios of the proposed cane are illustrated in Figure 2. When it is turned ON the system will initialize itself. There are two scenarios in the proposed hardware and these both are to be initialized and work simultaneously.

3.1 System 1

The system 1 is dedicated to the detection of any obstacle. The ultrasonic sensors are operated continuously. They send their waves in the surrounding. The distance values are computed by the Arduino. Based on the magnitude of the distance the Arduino sends the signal for motor to start vibrating and also turns ON the buzzer 1 which is dedicated to obstacle avoidance. Lesser the distance of the obstacle the vibration is greater making the visually impaired person to react to it in a quick session of time. The sound is kept the same for all distance values because in some situations (mostly outdoor) sounds do not reach to human ear thus making vibration a better choice instead. In an indoor scenario, the sound will make its impact in a better way.

3.2 System 2

The system 2 is dedicated to any liquid surface on the surface. On the bottom of this cane lie the electrodes. These electrodes detect any liquid on the surface like water, petrol etc. the electrodes send their observed data to the Arduino to process it further. The Arduino upon receiving input from the electrodes activated buzzer 2 and turns ON the motor to start vibrating in a pattern that the visually impaired person understands that the obstacle is now a liquid surface.

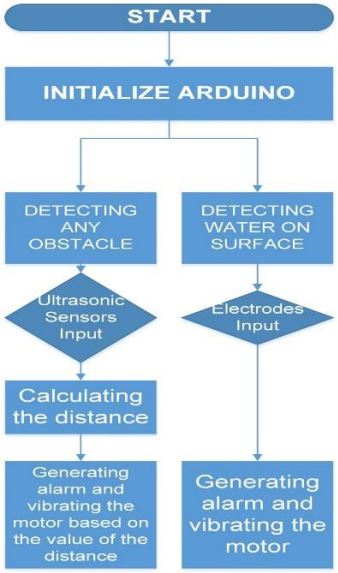

Figure. 2 Working principle flowchart

4. HARDWARE

The design of the system includes the components like ultrasonic sensors, nano Arduino, buzzer, vibration motor and LEDs, as shown in Figure 3. In Figure 3, it can be observed that how the components are embedded in a single board.

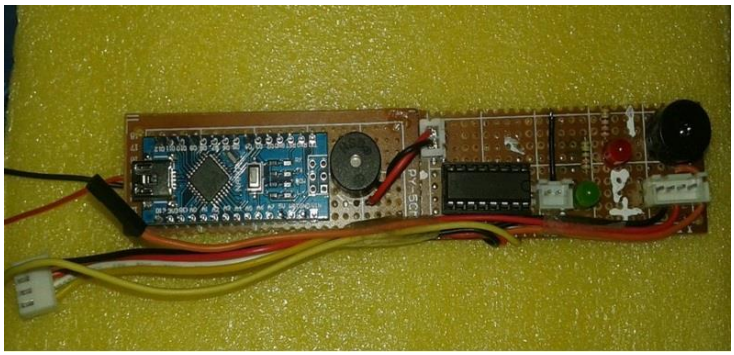

Figure. 3 Components for the proposed smart cane

4.1 Ultrasonic sensor

The ultrasonic range sensor is used to detect the distance of obstacles. The ultrasonic range sensor is preferred in the proposed hardware because it is small in size, and low-power consuming when compared with infrared sensor. The ultrasonic range sensor emits high frequency ultrasonic signals and gives an analog output value. It has the capability of detecting objects in a range of approximately 2 to 400 centimeters. The voltage and current required for it to operate is 3 to 5v and 15mA respectively. A vibrator has been used which produces vibrations as per voltage level supplied to it. The voltage required for operating the motor is 5v. A 2600 mA-h power bank has been used to power the system.

4.2 Water/liquid detection electrodes

For the detection of water or liquid on the path a mechanism has been used based on electrodes. The electrodes are connected at the bottom of the cane where they detect any sign of liquid as shown in Figure 4.

Figure. 4 Electrodes in proposed hardware

4.3 Arduino

It is an easy-to-use hardware and also simple to program. It is an open-source platform. In the proposed hardware, it is the brain. It is preferred to be used because of its cost, cross-platform, open source and extensible software, simple, and clear programming environment and cross-platform.

4.4 Vibrational motors

These are types of motors which generate vibration when they are given input. Initially developed for massaging purpose but now used in mobile phone for the fact that people realized that vibration alerting is an excellent way to alert operators to an event.

4.5 Power bank

It is an energy source. It charges itself and then provides energy to the components attached to it. It is used in proposed hardware to provide energy to the components of the hardware. The proposed hardware consists of alkaline

type power bank. This power bank is able to supply 5 voltages (v) and having a capacity of 2600 mA-h and is enough to power up all the components.

5. PERFORMANCE ANALYSIS OF PROPOSED HARDWARE

The final version of the proposed Low-cost Arduino-based Smart Obstacle (LASO) Sensing Cane hardware is shown in Figure 5. In Figure 5, it can be observed that this looks like an ordinary cane. It is provided with ON / OFF button in the case that if this cane is to be used then it must be turned ON otherwise kept OFF. A charging pin is also provided so that power bank may be charged.

Figure. 5 Final design of the proposed hardware

The tests are conducted for evaluation and performance of the proposed hardware. The four obstacles are tested and the results are presented in Table 3.

Table. 3 Results of obstacle detection

Obstacle	Test 1	Test 2	Test 3
Wall	198 cm	210 cm	203 cm
Human Body	100 cm	114 cm	122 cm
Plastic	115 cm	124 cm	145 cm
Metal	210 cm	199 cm	215 cm

The sensor emits ultrasonic waves of high frequency and produces analog output. The range that the sensor is able to detect for the obstacle is 2 to 400 centimeters.

6. CONCLUSION

In this paper, a low-cost smart cane has been developed for visually impaired persons. Due to developments in technology the research is now very much can be carried out towards the betterment of humanity. In developing countries people have low income and cannot afford to spend much amount on their medical facilities. This cane is smart and gets ready in a very low-cost. Arduino has been used with ultrasonic sensors. The components are embedded into a cane. ON / OFF button is provided in case if using or not using. These technologies are used because they exist in normal routine and in affordable prices. The aim behind this project is to support the visually impaired persons by helping them in developing a cane that may be helpful to them in sensing obstacles and liquid on the surface. Most of the developed canes focused on the obstacle avoidance system but not towards the path or surface which is wet by any liquid that might be water, petrol or any other liquid that can slip the impaired person causing any harm. The Arduino is the brain of our proposed hardware. The main idea behind using Arduino was its low-cost and affordable, availability and ease in programming. In this project, it differentiates between the signals either from ultrasonic sensors and / or electrodes and then generates a signal to turn ON the buzzer(s) and the vibrational motor. Some of the existing canes had used batteries (AA or AAA sized) for powering up their components but in this design a power bank has been used to power up the components used for longer span of time. Once advantage of using power bank is that the

batteries deplete their energy fast when they power any sort of motor. Once discharged the batteries cannot be recharged. They need to be replaced and it takes technical effort which is not an easy task for a visually impaired person. Our proposed system has advantage that if the power bank is fully discharged it can be recharged easily. This hardware is useful for visually impaired persons and could help to ease their normal routine life. The experimental results show that this is better option for its users. The future suggestion for this cane is to add Global Positioning System (GPS). Nowadays vehicles use GPS for finding their destination hence, in the same way the GPS will be added in this cane and then the users will be guided as such without the need to ask anyone.

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