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Development of an Automated Obstacle Detector for Blind People

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ABSTRACT

Eyes play a vital role in our life. Usually, all of us have seen the visually impaired people and know the problems that they face in their daily life. In order to detect the obstacles, blind people use sticks when they are walking but this instrument just can help them find objects on the ground. Obstacle detection is a field of effort that has led to vast progress in primary safety systems and in the primary-secondary safety systems interaction. Obstacle detector for the blind is an automated device for blind people. The main objective of this device is to make easy the walking environment for blind people. In this paper, a device is made which help the blind people by assisting through an android application. First, the device is made and then its performance is tested in three demanding conditions, for instance, normal, windy, and rainy conditions. The device shows a satisfactory level of accuracy in the three conditions. It helps the user to hear the distance and the location in an automated human voice.

1. Introduction

Nowadays blind people face several problems in their life. According to statistical data globally, every 5 seconds one person goes blind and every minute one child goes blind. According to Word Health Organization (WHO) statistics, approximately 1.3 billion people in the world have a vision impairment, of whom 36 million are totally blind. 217 million have moderate to severe vision impairment due to uncorrected refractive errors [1]. Bangladesh has almost 800,000 blind people, of whom 40,000 are children under the age of 15 [2]. Most of the time, the blind people wait for someone who can help him or her to cross the road. By using the obstacle detection device user can walk and cross the roads safely without any accidental issue. By considering this fact, researchers have developed several types of obstacle detector which are stated in Table1.

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Table1. *Previous work on obstacle detector.*

Year	Purpose of work	Major findings
2017 [3]	*Sensors can find the object with its location and distance.*	*Aware the user about the distance and the object location.*
2017 [4]	*Sensors measure the distance and GPS (Global Positioning System) and finds the shortest path.*	*Find the shortest and easy path for the user.*
2015 [5]	*Android app track down user's location from google map and user can call a predefined number by his headset.*	*User can get help from his relatives and can know the location.*
2016 [6]	*Application can convert any document into an interpreted form of blind.*	*Educational and general knowledge purpose.*
2017 [7]	*Seniors for detecting object, follow lines and motor drivers to navigate.*	*User can walk in the road by the stick navigator.*
2015 [8]	*GPS was used for navigation and ultrasonic use as an obstacle detector.*	*To navigate map and find the obstacles.*
2017 [9]	*Ultrasonic sensor for sensing obstacle.*	*Be warned to the user on the side of the obstacle.*
2015 [10]	*Camera and laser sensor were used for obstacle recognition.*	*Navigation and obstacle avoidance for indoor system.*
2005 [11]	*Sensors for sensing environment and detecting surface.*	*Aware the user about the obstacle in surface by online surface tracking algorithm.*

Overall, all of these previous systems have hence been proposed and executed; yet none have been broadly effective in enhancing the flexibility and lives of the blinds. Many systems exist that use this revolution, but they have some specific limitations, for example, the "White Cane" and "E-Cane" are devices which are big in size, this can be a problem of portability, some system used GPS for navigating the location but GPS is not very accurate and precise. Moreover, the risk of signal loss and limitations faced in offline reception of satellite signals restrain the practical implementation of GPS based system [12, 13]. Microcontroller based assistive robot mainly is an obstacle avoidance line follower robot which is not really sufficient to help the visually impaired people. Moreover, the blind reader is only for the educational purpose; it cannot help to find the obstacles. Android assistant Eye Mate tracks user's location from google map. Internet connection is a must for this service. So it cannot be a cost-effective system for the user. The voice-enabled stick has also some limitations. The user can shuffle the stick so the distance measurement can be inaccurate. Recovering the sight to blind people only works in an indoor system and it works in online mode, so it is not a cost-effective system.

This paper introduces an embedded device and a user self-customized android app "Easy way" to assist the visually impaired people by telling the distance of obstacles in the form of a human voice. It is compact, lightweight, and has an ultrasonic sensor to measure the distance of the obstacle in front of the user. The device uses Arduino microcontroller and provides output in the android phone. To verify the accuracy, three demanding conditions are considered in this paper and results are obtained and compared for validation of the system. There are two sorts of contribution in this paper; one is hardware based and another is software based. The hardware-based contribution is movability. The system is smaller and it lightweight than the previous system. The second commitment part is a human voice-based android application which can tell the obstacle distance and the location of the user without any internet connection.

2. System Architecture

2.1. Device Specification

In the discussed system, we have used a re-programmable open-source microcontroller device "Arduino Nano V3" [14]. There is also a micro-controller "ATMEGA328P" which works as same Arduino and it can also be used for this project, but in that case, it will be hard for the user to customize the system program according to their own. For distance measurement, there is an ultrasonic sonar sensor "HC-SR04". IR (infrared) sensor can also be used in replace of ultrasonic sensor, but the ultrasonic sensor is more stable than other sensors and the distance measurement ratio is more accurate than the others [15]. Bluetooth module "HC-05" is used to send the data from the device to the Android phone [16]. This module can be used in both slave and master mode. At last, the android application "Easy way" is used for receiving the data by Bluetooth module and convert it as a human voice. Fig. 1 shows the flow diagram of the working procedure and Fig. 2 illustrates the prototype of the device.

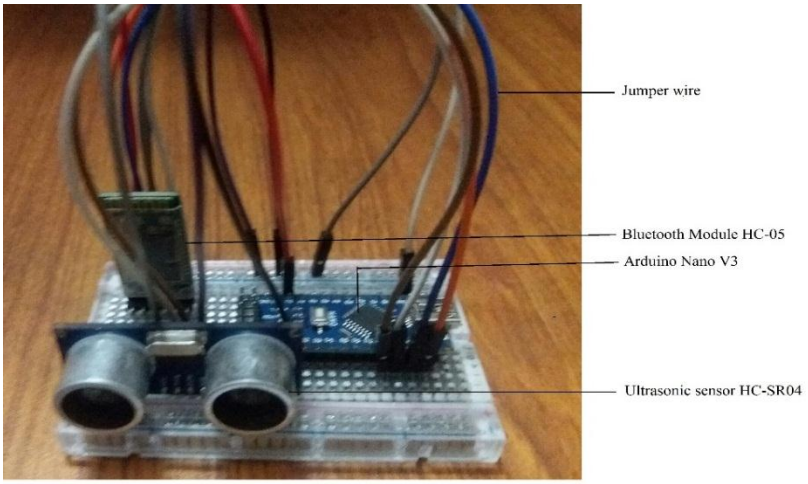

Fig.1. *Prototype of the device.*

2.2. Object Detection and Distance Measurement

At first, the device will be placed on the user's chest and when the user will run on the road the ultrasound will be emit by the ultrasonic sensor. This module consists of two drums, one is emitter which emits ultrasound and another is the receiver that receives the reflected ultrasound from the object. The emitter drum emits ultrasound for 10 microsecond's high pulse when the system triggers the module using trig pin. After emitting the ultrasound, the module makes the echo pin high. When an ultrasound is reflected by an object, it pursues the ultrasound and receives it by the receiver as well as echo pin is made low [17]. For measuring distance, the total time is stored in the Arduino. Therefore the distance between the sources and object is calculated by half the time is taken to travel source-object-source.

$$\text{Distance} = \text{Speed} * \text{Total time}. \quad (1)$$

But the time is taken to travel distance is half of total time source-object-source.

$$\text{Distance}=(\text{Time}/2) * \text{Speed}. \quad (2)$$

2.3. Sending and Receiving Data

Bluetooth module has been used for sending data from device to mobile phone. It has a secure protocol and it is perfect for short-range communication. It consumes low power and it is like a RF version of serial communication [18]. It converts the data into raw bits and sends it to the paired mobile phone. An android app "Easy way" is developed for receiving data. It has two main features; first one is the proximity sensor. This application uses the Android phone's proximity sensor. As a result, when the user shakes his/her android phone it will automatically launch the Android app, so the user doesn't need to anyone's help. Another feature is pairing. It needs to pair with the device Bluetooth only for the first time. After the first time, when the app will launch, it will automatically connect with the device within 2-3 seconds every time. The paired android application receives the raw data from the device and converts it into a numerical value. At last, after getting the numerical value, the application converts it into a human voice and the user can hear the distance with the help of headphone.

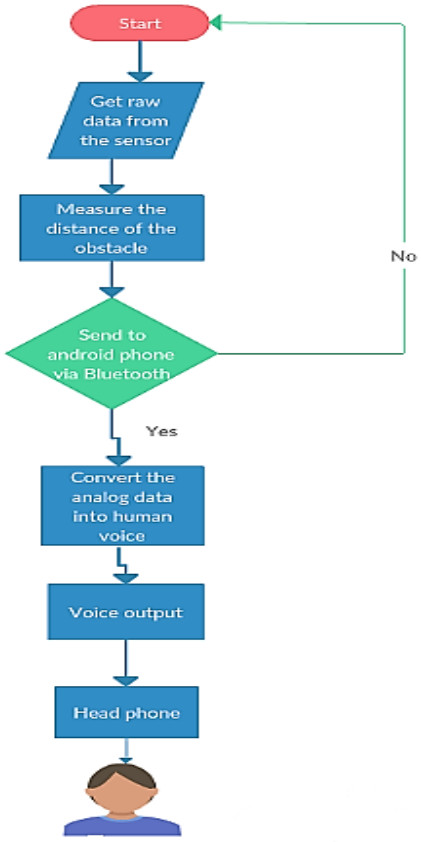

Fig. 2. *Flow Chart of the working procedure*

3. Results and Discussion

The experimental results that were obtained to measure the performance of the proposed system are described as follows:

3.1. Object Detection by Sensor

An ultrasonic sensor has been used in this prototype to detect the object. Ultrasonic sensors are best used in non-contact detection and it is independent of Light, smoke, dust, color, and material except for soft surfaces such as wool [19]. Whenever there was an object or obstacles in front of this sensor, the android app "Easy way" will command the distance in a human voice. The distance perimeter is in cm form as a default system user can change the perimeter in meter, inch according to their facility. Fig. 4 illustrates that the green object is detected by the ultrasonic sensor and the blue object is not detected because the blue object is not in the ultrasonic frequency. So the sensor cannot measure the blue object and it can measure the green object distance correctly.

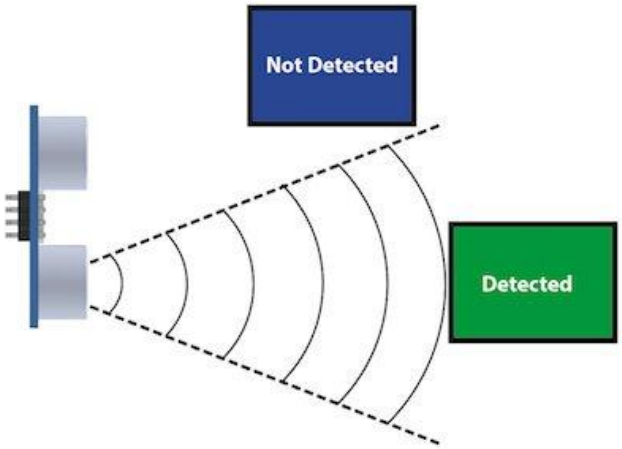

Fig. 3. *Ultrasonic sensor obstacle detection.*

Since the device is placed on the user's chest, so there is less chance of device movement. That is why the device can detect the accurate distance in normal air flow. Ultrasonic sensor can measure distance from 2 cm-400 cm [20, 21] .The sensor has to be fixed in its initial place to detect the object. Figs. 5, 6, and 7 represent the actual value (in distance) vs device measured value in normal, windy, and rainy condition, respectively. The following figures are line graphs, illustrate the difference between the actual measured value and the device measured value from the ultrasonic sensor in three different normal, windy, and rainy condition. Here the X axis shows the observation and Y-axis shows the distance in cm perimeter. From the first two figures, we can see that there was not much difference between measured and actual data, between the normal and windy condition. There was a slight fluctuation of measured and actual value in rainy condition, but the results were suitable enough. For the low distance such as 5, 10, and 15 cm, the actual value and the measured values were the same for the normal and windy condition.

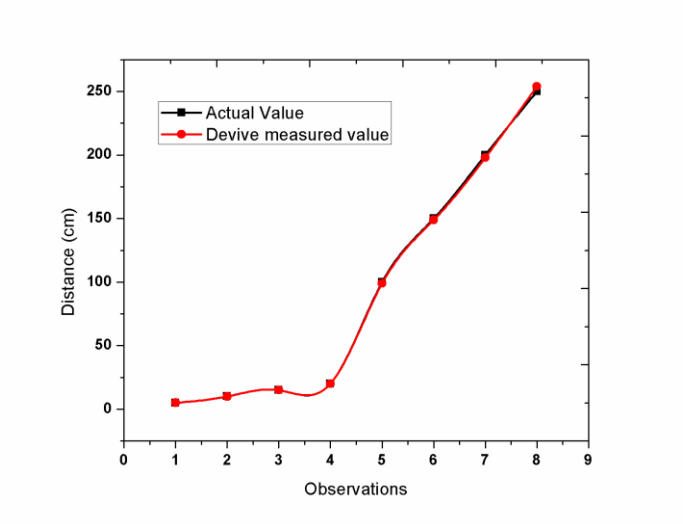

Fig. 4. *Actual measured value vs device measured value in normal condition.*

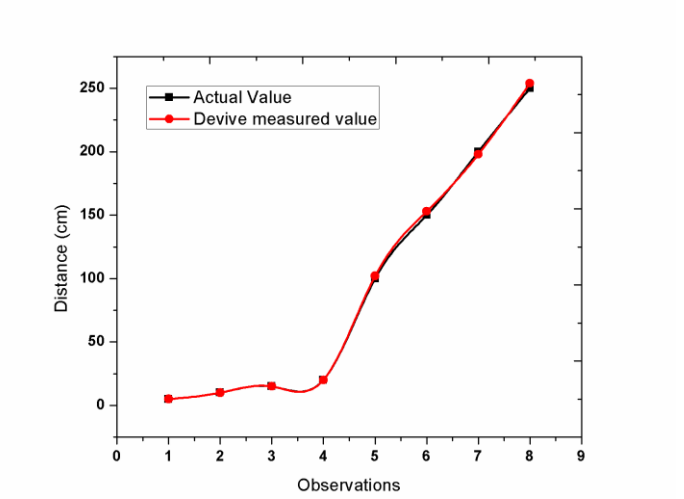

Fig. 5. *Actual measured value vs device measured value in windy condition.*

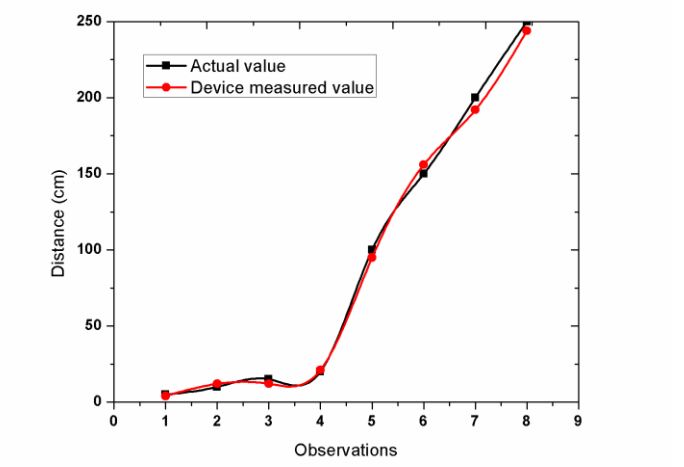

Fig. 6. *Actual measured value vs device measured value in rainy condition.*

Fig. 7 depicts the accuracy of measured data in normal, windy, and rainy condition. Here the X axis shows the observation and Y axis shows the accuracy in normal condition. The figure shows that normal and windy condition had a near accuracy. As the distance increased, the data accuracy changed slightly between normal and windy condition. For rainy condition, in case of small distance, there is a little fluctuation; but the accuracy increases as the distance increases. As an example for a distance of 250 cm, the accuracy is almost 98%.

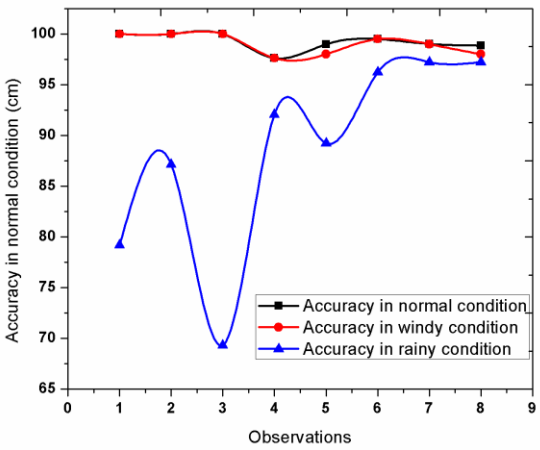

Fig.7. *Accuracy of the system in normal, windy, and rainy conditions.*

3.2. Voice Output from Android Application

We have developed an android application "Easy way" for voice output. When an object comes in front of the sensor, the voice tells the user about the distance. Voice output time interval can be set by the user, as a default, the time interval is 2 second that means the user can hear the voice output after every 2 seconds. If the users came less than 10 cm near to the object, the app will add a careful alert with the voice command. This distance can also be customized by the user but at first, as a default system is set in 10 cm.

3.3. Location Tracking and Voice Output

It is not adequate for a user to aware of the obstacle in front of him or knows about the distance between him and obstacle. Sometimes it is more important for the user to know about his present location than the distance. For solving this issue there is also another feature in this application. If the user wants to know about his present location, then he just has to say a predefined sentence "Where am I", then the app will convert the street address into a human voice and then the user can easily know about his present location.

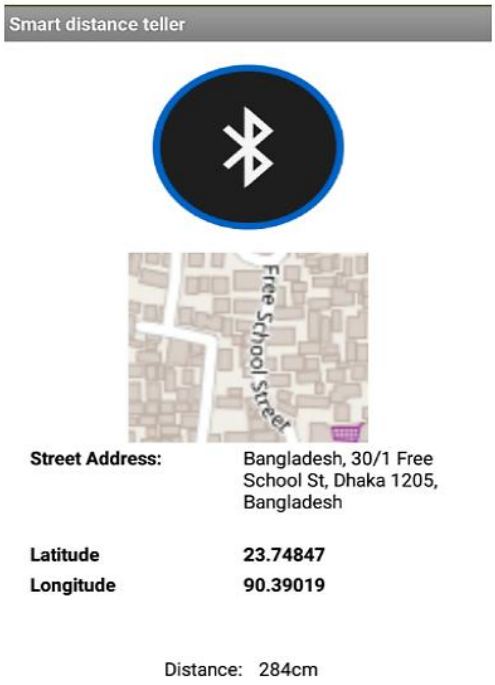

Fig. 8. *Android app "Easy way" text to voice screen.*

4. Comparison with Previous Work

Comparing to the previous work, our proposed system is more updated and modified. Some of the key comparisons are discussed below:

4.1. Portability

The previous "White Cane" and "E-Cane" use a sensor for sensing the objects and GPS for navigating the location. It makes the user aware of the distance of the object and the location of the user, and they are large but our system is relatively smaller than them and it is light. So, the user can easily carry the device with him.

4.2. Location Tracking

For navigating the location, some system used GPS in the early developments but GPS is not very accurate and precise. The proposed system is connected to an android phone so, the user can easily navigate the location with higher accuracy than the previous system and user can be tracked down by his family through IMEI (International Mobile Equipment Identity) number or simcard.

4.3. Programs Usability

In the previous work, microcontroller based assistive robot was a line follower based obstacle avoidance robot. This system consists of two sensors, one is to follow the lines and another is for sensing the obstacle and the system was mainly developed to navigate the user hastily. It only works in some

predefined lines and the device is bind with a stick. With the help of our device, user can easily travel any place or cross the road safely and it works everywhere.

4.4. Cost Effective

The previous android assistant Eye Mate, tracks user's location from google map and the user can call a predefined number through a headset. The user can get help from his known person by calling them, but for accessing in the google map user need the stable internet connection which is not possible for all the user. In the case of the aforementioned system, the user doesn't need any internet connection to operate the device. That's why it is a cost-effective device.

4.5. Distance Accuracy

The early voice-enabled stick, uses the ultrasonic sensor for sensing the obstacle and inform the user about the object. The main limitation of this system is that the user can shuffle the stick in his walking time, so the distance measurement can be inaccurate. In our proposed method the device is placed on the user's chest and the measurement accuracy is quite satisfactory.

4.6. Working Area

Recovering the sight to the blind people, this previous work used a camera for detecting the obstacle and laser sensor for measuring the distance of the obstacle. It navigated the user to avoid the obstacle, but this system only works in the indoor system, but practically the visually impaired people face several problems outside of the home. However, the aforementioned system works in everywhere and it also works in every weather situation.

4.7. System Speed

In previous works, the author didn't talk about the speed of the program, but the aforementioned proposed system has an android application named "Easy way". This is a user-friendly android app, where the user can open this application only by shaking their mobile. After opening the app it will automatically connect to the device Bluetooth module within 2 seconds.

4.8. User Friendly and Customization

In the previous system, all the facilities which were given had no user customization facility. In these systems, the user had to use the system according to the authority manual way but the proposed system is fully user-friendly and it can be customized by the user. There is a user-customized time interval for the human voice. User can set their time interval by their own choice.

5. Conclusions and Future Enhancement

In this paper, the overall two things, user facility and distance accuracy were briefly discussed. The distance accuracy that results in two different situations is very important for its accuracy measurement and the user conveniently customized android application "Easy way" is useful for hearing the distance in human voice. Some of the major findings of this project were given below:

- This device is small in size and it has a low weight so the user can bear the device easily on his chest.

- The average distance accuracy in two different mode (normal and windy) is 97.62% and in rainy condition the highest accuracy is around 95%.
- The distance teller android application "Easy way" can be easily customized by the user.
- User can hear the distance in every two seconds.

Moreover, some future developments of the discussed system are mentioned below:

- Another microcontroller device Arduino Nano works as same Arduino Uno and it can minimize the device more but it has not been mentioned in this paper, which should be a future implementation.
- Costly updated distance measurement sensor can be used in a place of ultrasonic sensor; it can be a future consideration.
- A 9V rechargeable battery is used as a current power source but Lithium-ion (Li-ion) battery can perform a better service than the current power source; it can be a future consideration.

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