“BlindShoe”: An Electronic Guidance System for the Visually Impaired People

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***Abstract*— The number of visually impaired people is rising with the rapid growth of population. The visually impaired people face difficulties in their daily living owing to the lost of their vision. The primary purpose of this paper is to develop a low-cost tool that can help the visually impaired people by providing proper instructions while moving on the surroundings. We proposed a solution by developing an electronic guidance system to aid the visually impaired people in navigation by detecting obstacles in the front and the back-side of the individuals. This system comprised a smartphone, sensors, microcontroller, and a data transmission device. The sensors gathered information from the surroundings, and the microcontroller detected the obstacles by processing the information. The communication between the microcontroller and smartphone was done via data transmission device (Bluetooth module). The smartphone provided continuous instructions to keep the individuals in proper track. The proposed system could detect the obstacles within 100 cm with an accuracy of 97.33%. This implies that the proposed prototype is able to facilitate the visually impaired people in safe navigation.**

***Index Terms*— Visually Impaired People; Obstacle Detection; Ultrasonic Sensor; Water Level Sensor; Smartphone.**

I. INTRODUCTION

According to the World Health Organization (WHO), about 253 million people are visually impaired. Among them, around 36 million people are blind and the rest 217 million people have low vision. Among them, more than 80% people are 50 years of age or above [1].

Most of us are fear of darkness, but the people who are visually impaired are born with darkness or have it due to accident or other reasons. They face various difficulties [2] in almost all of their daily activities. Sometimes they become hopeless and fed-up with their life. The most challenging task is to walk around the surroundings for which they have to depend on someone to move safely.

Modern science is trying to reduce the difficulties of visually impaired people. The development of walking assistants has become challenging, and the necessity of the assistance devices is still now endless. However, there are many navigation tools and frameworks [3]-[6] accessible for the blinds. A large number of researches have been done in this area. The most significant devices are the dog guides and white cane. Though they are very famous, they are limited in terms of their speediness, coverage, and capacity, which are generally accessible to persons having eyes for navigation [7].

Though some researches have been demonstrated, almost all of the systems [8]-[10] can detect obstacles in front of the users only: They could not detect all objects within the surroundings and notify the user by vibration or buzzer module, which lacks of precision to navigate confidently. These tools can identify the obstacles and generate an alarm signal to notify the users but could not detect the obstacles (vehicles, human, animals, etc.) that are at the back-side of the users.

From this motive, we have developed an electronic guidance system prototype, named as "BlindShoe" to assist the visually impaired people. The device can detect the obstacles that are not only in front but also at the back-side of the users. For notifying the user, we have used text to speech application, which is simple and easily understandable. Besides, the system can identify the water on the road surface, and the users can send messages directly from this device to a particular person, in case of danger.

The rest of the paper is organized as follows. The related work that covers the recent developments in this area is described in Section II. The major hardware components that are used to develop the system is described in Section III. The proposed methodology to establish the electronic guidance system is illustrated briefly in Section IV. The implementation of the prototype is described in Section V. Section VI outlines the experimental outcomes of the developed prototype. Section VII concludes the paper.

II. OVERVIEW OF THE STATE OF ART

Several assistants have been developed to guide the visually impaired people for easy walking. Many organizations have been working for a long time to make cost-effective and well-organized tools for them. The work associated with this field is outlined briefly as follows.

A. J. Ramadhan [11] proposed a wearable system for the visually impaired people to aid them in walking through streets, public places etc. The system comprised microcontroller board, Global System for Mobile communications (GSM) and Global Positioning System (GPS) modules, various sensors, buzzer and a solar panel. The system used ultrasonic sensor to detect the obstacles on the track and notified the users through alarm generated by buzzer. The users can send a phone message along with their location to their family members when they are in stumbles. However, the system cannot detect the presence of water, fire, potholes and staircases as well as head level obstacles. Ton et al. [12] proposed a Light Detection and

Ranging (LIDAR) assist sensing system for the visually impaired people that provides spatial information to these individuals using a LIDAR sensor. The feedback signal is achieved through stereo sound. The system can detect obstacles in different angular direction and horizontal distance. However, the system could not return better signal in case of body movement and needs long time training for usability.

Sharma et al. [13] developed a smart stick for the visually impaired people to provide independent mobility. The system could detect the ground level and knee level obstacles, potholes and staircases. It provided vibration signal with the presence of hindrances. The system comprised three sonar sensors, a moisture sensor, two vibration motors, two buzzers and Arduino microcontroller. However, the detection range of pothole was approximately 30 cm, which was too small to avoid the risks of accidents. Pissaloux et al. [14] proposed a system that assisted users in walking with obstacle avoidance, orientation, real physical displacement, etc. It was based on the real gist. The system consisted of TactiPad for obstacle detection and tactile gist for display. The system was beneficial for the visually impaired people in their mobility at an unfamiliar environment, but the system was comparatively bulky.

Sareeka et al. [15] developed a wearable device named as pseudoEye that captures the texts from the environment and converts it to voice signal delivered to users. The system used a mini camera, a push button, raspberry pi and a SoC (System on Chip) attached to a cap. The raspberry pi captured the data from the environment using camera and extracted texts from the images and generated voice signal corresponding to the texts. A portable power bank was used to power on the raspberry pi. However, the system could recognize few numbers of texts only and failed to detect handwritten character. Khade and Dandawate [16] developed an obstacle detection framework for the visually impaired people in unknown surroundings using Raspberry Pi. The system perceived the obstacles in the ROI without the help of cameras. The hardware used in this scheme is ‘Raspberry Pi 2-B', a wearable camera with 5MP resolution and the overall system was simulated in MATLAB as well as Python language. The authors generated the database by visiting a school for the blinds. The database was retrieved by capturing the video of the blinds head, and approximately 25 videos were taken for the research purpose. The database was converted into a video frame initially, and the motion vectors were used for the obstacles' detection. The segmentation was done using background subtraction procedure. Finally, the Region of Interest (ROI) was created to detect the obstacles. The system was cost-effective and had lesser weight, but the illumination and brightness situations were constant. However, in the real-world scenario, these properties changed frequently. So, the prototype was not compatible with the real world. The system could detect the obstacles only but it was not able to categorize them.

III. MAJOR HARDWARE COMPONENTS

Many hardware components were used to develop any types of assistance for the visually impaired people. The major elements used to build our electronic guidance system are outlined as follows.

A. Arduino Uno

Arduino is referred to as a platform where both software and hardware can be embedded through Arduino board. It is compatible with an operating system like Windows, Linux, Mac OS and built with a microcontroller as well as microcontroller kits. Arduino can execute the set of instructions and perform the tasks through these microcontrollers. Nowadays, it serves as a brain of thousands of projects. It consists of digital pins, analog pins, power pins. The Arduino Uno with all of its components is shown in Figure 1 (a).

B. Ultrasonic Sensor

Several sensors are used to construct different types of assistance to provide various services. Among the different sensors, ultrasonic sensors are widely used. The sensor can measure the distance of the obstacles in front of it in the specified range. The range can be 2cm to 4m and can cover up to 15 degrees. It consists of only 4 pins. The pins are VCC, trigger (transmitter), echo (receiver) and ground which are shown in Figure 1(b). VCC pin is used to power-up the sensor. It accepts up-to +5V, and ground pin is connected with ground. It sends ultrasonic pulse continuously when trigger pin is high. When any obstacle reflects the signal, it receives the signal and gives high output to Echo pin.

C. Digital Buzzer Module

The buzzer module is used to generate an alert signal by producing sound. This module produces sound by getting a signal from the microcontroller. It is used widely in various applications. It has 3 pins, named ‘+' (VCC), ‘-' (GND), ‘S' (Signal), which are shown as Figure 1 (c). In general, VCC is attached with ‘high voltage,' GND with ‘ground voltage' and ‘S' is used to receive signal from the microcontroller

D. Water Level Sensor

Water level sensors are mainly used to detect liquid levels as well as to sense water. When the surface of the sensor comes in contact with water, it returns a non-zero value, which indicates the presence of water. It has three pins, and those are VCC ↔ 2.0V ~ 5.0V, GND ↔ power supply ground, AOUT ↔ MCU.IO (analog output) which are shown in Figure 1 (d).

E. Bluetooth Module Breakout (HC-05)

Bluetooth module HC-05 is designed for transparent wireless serial connection setup. Any serial data stream from 9600 to 115200bps can be passed from an Arduino to a target device. The Tx pin of Bluetooth module is connected with Arduino's Rx pin and its Rx pin is connected with arduino's Tx pin. VCC and GND pin is connected with 3v to 5v and ground voltage respectively. The Bluetooth module is shown in Figure 1 (e).

(a) (b) (c) (d) (e)

Figure 1 : Major hardware components that are used to develop the system. (a) Arduino Uno (b) Ultrasonic Sensor (c) Digital Buzzer Module (d) Water level sensor (e) Bluetooth Module

IV. The Proposed Methodology To Develop The Electronic Guidance System

In the proposed method, two ultrasonic sensors were used for obstacle detection for both in the front and the back-side of the users. The water detection sensor was used to detect the presence of water. The user will be notified about obstacles situated in both the front and back through a buzzer as well as a voice signal was sent to the user. The block diagram of our proposed system is depicted in Figure 2. The proposed system consists of three modules, named as the sensor module, communication module, and smartphone module. Each of the modules is described in the following steps.

A. Sensor Module

Two sonar sensor were used in our proposed electronic guidance system. They were added in the front and the back-side of one of the pair of shoes. They can detect any obstacles at both front and backside. The working flow of the ultrasonic sensor module for our proposed system is illustrated in Figure 3. If the obstacle is detected around 200cm front, sonar sensor sends the signal to the micro-controller. Micro-controller sends the message to a smartphone through a Bluetooth module, and the user gets a notification. A buzzer will generate an alert signal when the obstacle is around the 100cm front, and the user will also get a notification through smartphone. The backward sonar sensor also detects any presence of obstacles (vehicles, human) and provides notification to the user.

A water detector sensor was also used to develop the electronic guidance system. It was used to detect slippery or wet surface. When it detects any water on the surface it sends notification through Bluetooth module to smartphone and user gets the notification. The water detection procedure of our proposed system is illustrated in Figure 4.

B. Communication Module

The process of communication between the developed prototype and smartphone plays a vital role to notify the user. The interaction between the prototype and smartphone is done through the Bluetooth module. The sensors send the signal to the microcontroller, and the microcontroller processes the message and sends it to a smartphone through a Bluetooth module.

C. Smartphone Module

An android app was developed to receive the signal from the prototype and execute the instructions. It used TTS (Text to Speech) technology for giving real-time directions to the user. The user will listen to the notifications through earphone.

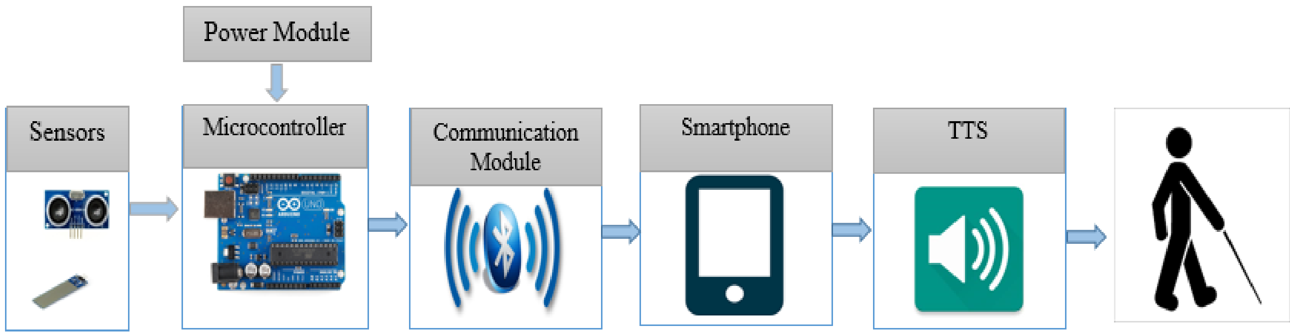

Figure 2: Block diagram of the electronic guidance system

IV. Implementation of the Prototype

We have integrated our proposed system in one of the pair of shoes, which is very lightweight and cost-effective. In the prototype, the ultrasonic sensors were attached with a belt at the upper portion of the shoe in the front and backward direction. The water level sensor was attached at the heel position of the leg. The overall circuit with a microcontroller, Bluetooth module and buzzer was equipped in the front portion of the shoe. The prototype of the proposed electronic guidance system is shown in Figure 5.

The connection of each component was mapped with the microcontroller which is shown in Table 1. From Table 1, it can be shown that the Trigger and Echo pin of the front sensor is connected with D9 and D10 pin of the microcontroller. The Tx and Rx pin of Bluetooth is connected with Rx and Tx pin

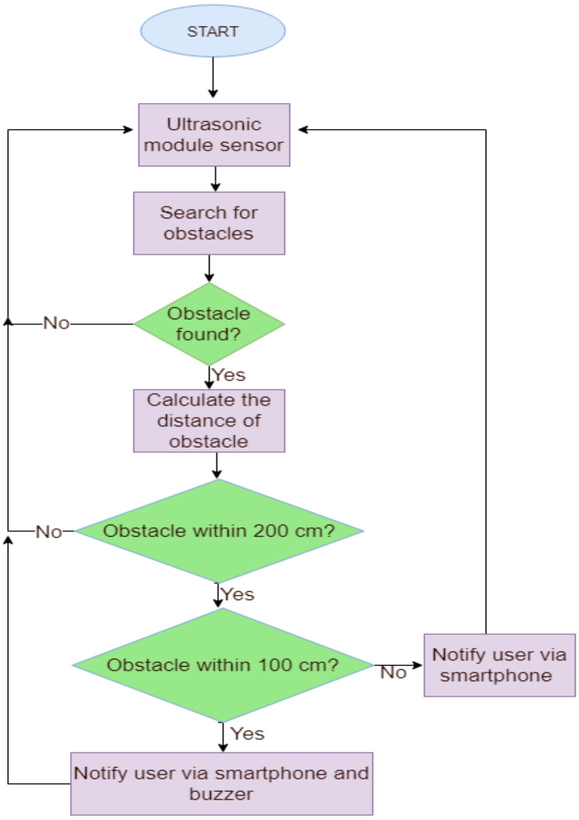

Figure 3: The working flow of the ultrasonic sensor module for our proposed system

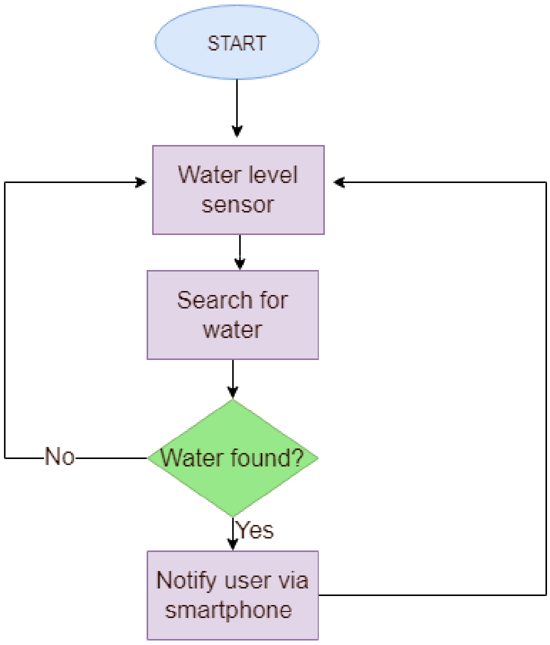

Figure 4: Water detection procedure of the proposed system

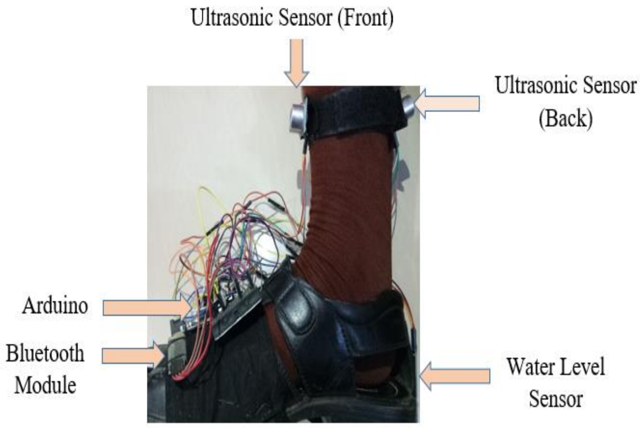

Figure 5: A prototype of the electronic guidance system

Table 1
Mapping between arduino and other components

Arduino Pin	Connected Device
D9	Trigger Pin of Front Sonar Sensor
D10	Echo Pin of Front Sonar Sensor
D11	Trigger Pin of Back Sonar Sensor
D12	Echo Pin of Back Sonar Sensor
D7	Buzzer
Rx	Tx pin of Bluetooth
Tx	Rx pin of Bluetooth
5V	Common +5V for all Device
GND	Common Ground(-) for all Device

V. RESULTS ANALYSIS

The prototype was tested in a real environment. We collected data for both the front and back ultrasonic sensors by placing obstacles in different positions. We measured data for 50cm, 100cm, 150cm, 200cm and 300cm distances away from the obstacle. For each interval, we took data three times and calculated the average value of these data. We also estimated the accuracy and the error rate of the measured data. The collected data from each sensor with accuracy and error rate is represented in Table 2 and 3.

Figure 6 and Figure 7 presents the comparison between the actual distance and the measured distance. This representation shows the distortion of the measured distance from the actual distance. It is shown that the deformity is not severe and the measured distance is acceptable. The distortion of the back sensor is comparatively higher than the front sensor

Table 2
Real-time data collected from ultrasonic sensor (front)

Actual Distance (cm)	Measured Distance (cm)			Average	Accuracy (%)	Error (%)
	1	2	3			
50	48	44	54	48.67	97.33	2.67
100	93	107	92	97.33	97.33	2.67
150	145	154	135	144.67	96.44	3.56
200	187	191	194	190.67	95.33	4.67
300	288	273	293	284.67	94.89	5.11

Table 3
Real-time data collected from ultrasonic sensor (back)

Actual Distance (cm)	Measured Distance (cm)			Average	Accuracy (%)	Error (%)
	1	2	3			
50	44	56	47	49	98	2
100	93	104	95	97.33	97.33	2.67
150	146	144	143	144.7	96.22	3.78
200	214	194	222	210	95	5
300	290	285	278	284.3	94.78	5.22

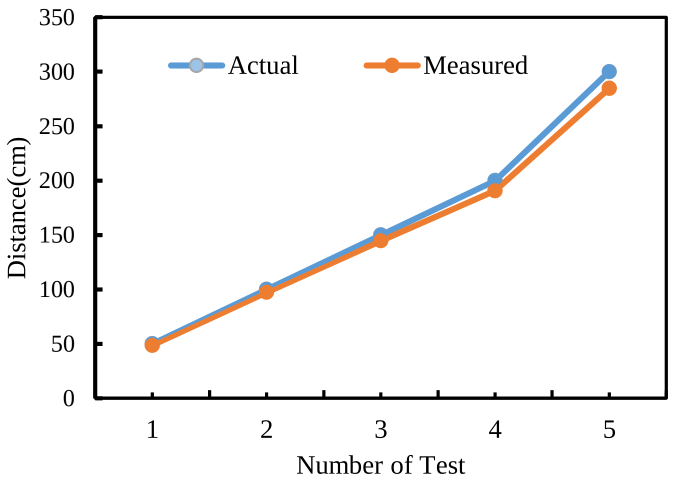

Figure 6: The comparison between actual and measured distance for front sensor

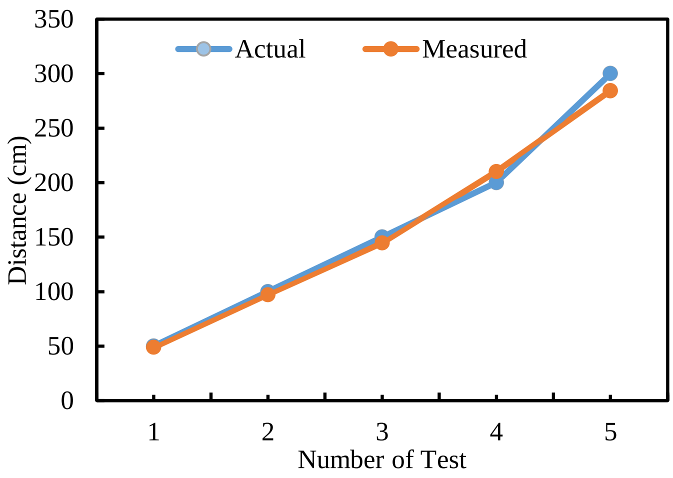

Figure 7: The comparison between actual and measured distance for back sensor

The comparison between the accuracy rate of the front and back ultrasonic sensor along with the distances is shown in Figure 8. From Figure 8, it can be demonstrated that the highest accuracy of 98% and 97.33% was achieved respectively from the front and the back sensor at the actual distance position of 50cm. The accuracy decreased when the distance increased. The lowest accuracy was about 94.78% and 94.89% respectively for the front, and the back sensor was found at the exact distance position of 300 cm.

The comparison between the error rate of the front and the back ultrasonic sensor along with the distances is shown in Figure 9. From Figure 9, it can be shown that error of 2% from the front sensor and 2.67% from the back sensor was found at the actual distance position of 50cm. The error rate increased with the increase of distance. The highest error was found at the exact distance position of 300 cm, which was about 5.22% for the front and 5.11% for the back sensor.

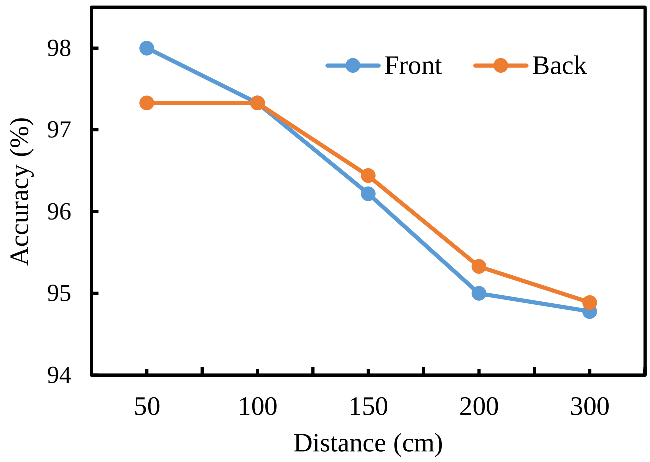

Figure 8: The accuracy rate achieved by the proposed prototype for front and back sensors

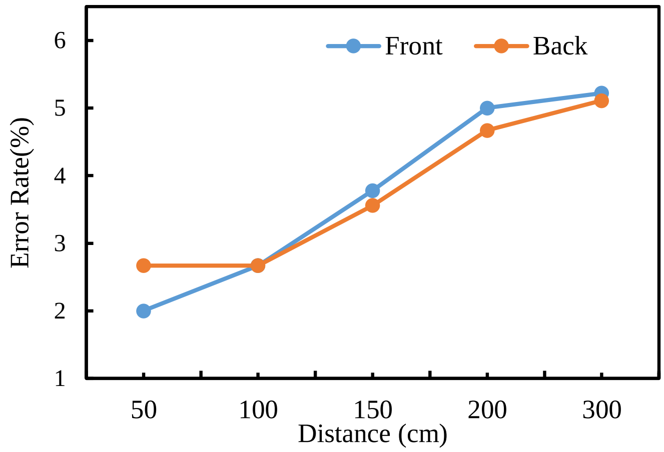

Figure 9: The error rate achieved by the proposed prototype for front and back sensors

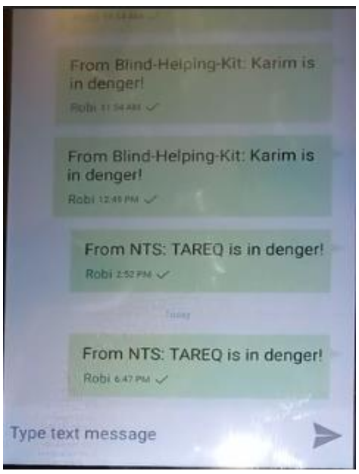

Figure 10: Danger message received from the user

Water level sensor was tested on both wet and dry surfaces. On a dry surface, the sensor provided output zero, and on a wet surface, it gave a non-zero value. Thus, the sensor detected water accurately and sent a response to the microcontroller. The buzzer and Bluetooth module also worked correctly. An android application received the data, which were forwarded from the microcontroller and notified the user using Text to Speech method. At the time of danger, the user could send a message to a specific person by pressing a simple switch. Figure 10 shows the received message from a user.

VI. CONCLUSION

The main objective of this paper is to build a user-friendly and cost effective prototype. We have successfully designed the prototype and integrated it with one of the pair of shoes. It was able to detect obstacles in both the front and the back-side of the user efficiently. It also recognized the wet surface. The system identified the obstacles in front of the users with the accuracy of 98% when the obstacles were in 50 cm far from the users. For the back-side, the highest accuracy of 97.33% was obtained at the same position of the obstacles. The lowest error rate of 2% and 2.67% was obtained by the front and the back sensor respectively. The user received real-time notifications about the surroundings via a mobile application. The prototype will aid the visually impaired person to move safely. Hopefully, the prototype will play a vital role for navigation by millions of visually impaired people.

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