Obstacle Detection for Visually Impaired Using Raspberry Pi and Ultrasonic Sensors

Ayush Wattal
Dept. of Information Technology
JSSATE
Noida, India
wattal.ayush@gmail.com

Ashutosh Ojha
Dept. of Information Technology
JSSATE
Noida, India
ashutoshojha30163@gmail.com

Manoj Kumar
Dept. of Information Technology
JSSATE
Noida, India
manojkumar@jssaten.ac.in

***Abstract*—This paper proposes to develop an electronic device for obstacle detection in the path of visually impaired people. This device assists a user to walk without colliding with any obstacles in their path. It is a wearable device in the form of a waist belt that has ultrasonic sensors and raspberry pi installed on it. This device detects obstacles around the user up to 500cm in three directions i.e. front, left and right using a network of ultrasonic sensors. These ultrasonic sensors are connected to raspberry pi that receives data signals from these sensors for further data processing. The algorithm running in raspberry pi computes the distance from the obstacle and converts it into text message, which is then converted into speech and conveyed to the user through earphones/speakers. This design is benefitial in terms of it's portability, low-cost, low power consumption and the fact that neither the user nor the device requires initial training.**

Keywords*—embedded systems; raspberry pi; speech feedback; ultrasonic sensor; visually impaired;

I. INTRODUCTION

Commuting in crowded environment is a challenge for visually impaired people. Visually impaired people are at disadvantage because they do not have access to any contextual and spatial information around them. According to a survey, as of 2010 there were more that 285 million visually impaired people worldwide, out of which 39 million were blind [1]. We have proposed to develop a cost effective application systems for visually impaired people so that they can move freely in known or unknown environment.

In today's fast paced world, the daily lives of people has been affected by the aid and support offered by technology. People, who are differently abled, now have the option of many devices, which can help them in their day-to-day activities. A lot of devices have been created in this field however, most of them are either not in use or requires a lot of training. Some of the works done in this field are explained below:

DRISHTI [2] is a wireless pedestrian navigation system for the visually impaired and differently abled. It emphasizes on enhancing the navigation experience of visually impaired people by focusing on contextual awareness. However, a lot of effort took in integrating this technology thus, the components were not optimized fully.

TYFLOS [3] system focused on integrating different navigation technologies such as a wireless computer, cameras, natural language processor, microphone, range sensors, GPS sensors, text-to-speech device, etc., and methodologies such as region-based segmentation, fusion, range data conversion, etc., to allow more independence during navigation and reading. The drawback of this system was that it was not tested on blind people thus, it did not have any feedback to improve on its hardware and software integration.

NAVBELT [4] is a guidance system that used a mobile robot obstacle avoidance system. The prototype consisted of ultrasonic range sensors, a computer and earphones. The disadvantage of this system was that it exclusively used audio feedback and was also very bulky for the users. Moreover, the users required extensive training to operate this system.

Most of the projects that have been created requires internet connection [5] i.e. there is a need to maintain continuous connectivity, which is not only difficult to attain in certain areas, but also adds the additional cost of data usage. In terms of sensors, these projects use proximity sensors, infrared sensors, laser diode, etc., which are affected by external atmospherics such as sunlight, rain, dust and may not function properly in outdoor environment [6] [7] [8]. Moreover, the end products that were created are difficult to wear, non-portable and are very costly, making them out of reach for common people [4].

All these reasons resulted in research and development of a device, which is easy to wear, portable, cost-effective and can work without the use of any additional connectivity such as the internet, thereby, making a visually impaired person aware of the obstacles in an easier way. In this paper, Section II explains the proposed design for this system. The obstacle detection and distance calculation process is detailed in Section III. The complete end-to-end working of the electronic device is explained in Section IV. Lastly, the test results, conclusion and future work are discussed in remaining sections.

II. PROPOSED DESIGN

The proposed design makes use of Ultrasonic Sensor that detects objects by sending a short ultrasonic burst and then listening for the echo [9]. The Raspberry Pi connected to the sensors calculates the distance from the object based on the time the echo took to come back. Next, we generate a Text output based on the distance calculated. This Text output is converted into an Audio Format, which is then relayed to the visually impaired using an Earphone or a Speaker. This system could be integrated on top of a belt, making it portable. This system is made up of four main components: (1) Ultrasonic Sensors, (2) Raspberry Pi, (3) Power Source, and (4) Earphone as shown in Fig. 1.

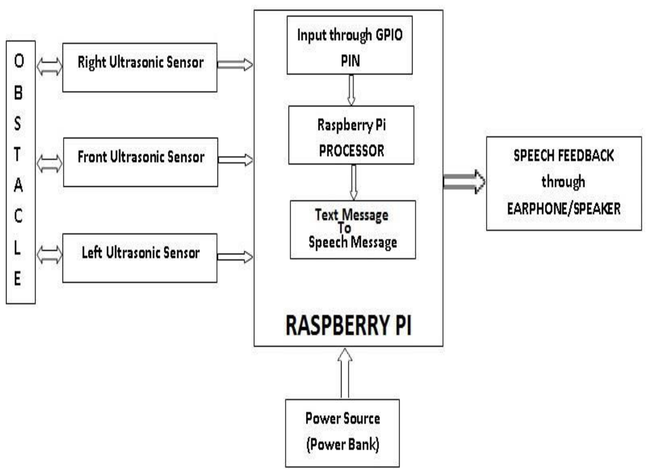

Fig. 1. Block Diagram of Obstacle Detection System.

A. Ultrasonic Sensors

The Ultrasonic Sensors belongs to a category of sensors that emits ultrasound i.e. sound of frequency more than 20 kHz [10]. Initially, a *trigger pulse* is given as an input to the ultrasonic sensor using Raspberry Pi. The ultrasonic sensor then emits a short 40 kHz ultrasonic burst signal. This burst signal travels through the air at approximately 343ms-1, hits an object and then bounces back to the sensor resulting in an *output pulse* [9]. This output pulse is captured by Raspberry Pi. Then using the time taken by the pulse to return back we calculate the distance from the obstacle.

The sensor consists of four pins: (1) VCC, (2) Trigger, (3) Echo and (4) Ground as illustrated in Fig. 2.

- **VCC -** It is used to provide 5V power to the sensor.
- **Trigger (Trig) -** Takes in Input Pulse to trigger the sensor.
- **Echo -** It is used to receive the Output Pulse i.e. the echo from the object detected.
- **Ground (GND) -** It connects sensor to the ground.

Fig. 2. Ultrasonic Sensor (HC-SRO4).

B. Raspberry Pi

Raspberry Pi (Fig. 3) is a credit card sized single board, low cost computer [11]. It takes input from the GPIO pins, which can be attached to LEDs, switches, analog signals and other devices. For our proposed design, we connect the GPIO pins to the ultrasonic sensors. It requires a power source of 5V to be operational and we have to insert a Micro SD memory card in it, which acts as its permanent memory. For our design Raspberry Pi 1 Model B+ is used. It contains 4 USB ports, a HDMI port, an audio jack port and an Ethernet port. The Ethernet port helps the device connect to the Internet and install required driver APIs. It has a 700 MHz single core processor and supports programming languages such as Python, Java, C, and C++ etc.

This mini computer runs our algorithm, which helps to calculate the distance from the obstacle based on the input it receives from the sensors. Then a Text-to-Speech driver API [12] is used to convert the text message (distance) to speech, which is relayed to the person wearing the earphone.

Fig. 3. Raspberry Pi 1 Model B+

C. Earphone/Speaker

Earphone/Speaker is used to make the visually impaired person aware of the obstacles that are there, by telling the direction and distance from the obstacle. It is better than a *buzzer* [13] [14] since, it provides more accurate results and is more perceptive, thereby, helping the person to react more easily.

D. Power Source

This system requires a 5V power supply. We can use a battery, portable charger, micro USB or a rectifier as the input power source.

III. Obstacle Detection and Distance Calculation

This section explains the details on the process of obstacle detection and distance calculation.

A. Obstacle Detection

Ultrasonic sensors are used for obstacle detection and calculation of distance between the obstacle and the visually impaired person. ultrasonic sensors are used in pair as *transceivers* [9] [10] i.e. a single sensor can both send and receive signals. The transmitter emits eight 40 kHz pulse, this pulse after hitting the obstacle is received back at the receiver, as shown in Fig. 4. The ultrasonic sensor works on the principle of *sonar* [15] i.e. it records the time taken by the emitted pulse to return back at the receiver end. Our algorithm implemented in Python programming language is deployed on Raspberry Pi. This algorithm is used to calculate the distance between the obstacle and the person, by recording the time interval between the pulse sent and pulse recevied. In this setup we use 3 ultrasonic sensors, which help the person to find any obstacle in left, right or front direction.

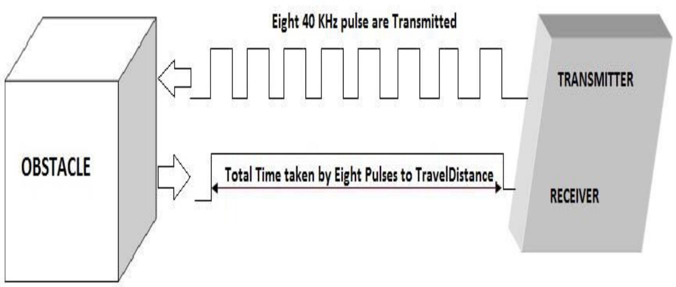

Fig. 4. Working of an Ultrasonic sensor.

B. Distance Calculation

To find the distance between the obstacle and the person, we use Distance Formula:

$$distance = speed * time$$

$$OD = \{[Speed\ of\ Sound * Time\ Taken] / 2\} \quad (1)$$

Where,

- ***OD:*** Distance between an obstacle and the person in meters.
- ***Speed of Sound:*** We take speed of sound as 343 meter/sec.
- ***Time Taken:*** It is the time interval between the pulse emitted and the pulse received.
- Since, the time taken by the pulse is twice the distance travelled, we divide the equation by 2.

IV. Working

The process starts when power is supplied to the Raspberry Pi. As Raspberry Pi boots up its operating system, it triggers the ultrasonic sensor to start sending burst signal. All the sensors are triggered at approximately the same time thus, there is very less delay. After the signal returns back to the receiver of the sensor as an echo, the Raspberry Pi calculates the time taken from transmitting and receiving the echo. Using this time we calculate the distance of an obstacle from any of the sensors. Next, it checks if any of the distance calculated is less than the minimum distance specified i.e. 0.5m in our case. If none of the sensors have distance less than the minimum distance, the entire process starts again. However, even if one of the sensors detects distance less than 0.5m, it triggers the pre-defined conditions (Fig. 5).

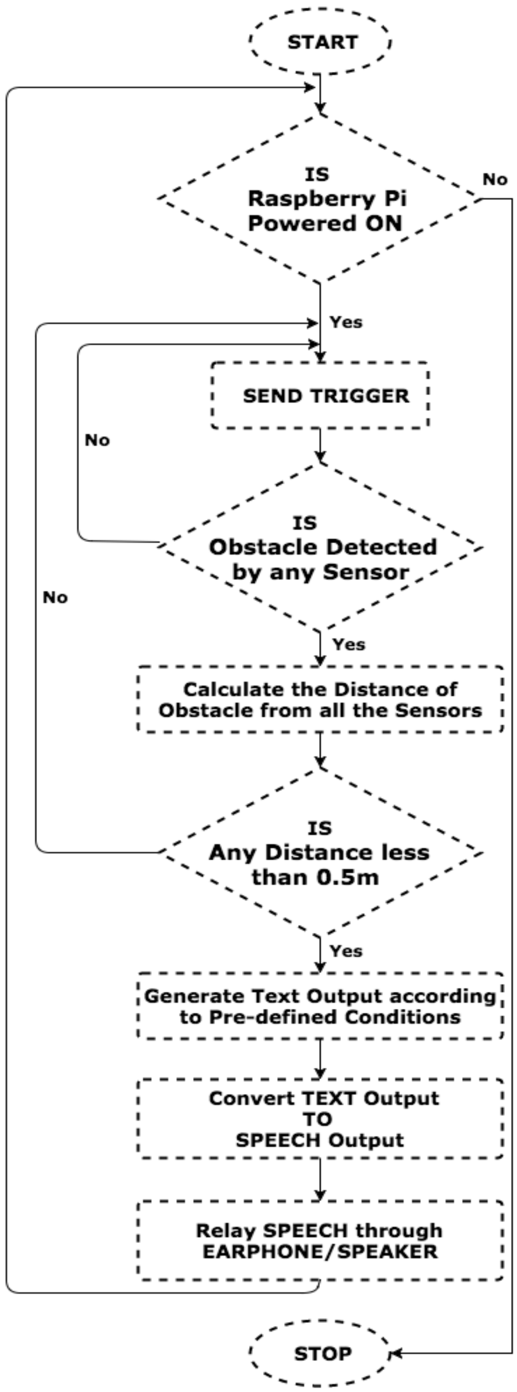

Fig. 5. Flow Chart of Raspberry Pi Belt.

Depending on the triggered condition a text output is created. This text output is converted to speech using Text-to-Speech API and as the last step this message is relayed to the visually impaired person via earphone or a speaker. After the message is sent the process starts again and continues till the power supply is connected.

V. RESULT

An electronic device is built in the form of a Raspberry Pi Belt to detect obstacles. The device is tested, by placing various obstacles at different positions and distances from the sensors on the belt. The system is successful in warning the user about the presence of obstacles in their path. It can detect any object within a pre-specified minimum distance in any direction. For out tests, we set the minimum distance value to 0.5m. The system announces the distance calculated in real time in meters or centimeters. For the simplicity of the user, the speech messages are stored in the form a universal language i.e. English.

The distance calculated based on the receiving pulse (echo) is not hundred percent accurate, however, we take into account the worst case and thus provide with the best results to avoid the obstacle. The test case results have been documented in Table I.

TABLE I. TEST RESULTS OF THE RASPBERRY PI BELT

Object Distance and Position (cm)	**Sensor Reading**			**Output**
	Left	***Center***	***Right***	
5cm, left	5	0	0	Move towards right
10cm, right	0	0	10	Move towards left
10cm, in front	0	10	0	Turn left or right
20cm, in front	0	20	0	Turn left or right
25cm, in left right and front	25	25	25	Turn around
25cm in left right, 20cm in front	25	20	25	Turn around
35cm in left and front	35	35	0	Turn right
40cm in right and front	0	40	40	Turn left
45cm in front	0	45	0	Turn left or right
50cm in left and right	49	0	50	Move forward

VI. CONCLUSION AND FUTURE WORK

This paper proposes to develop an electronic device in the form a Raspberry Pi Belt (Fig. 6) using a system of Raspberry

Pi and various other components (sensors, earphones, etc.). It has the following features:

- A device that helps visually impaired people as walking assistance.
- Uses sensors to gather information of obstacles.
- A device that can be used without Internet connectivity.
- A device that is cost effective, easy to use and portable.
- A device that notifies the user about obstacles in the form of speech.

As explained earlier, the current system is designed to be placed on the visually impaired person's belt. This increases the ease with which the device can be carried and also the time to setup the device becomes very less. Enhancements could be done to make the system more mobile as compared to the current design. It can be made more compact so as to make it easier to carry. In addition, if a GPS is installed onto the device, it could also help navigate the person in outdoor environment.

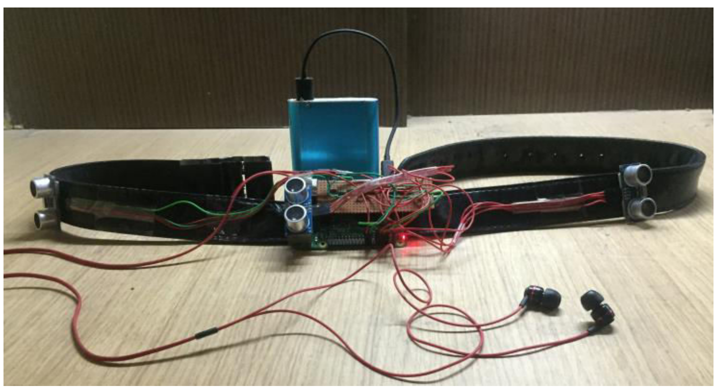

Fig. 6. Raspberry Pi Belt.

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