Design and Implementation of Smart Navigation System for Visually Impaired

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Abstract — *This work presents a navigation system for visually impaired using sound navigation and ranging. Here, ultrasonic sensor and Infra Red (IR) proximity sensor have been used for real time obstacle detection. Real time image processing is used to generate idea about the size and distance of the obstacle from the blind person, thus creating safe path for navigation towards destination. Voice recognition is used for controlling the device. A method of finding the device in case it is lost is also provided in the work. The goal is to create a cost effective, light weight, portable system for the blind people enabling their movement without assistance.*

Keywords— *Smart Blind Navigation, Voice Recognition, Real Time Image Processing, Obstacle Finding, Global Positioning and Routing.*

I. Introduction

The World Health Organization (WHO) estimates that 285 million people are visually impaired worldwide. 39 million of them are blind. About 246 million people suffer from severe reduction of vision. People who suffer from a severe reduction of vision that cannot be corrected with conventional means like glasses are blind. A blind person cannot see any obstacle and thus cannot move without any help of other means. Moreover, these blind people use a white cane as a tool for direction when they walk or move. The traditional white cane can't give any idea about the environment or surroundings to the blind person. It just helps to find the ground or objects by the sense of touch. It can't give information about an obstacle whether it is in front of him or not until it comes with a collision with the obstacle. So, scientists and engineers are trying to provide a self-dependent and efficient navigation system for the people who have vision disability. In the last few decades, several guidance systems for blind and visually impaired pedestrians were proposed [1]. Bousbia-Salah et al. suggested a system where obstacles on the ground are detected by an ultrasonic sensor integrated into the cane and the surrounding obstacles are detected using sonar sensors coupled on the user's shoulders [2]. Shoval et al. proposes a system which consists of a belt, filled with ultrasonic sensors called Navbelt [3]. One limitation of this kind of system is that it is exceedingly difficult for the user to understand the guidance signals in time, which should allow for walking fast. Castells et al., use vision sensors in their system's setup. In this case, part of a vision system is proposed to detect possible obstacles as a complement to normal navigation with the cane. Using computer vision, images are analysed to detect sidewalk borders and two obstacle detection methods are applied inside a predefined window [4]. Another system using a vision sensor is presented by Sainarayanan et al. to capture the environment in front of the user. The image is processed by a real time image processing scheme using fuzzy clustering algorithms. The processed image is mapped onto a specially structured stereo acoustic pattern and transferred to stereo earphones, as seen in the system description in [5]. All these systems have been proposed to make an efficient way or medium for the purpose of making visually impaired peoples' daily movement easy and self-dependent, whether in a known or an unknown environment. In this work, a new smart blind navigation system is proposed which uses ultrasound wave and time delay to detect the obstacle along the way and give an idea about how far the person is from the obstacle. The components of the system not only help the navigation but also provide guidance about the surrounding environment and determine a safe path to a desired destination. Real time image processing had been used in the work to detect and tell about the type of the object to have a better idea. Global Positioning System (GPS) based navigation system is provided along with voice recognition system. Most often all these features mentioned are not offered in a single device. So this work aims at combining these methods to create a cost-effective, lightweight, portable system for the blind people enabling their movement without assistance.

II. Proposed System

A. *Finding The Obstacle*

A blind person can't see any obstacle on the track he is walking. So collision with any obstacle occurs often. Now the white cane just provides the sense of touching of the object which is not a very pleasant experience. Moreover, if s/he comes in contact with a passer-by it could be an annoying experience. So to avoid the direct contact as much as possible a system should be introduced so that the blind person can have an idea of the obstacle before it comes directly in contact with her/him. Now the proposed stick finds any obstacle in front of it in a range of 1 meter and starts to make sound. A blind person can't see any obstacle, but can hear this sound and identify the presence of an obstacle. It'll be a great help for him to avoid collision on the track whether he is indoor or outdoor.

B. Idea about Distance from the Obstacle

The range could be 4 meters with respect to the sensor used. But in a crowded place it'll be a great disadvantage because of the presence of redundant objects in this range. So the suitable range chosen here is 1 meter. The information about closeness is provided by a buzzer system attached to the stick. When the stick gets within 1 meter of the obstacle, the sound from the stick varies with the distance. The more the obstacle comes closer, the more the sound becomes louder and its pitch becomes different. Thus the blind person can have an idea about the distance from the obstacle. Before the person gets any more close to the obstacle, i.e. sound gets louder with different pitch, s/he should change her/his direction.

C. Finding the Stick if it is Dropped or Lost

While walking on the street it is possible that the stick fell off from the hands of the blind person. Similarly, s/he may lose it in his own room or anywhere. In this case, there should be a method of finding the stick. The proposed system provides a secondary device with which the stick, when dropped or lost, can be found. If anytime the blind person drops the stick, he or she can find it with the help of this device. This device has a switch that will turn on the buzzer in the stick when pressed. Now hearing this sound, the bind person can find the stick.

D. Real Time Image Processing

From research it is known that when the blind people hear about an object, they make an imaginary image associated with the object in their mind. So, knowing what type of object is in front will be very helpful to understand the behaviour of the object from personal experience. We are using real time image processing to give the blind person an idea about the type of the object. There will be a camera which will take photo every 10 seconds and tell her/him information about the object in front, so that s/he can have an idea about the size, behaviour and movement etc. of the object.

E. Route Information

Without knowing where to go, a blind person can't move in an unknown environment. Basically the blind person makes an imaginary route or navigation system of her/his own considering the environment where s/he is moving daily. Sometimes s/he sort of memorizes the touch, sound, footsteps, directions etc. everything in her/his mind to make a map of her/his own. Without that s/he is very helpless. When a blind person moves outdoor, the total environment can be known, unknown or can be modified from her/his past experience. So walking independently outdoor is almost impossible or can be very hard. This makes the blind person frustrated and dependent on help of the pedestrians. That's why we are trying to introduce the route information to them. With the help of the proposed system s/he'll get the route information, i.e. where to go, how to go, how much is the distance from the source to the destination etc.

F. Emergency Help

While roaming outdoor or indoor the blind person may face difficulties that s/he can't escape on her/his own, i.e. the person may get sick or hurt. We are providing a method so that the blind person can ask for an emergency help when needed. If the person somehow moves out from the route to an unknown place where it's very hard to find the location or the person is hurt or feeling sick, with just a help of pressing a button s/he can send the present location and ask for help from her/his friends and family.

G. Voice Recognition

Voice recognition method is being used by various systems nowadays. We have seen the Siri in Apple products, The Google assistant in Android systems, Cortana in Windows. These apps work as artificial intelligence systems. The user can give order or ask for anything and the assistant executes it within its level of intelligence. Unfortunately, till now to use a smart phone is very tough for a blind person and can be high maintenance. So we are trying to provide a voice recognition system along with some buttons which are easy to maintain. When pressed the system will take input from the person through the microphone and will execute the task.

III. CONSTRUCTION OF THE DEVICE

The proposed device mainly serves the navigation system and we want to help the blind people with better navigation and lesser dependency on other people. We want the blind person to feel free to move anywhere. To do this we are dividing the work into two sections. One of the parts should be done in the stick because the other purpose of the stick is to have a sense of the ground the blind person is on and we don't want to interrupt that. The second part is done separately and can be placed in a helmet. The two parts have different objectives and the elements used in them are not similar.

A. The Stick

The sole purpose of the stick is to find the object in front of it and to understand the type of the ground. As the blind people can't see where they are walking on, it is very hard to understand the type of the ground whether it is smooth or rough. So we don't want to interrupt this advantage of the stick and basically want to work along with it. We just want to find the object which is in range with the sensors used in this project and to give a signal to the blind person so that it may not come into collision with the blind person. Now, in every project there are two sides. One is the hardware portion from where we get to know about what physical components have been used by the computer or the electronic device. The other side is what types of software have been used as the operating information to implement the project. The hardware is the body and the instruction applied by the software is the brain. Software can be thought of as the variable part of a computer and hardware the constant part.

1) Hardware Requirements: Hardware is the physical portion of any device. It consists of the processing unit, sensors, input or output elements and so on. To construct the project we have used some components. These elements are used in the Stick. There is a processing unit, Arduino Nano R3. Ultrasonic sensor HCSR04, IR Proximity Sensor and the RF module are the sensors. A Buzzer is the output device. To keep the device working a power source should be provided. In this case we are using a Battery. To regulate the voltage up to the input requirements of the elements, a buck module has been used.

2) Software Requirements: The software portion is divided into two sections. One is to design the project and simulate it and the other is to give input in machine language to the processing unit. For the schematic design we have used Proteus 8.6. In the schematic design we first drew the circuit and then saw the results via simulation. To implement the code into the Arduino Nano R3 we have used Arduino Software 1.8.2. Here machine language is used to give instructions to the hardware.

B. The Helmet

We are using another device which can be mounted as a helmet. In this helmet there are several sections. One section will be used to provide real time image processing system. Another portion will be used to provide route information. To operate the system there are two portions. One is button system and another is voice recognition system. There is a switching mechanism which will be used to provide the facility of triggering the stick buzzer. All the equipments are mounted on the helmet in a convenient way so that the blind person can easily carry the helmet and the helmet's system can efficiently carry out the instructions introduced to it. The camera should be facing front to do the continuous image processing. The purposes of this helmet are to do image processing, navigation, voice recognition, sending sms etc.

1) Hardware Requirements: To carry out the purposes we have used some components which are set up on the helmet. Here there are two processing units, Arduino Nano R3 and Raspberry Pi V3. The Raspberry Pi V3 is the main processing unit and the Arduino Nano R3 is the secondary processing unit working along with it. RF module is used to trigger the stick from the helmet. We are using a webcam as a camera for the image processing purpose. GPS and GSM module is used to execute the navigation process and to send sms in case of emergency. There is a mic in option to take input for the voice recognition system. To keep the device working a power source should be provided. In this case we are using the Battery. To regulate the voltage up to the input requirements of the elements, a buck module has been used, just like the stick.

2) Software Requirements: The software portion for helmet is divided into two sections, just like the stick. One is to design the project and simulate it and the other is to give input via machine language to the processing unit. For the schematic we have used Proteus 8.6. In the schematic we first drew the circuit and then saw the results via simulation. To implement the code into the Arduino Nano R3 we have used Arduino Software 1.8.2. Here the machine language is done to give instructions to the device. To implement the machine code into the Raspberry Pi V3 we used Python 2.7.

IV. SCHEMATICS OF THE DEVICE

To design schematic of the device Proteus 8.6 was used. It is quite a well known software among the designers. It is less complex and easy to use. The library of this software is also very rich.

A. Schematic of the Circuit in the Stick

The stick has Arduino Nano R3, ultrasonic sensor, IR proximity sensor, buzzer, diode etc. So before implementing these on a board a sketch was made first and by sketch we mean schematic. So using Proteus 8.6 the circuit had been implanted on the software as in fig. 1.

B. Schematic of the Circuit in the Helmet

Now, the circuit of the helmet is a little bit complex than the circuit of the stick. There are several components we are using here such as RF module, Raspberry pi V3, webcam, GPS & GSM module, Arduino Nano R3, MPU9255, Lipo battery etc. The schematic of the helmet's circuit is look like as in fig. 2.

The actual circuit diagrams are not provided here because they are quite messy even after using zoom in option in Proteus software.

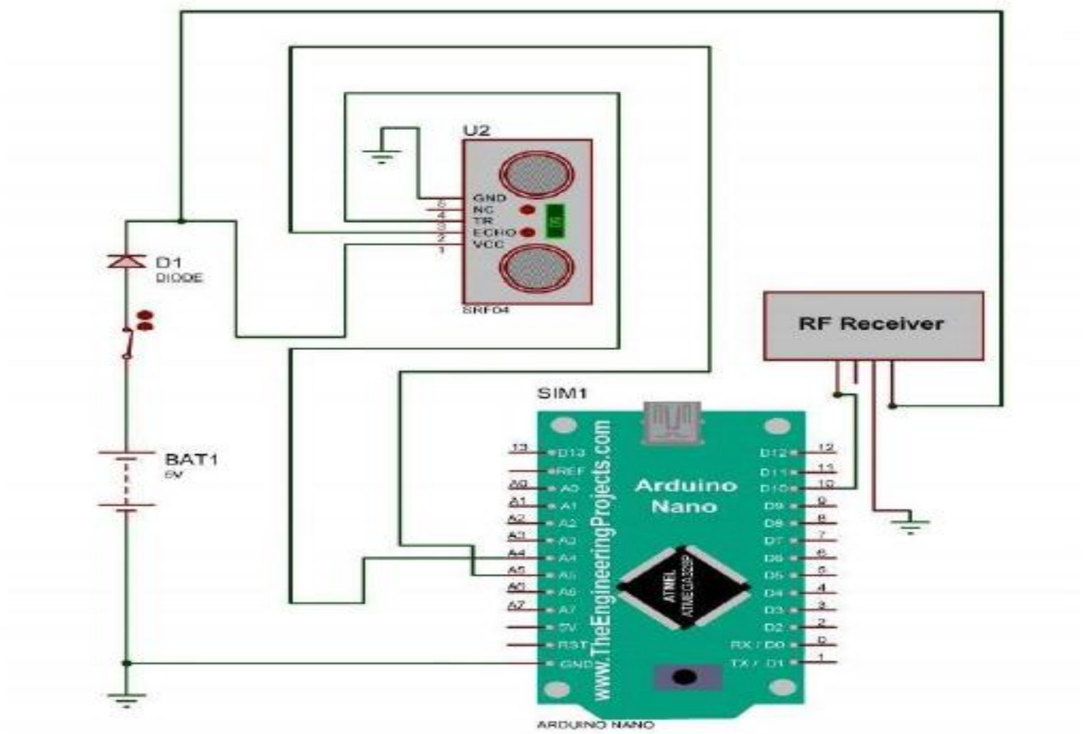

Fig.1: Schematic of the circuit in the stick.

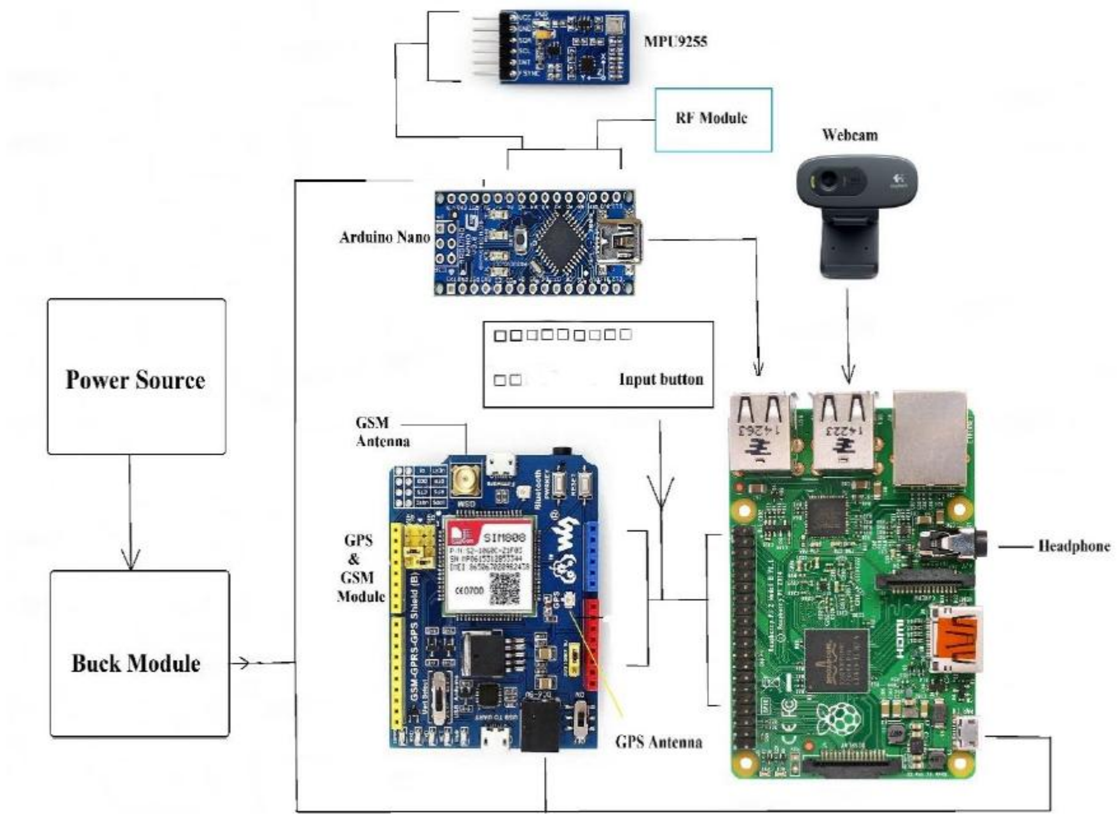

Fig. 2: Schematic of the circuit in the helmet.

V. WORKING PRINCIPLE

A. Obstacle Detection

Detection of the obstacle is done basically by using the ultrasonic sensor. The device continuously measures the distance if the blind person switches on the device. The ultrasonic sensor emits an ultrasound of 40,000 Hz which propagates through the air and bounces back to the main device if there is any obstacle in its way. It actually works like the bats do for their navigation process which is called “Echolocation”. Echolocation is the use of sound waves and echoes to determine where objects are in space. To echolocate, bats send out sound waves from their mouth. When the sound waves hit an object they produce echoes. The echo bounces off the object and returns to the bats’ ears. Bats listen to the echoes to figure out where the object is, how big it is, and its shape. Using echolocation, bats can detect objects in complete darkness. Just like bat echolocation, sonar uses sound waves to navigate and determine the location of objects. Here, the sensor emits an ultrasound at 40,000 Hz. If there is an obstacle on its path, it will bounce back to the module. Considering the travel time and the speed of the sound, the distance is calculated. When it finds an obstacle it sends signal to the Arduino.

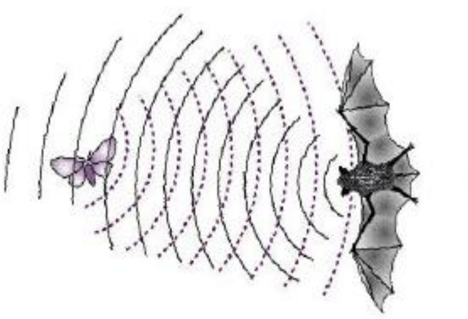

Fig. 3a: Bat Echolocation

Fig. 3b: HC SR04 Echolocation

Fig. 3: Echolocation Process.

Now, Arduino with the help of the instruction given decides whether it is in the declared range. The range is declared in the machine language. If it’s in the declared range the Arduino executes an operation by turning on the buzzer. If there is not any obstacle on the way, the buzzer is off and the person is free to go. The full process can be seen in fig. 4.

B. Sound Variation with Distance

To give the blind person an idea of the distance from the obstacle we are using time delay of echolocation. If it sounds continuously with the same tone then it’s hard for the person to understand the distance from the obstacle. But we are trying to generate different sound so that s/he can understand how much near s/he is to the obstacle. When the stick gets closer to the obstacle, the sound from the stick varies. The more the obstacle comes closer, the more the sound becomes louder and of different pitch. Thus the blind man can get an idea about the distance of the obstacle. Before s/he gets closer to the obstacle, s/he will change the direction of his movement. In fig. 5 the process is shown. One can see how the delay is working with the distance changed. The more s/he comes closer to the obstacle, the louder the sound is.

C. Finding the Dropped Stick

If the stick is somehow dropped by the user, s/he can find it using a second device. There is an arrangement of an additional device to the stick connected through the RF module. This second device will be on the helmet. If the blind person loses his stick s/he has to switch on the second device. Then this device will work as the block diagram given in fig. 6.

To make this second device we have used following described materials. When the blind person drops the device s/he has to turn on the switch of the second device. It then transmits a RF signal continuously. On the stick there is a receiver. It can receive the RF signal sent by the transmitter. It receives the signal and sends information to the Arduino Nano R3 of the stick. The Arduino Nano then, with given instructions, turns on the buzzer. So the blind person can hear the sound and locate the position of the main device nearby. We can have an idea from the block diagram in fig. 6 how it has been done. Here RF module is of great use. If we have used the Bluetooth module to connect both the devices, then it would have been a great hazard for the blind person since the Bluetooth devices often get disconnected. The RF module thus is very useful for this type of communication. Moreover, it has a very large range of support so that the blind person can turn on the device from a distance which is very convenient.

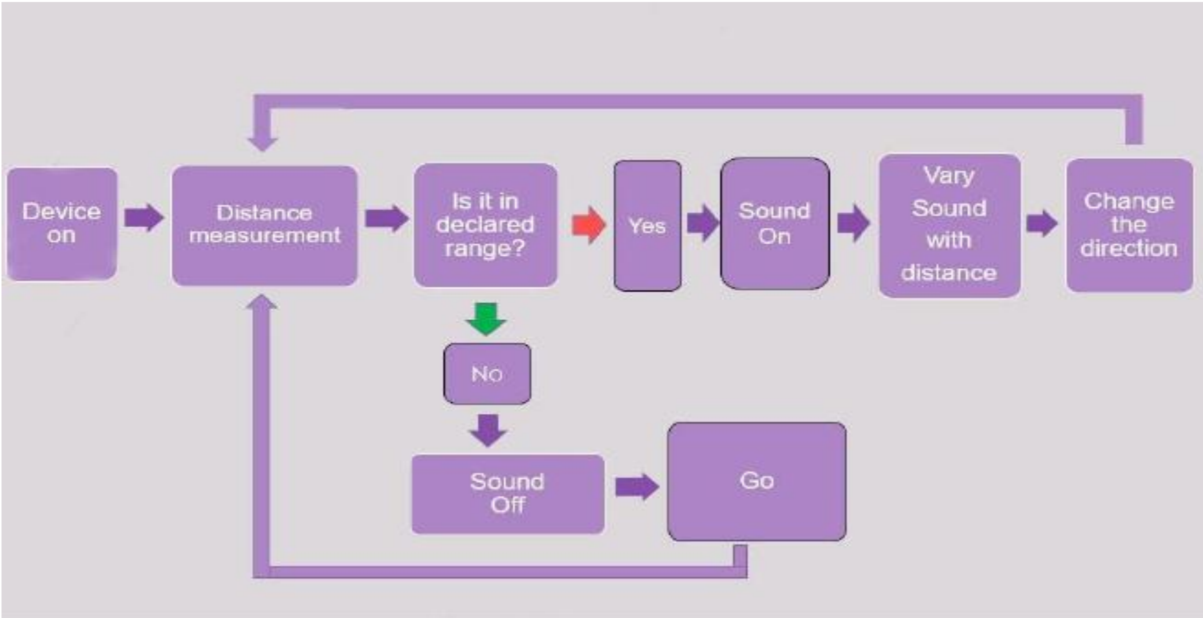

Fig. 4: Block diagram of the obstacle detection process.

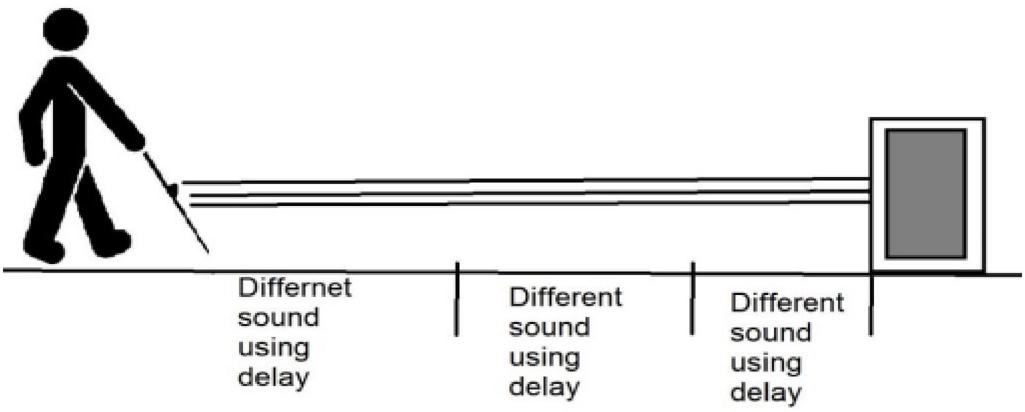

Fig. 5: Sound variation with distance from obstacle.

Fig. 6a: Process done by the second device.

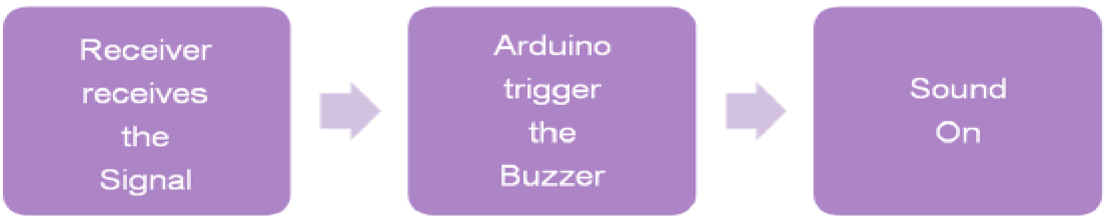

Fig. 6b: Process done by the stick.

Fig. 6: Finding the dropped stick.

D. Real Time Image Processing

We are using real time image processing to detect the object. In specific, we are using gray scale image for processing. Pixel is the smallest element of an image and an image is nothing but a set of matrix. Each pixel corresponds to any one value. Image can be in color format, grayscale format, binary format etc. In an 8-bit gray scale image, the value of the pixel is between 0 and 255. Here 0 means the darkest point and the 255 means the brightest point. Darkest point means everything is black and the camera can't detect any object through image processing. So in our Raspberry Pi V3 we are using python to implement the code with the help of the Open CV library function. Open CV, a computer vision library, is extremely popular and has considerable functionality relevant to this project. Grayscale image is being using here for image processing. We are using a webcam which is capturing an image in every 10 seconds, converts it to the grayscale and compares it with the other similar images stored in the database and when it finds a match it can tell what the object is. The process is shown in fig. 7.

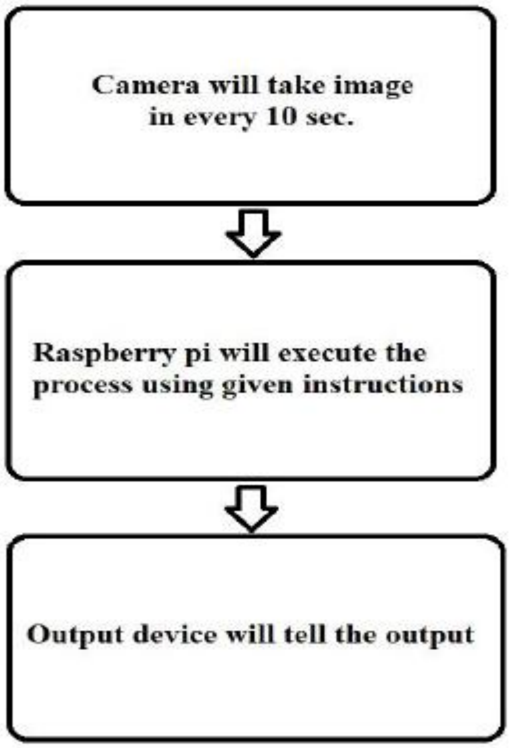

Fig. 7: Real time image processing.

E. Route Information

We set some points as our route information. By covering every possible route of this area we made an offline map. We have collected information on the route and put that into our code in Python. Thus collecting the GPS coordinates several paths were created for the offline map. Now, we want to provide the distance from the destination. When the blind person sets the destination, the system at first tells her/him the distance from the destination using the GPS coordinates from the offline map. Here we are using 10 DOF IMU Sensor (B) MPU9255 and SIM808 for this navigation purpose. From the IMU Sensor only the magnetometer is used along with the Arduino Nano R3. From SIM808, the GPS is used for the coordinates. The Raspberry Pi V3 uses the given instructions and compare with the coordinates and compass value and execute the process continuously. In Raspberry Pi the code has been done in Python. The process is shown in fig. 8.

F. Emergency Help

If the blind person needs help reaching desired destination and is lost, with just a help of pressing a button he or she can send the present location as sms and ask for help from her/his friends and family. Here we are using SIM808 of which the GSM portion will do the work when pressed the emergency button. The process is shown in fig. 9.

G. Voice Recognition

We are here trying to provide a voice recognition system along with some buttons which are easy to maintain. When pressed the system will take input from the person through the microphone and will execute it. We have done the code in Python in Raspberry Pi. When the system goes online we can give input and the system will recognize the task. Basically we are using voice recognition here for the purpose of navigation system. So the person can give the destination as an input and the system will find out the route for the blind person. Instead of using buttons, the person can set the destination via voice recognition system. The process is shown in fig. 8.

VI. RESULT ANALYSIS

A. Obstacle Detection

We declared the maximum distance for the sonar to be 200 cm. Then we divided the distance into three parts. If we assume the range is x, then the first range is $0<x<15$ cm and the time delay is 50 seconds. So when there is an obstacle in the range the sound would be different for the time delay. On the Arduino 1.8.2 there is a serial monitor. We have to connect the Arduino Nano R3 with the USB cable and select the COM port. Then we can see the result in the screen as in fig. 10a. Again, we declared the second range is $15\leq x<50$ cm and the time delay is 150 seconds. So if there is an obstacle in this range the sound would be different for the time delay as shown in fig. 10b. Then we declared the third range as $50\leq x<100$ cm and the time delay was 200 seconds. So if there is an obstacle in this range the sound would be different for the time delay, can be seen in fig. 10c. We didn't increase the range further. If we declare the range more than this, then there will be some complications. Suppose the blind person is walking in a crowded area, then there will be a lot of obstacles in the ultrasonic sensor's working range of 400 cm and it's a huge range actually to walk without any complication in a crowded place. So the range is narrowed down in the machine language.

The IR proximity sensor is not set this way. It has a range of 10-80 cm. When something comes in its way, it works just as the ultrasonic sensor does. If the ultrasonic sensor misses any object like a slant surface, the IR proximity sensor catches it.

B. Finding the Stick

We have showed the obstacle finding and the sound variation till now. How to find the main device had been discussed in the previous chapter and the theory worked perfectly in practical. The RF module made the work easy with its adaptive configurations. Since the range of the RF module is 3000 cm we can easily find the main device using the second device with a suitable range.

C. Image Processing

Now, in image processing system, we told that our device is continuously capturing images every 10 seconds. We took the images of several minutes and checked the result for detecting humans and the device gave the result of how many humans were found with a very little error sometimes. The error is occurring because of the scale factor and frame size declared in the programming language. If we change the value of this factor and the frame size the error can be reduced. The result is shown in fig. 11.

D. Voice Recognition

We are here trying to provide a voice recognition system along with some buttons which are easy to maintain. When pressed the system will take input from the person through the microphone and will execute it. So at first we took several inputs to test whether the voice recognition system can take the input or not. After several tests we found some errors. When there is a lot of sound pollution the input was not taken well by the processor. Moreover the processor is a bit slow to handle these types of instructions too. But overall performance was good. At least, from the results we got we can say that it can be provided with the system. There is an image of the input value taken by the system in fig. 12.

E. Route Information

To take the input of the destination from the blind person we provided two different ways- button input and voice input. When the system is online we can easily use the voice recognition system to take the input. But the button system also works just fine and faster than the voice recognition system. Several destination buttons were placed to take the input from the blind person. S/he can even know about the present condition also. When a destination button is pressed or voice input is taken for a destination, the system will create the path, tell the person about the distance between her/him and the destination. After starting to walk, when the person passes a point placed in the route the system will continuously tell the person in every 10 seconds what is the present condition and how much far the destination is. One can see from fig. 13 that all of the details are being provided. Another important thing is that, to keep the blind person in the route and tell her/him about the road banking the magnetometer takes data and tells the person how much to move right or left along with information of angle.

F. Sending SMS:

Here in fig. 14 one can see that the system is sending sms when it gets an instruction including current location information.

VII. CONCLUSION

This project proposes a system to assist blind users in their navigation. With the proposed design and architecture the blind people will able to move easily from one place to another without help from other people. Our paper analysed the existing electronic aids for the blind people. The proposed system is more useful and efficient than the conventional ones. As far as the localization is concerned, it will be able to provide accurate details of the location of the blind person with the help of the GPS if in case s/he gets lost or faces any danger. The proposed system is able to provide information about the surrounding environment. It can be further improved to have more decision making capabilities by employing varied types of sensors, which are not used in current work. Despite this scope of improvement, it is hoped that the proposed system will efficiently aid the blind at navigation. It is practical, cost efficient and extremely useful. To sum up, the system provides numerous additional features which the competing systems do not provide fully and can be an alternative or a very good enhancement to the conventional ones.

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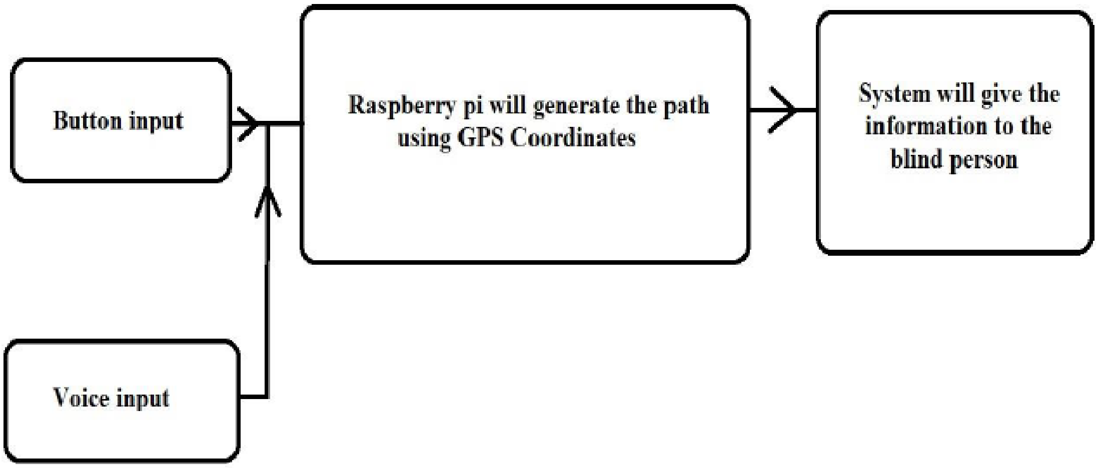

Fig. 8: Giving route information and voice recognition of command.

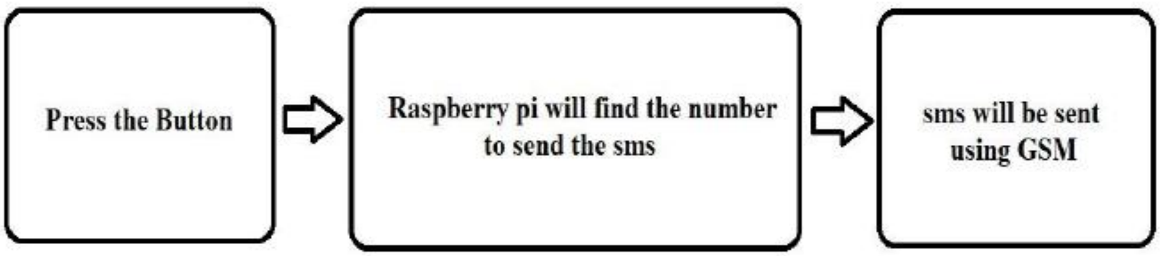

Fig. 9: Calling for emergency help.

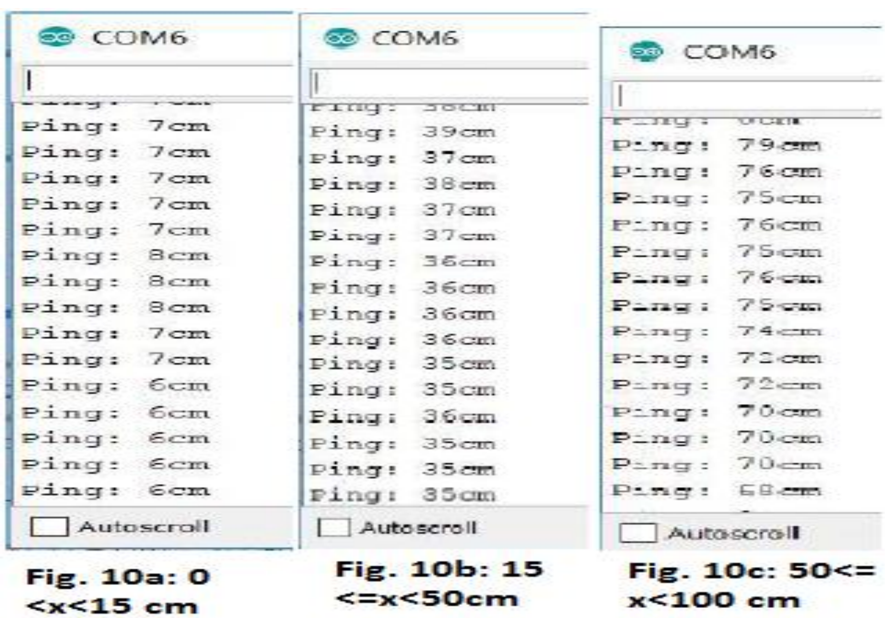

Fig. 10: Obstacle detection performance.

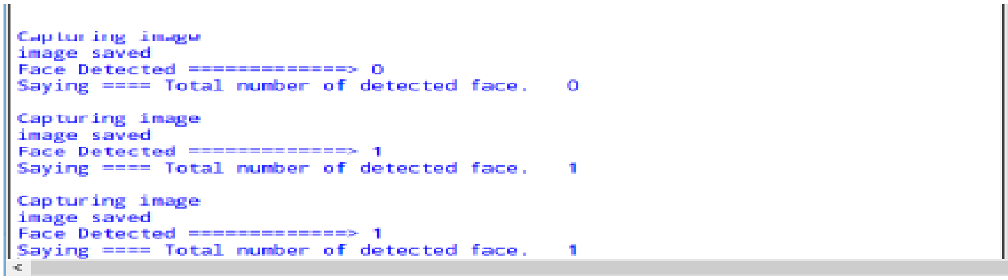

Fig. 11: Image processing and human face detection.

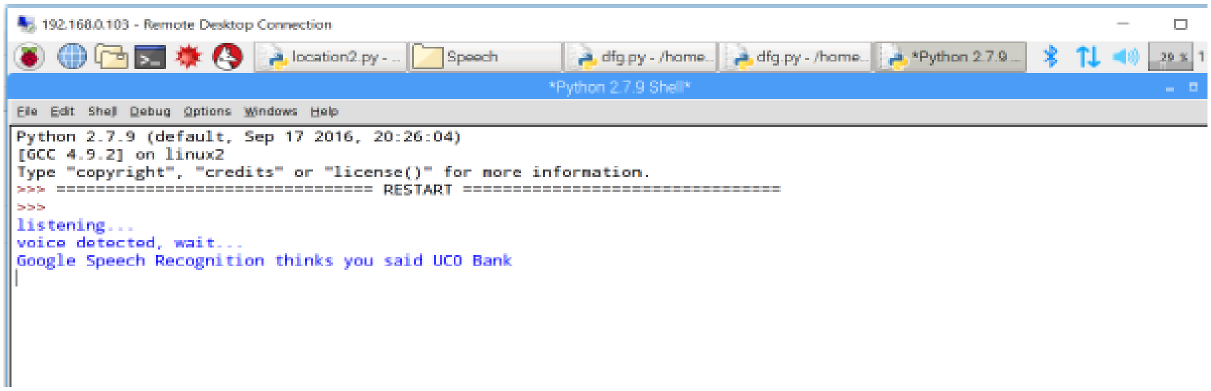

Fig. 12: Voice recognition for command input.

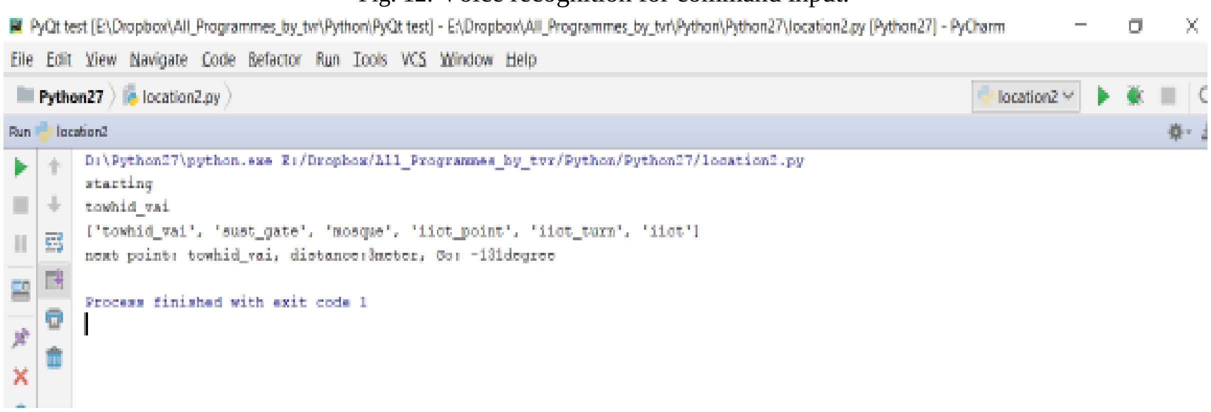

Fig. 13: Giving route information

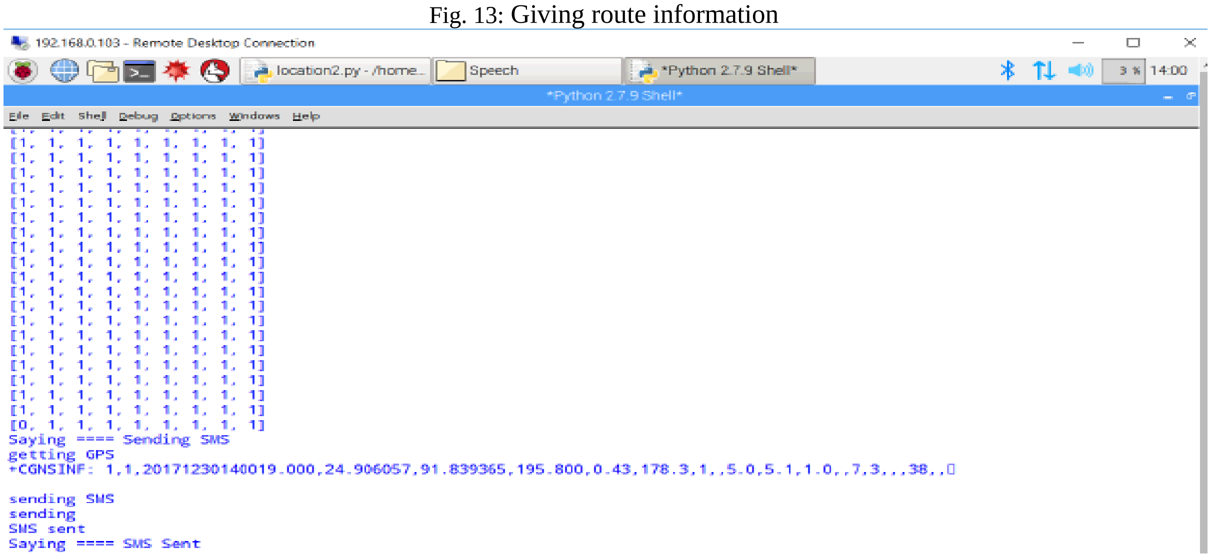

Fig. 14: SMS sending for emergency help.