Internet of Things (IoT) enabled Smart Navigation Aid for Visually Impaired

Mriyank Roy[1], Purav Shah[1]
[1] Faculty of Science and Technology, Middlesex University, London NW4 4BT, UK
mr1330@live.mdx.ac.uk, p.shah@mdx.ac.uk

Abstract. Blindness is a disorder in which a person's ocular vision is lost. Mobility and self-reliability have been a primary concern for visually disabled and blind people. Internet of Things (IoT) enabled Smart Navigation Aid, a smart Electronic Traveling Aid (ETA), is proposed in this paper. This smart guiding ETA improves the lives of blind people since it is enabled with IoT-based sensing and is designed to help visually disabled/impaired people walk and navigate freely in both close and open areas. The proposed prototype provides highly powerful, accurate, quick responding, lightweight, low power consumption, and cost-effective solution that would enhance the lives of the visually impaired people. Within a 1m radius, ultrasonic sensors were used to locate the barrier and potholes. The location was shared with the cloud using GPS and an ESP8266 Wi-Fi module. The stick was also installed with an emergency button, which will call on the mobile when pressed. The stick can also detect wet surfaces with the help of a water sensor. The entire system was built on the Arduino UNO 3 platform. Thus, the proposed prototype is an excellent example of how IoT enabled sensing could aid in the day-to-day lives of the visually impaired people and allowing them the freedom to navigate independently.

1 Introduction

The time is not too far that the PCs would overwhelm the world by beating human processing capabilities. The Internet and computers are playing a vital role in assembling components of a rocket for space transportation. Since the mid-1990's electronic and electrical gears("Things") has become essential in every field but it is yet to be deployed in our daily activities with full throttle. The term "Things" allude to everything around us from a little molecule to an enormous boat. During the most recent decade, the Internet of Things (IoT) has enticed intensive consideration because of a broad scope of the implementation in biomedical perception, Industrial development, monitoring environment, smart cities, agriculture, etc.

IoT is the internetworking of physical gadgets used in our regular day to day existence that utilise standard communications designs to offer new administrations/services to end-clients [1]. IoT can be summarised into an equation below:[2]

Internet of Things =Human beings + Physical Objects (controllers, sensors, storage, devices) +Internet

IoT is being used everywhere in our day-to-day life and is providing with a new vision to investigate the future. IoT is a technology which is uniting human beings by exploring emerging technologies which will help people to connect on a deeper level.

The proposed prototype includes a smart stick integrated with smart sensors for detecting obstacles around a blind person by emitting reflecting waves. These reflected signals received from the obstacles are used as inputs to micro-controller. This micro-controller then makes the person alert about the presence of some object by sounding a buzzer which will then allow the user to walk freely by detecting the obstacles. The system will have all the sensors attached to it so that the sensors can sense the environment around them and guide the blind person through all the obstacles by sounding a buzzer. This buzzer can be heard from an earphone. The smart stick is a basic and purely a mechanical gadget to make a person aware of any impediments on the path. The smart stick will also try to detect uneven surfaces while walking.

A GPS and GSM unit will be attached to the system so that it is possible to track the location of the blind person and contact with the mobile devices via messaging. Along with object detection and tracking, the system will have a rescue button. The blind person can press the rescue button whenever the person feels insecure. After pressing the button, a message will be delivered to a mobile number already stored on the system. The message will have information about the location of the blind person. The relative then can go to the location and help the blind person [3][4]. IoT is playing a vital role in transforming the lifestyle. The smart stick for blind people will help them to be independent by trying to be their artificial eye.

The rest of the paper is organised as follows: Section II explores the related work on this topic, Section III provides an overview of the proposed system and presents results based on the operation of the smart navigation aid, and finally, Section IV focuses on conclusions and future enhancements.

2 Related Work

Visually disabled people find it difficult to communicate with and sense their surroundings. They have very little interaction with their surroundings. Physical mobility is difficult for visually disabled people because it is challenging to discern obstacles in front of them, and they are unable to travel from one location to another. For mobility and financial support, they often have to depend on their relatives. Their mobility prevents them from engaging in social interactions and bonding with others. Different devices have been designed with shortcomings in the past due to a lack of non-visual vision. Researchers have spent decades developing an intelligent and IoT based smart stick to help visually disabled people avoid barriers and provide location information. For the past few decades, scientists have been working on new devices to provide a good and effective way for visually disabled people to sense obstacles and alert them when they are in danger [5].

The researchers developed a voice-operated outdoor navigation system in [6] for visually impaired people. The stick uses an audio output system, Global Positioning System (GPS) and ultrasonic sensors in the system. To store different locations of the blind individual, the stick is equipped with a GPS along with SD memory card. The blind person can search for any destination using the stick by using his/her voice command, and finally, the GPS will guide the person to the finalised destination. This framework will likewise give the speed and the leftover distance to arrive at the destination. Ultrasonic sensors are fixed on the stick to protect the visually impaired person from obstacles. If ever the person comes across any obstacles in the front, the ultrasonic sensor on the stick will be activated, and voice command will be sent to the person so that he/she can change direction. As the system is low-cost, it is affordable by the users. Along with that, it delivers a solution with great precision accompanied by a voice guide's assistance. To increase the operating speed of the system, it utilises ARM processors with more memory space. Since there will be no signal for the GPS indoors, the system cannot operate indoors. To use the stick efficiently, the person using it must be adequately trained.

In [7], the system uses the pulse-echo technique to help the visually impaired people detect the obstacles by providing a warning sound. United States military uses the same technique to locate submarines. They utilised ultrasound beats ranging from 21 kHz to 50 kHz, which creates reverberation pulses when it hits a solid surface. It is possible to anticipate the distance between the obstacle and the user by calculating the difference between signals transmission and receiving time. This framework is sensitive regarding recognising the deterrents. The system has a detection angle of 0 to 45 degrees and a detection range of up to 3 metres. Since the system requires receiver and transmitter circuits, it requires more power to function. So, as a result, the system must be redesigned to use less power while functioning.

The researchers in [8] propose a smart cane for assisting the mobility of blind people. ATMEL microcontroller and standard ultrasonic systems are utilised in the system. The system depends on two rechargeable battery (7.4v) each to operate. The batteries can be recharged utilising AC adaptor or USB cable. ATMEGA328P microcontroller and ATMEL AVR microcontroller is utilised to program the control unit. When any impediments are recognised, vibration and buzzer will ring to caution the client. This system is non-complex, and it can cover a distance up to 3 meters. To make it easier to carry, the stick's structure can be folded into a small piece. Since the system detects obstacles in only one direction, it cannot detect the obstacles accurately.

There has been much research carried out to assist blind people with their mobility. From the research mentioned above, Ultrasonic sensors are the best technology to detect obstacles efficiently with low power consumption. Also, to make the system user friendly, a non-complex microcontroller must be utilised. The system should also have a GPS built to track the current location of the blind adult.

Wet doors are dangerous as the person can fall and hurt himself. However, none of the research mentioned alerts the blind person about the wet door. So, the system proposed in the paper utilise a water detection sensor module to alert the blind person about the wet door. Also, the system is equipped with an emergency button which when pressed delivers the current coordinates of the location to a known person in the family of the blind adult via email already stored in the system. The coordinates of the blind person's location can be determined from the GPS system installed on the stick. The person from the family can then track the position of the blind person on the map and approach the site as soon as possible. In this way, the system will assist the blind person with their movement in any corner of the world.

K sonar [9], Palmsonar [10], iSonic cane [11], Laser cane [12], Ultra cane [13], and Virtual Eye (using Image processing) are some of the visual aid systems. These devices are not very user-friendly or simple to operate. Laser canes and Virtual Eye Aids are both expensive and inconvenient to use. The smart stick proposed in the paper enhances the lives of blind people by helping them to navigate without relying on others. Unlike in the past, blind people will now be able to live everyday lives. Aside from that, the blind person's family members would be able to locate him at any time to get his precise location from anywhere. The smart IoT blind stick is an IoT-based system that is cost effective, reliable, and easy to use.

3 Implementation of the Smart Navigation Aid

An Advanced IoT-based system with an Arduino Uno R3 microcontroller is the crucial component of the system. Several sensors and modules are connected to the Arduino Uno R3 microcontroller [14]. The following specifications are included in the suggested system:

- A low-cost navigation smart stick with a total cost of less than £ 40.
- Obstacle sensors respond quickly in close range of up to 4m.
- Lightweight components are built into the rod, making it user-friendly and consuming less power.
- The overall circuit is easy, and the microcontroller is programmed using Java basics.
- An emergency button is provided on the stick, which, when pressed, will call a relative of the blind person notifying that the blind person is in trouble and needs assistance.
- A speaker who will alert the blind person of the type of obstacle ahead on the path of the blind person.
- A GPS module is linked to the cloud for location sharing. Every 20 milliseconds, the location is updated on the cloud.

For the successful completion of the innovative IoT-based smart navigation aid, the proposed system is divided into two categories while implementing:

1. Obstacle Detection System (Figure 1)
2. Location Tracking System (Figure 2)

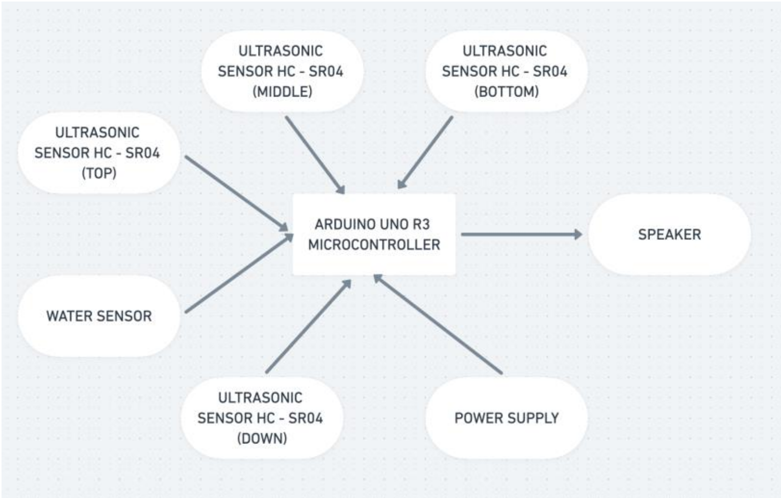

Fig1: Block diagram of the sub-system for obstacle detection

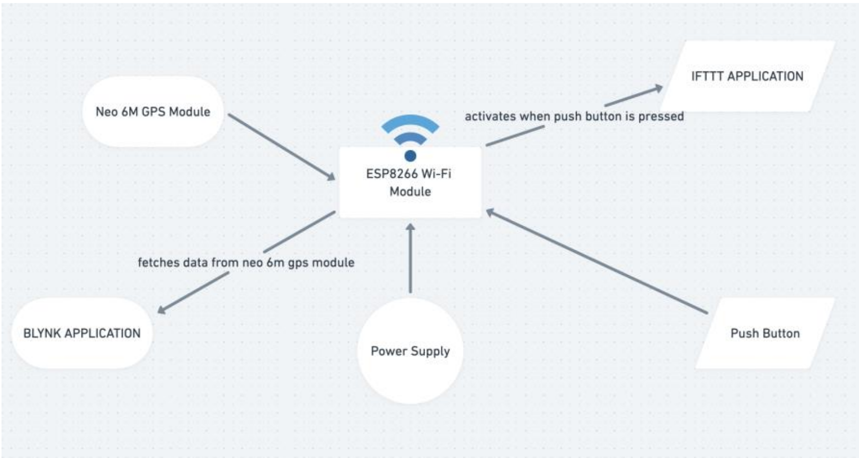

Fig2: Block diagram of the sub-system for location tracking

3.1 Obstacle Detection Sub-system

The obstacle detection system's primary function is detecting obstacles on the path of the blind person and alerting him/her about the type of obstacle present in front and preventing the person from a fall. The central brain of the obstacle detection system is Arduino Uno R3 Microcontroller. The hardware requirements of this sub-system include the following:

1. Arduino UNO R3 microcontroller – Main engine of the navigational-aid
2. Ultrasonic Sensor (HC-SR04) – Obstacle Detection

3. Speakers – Integrated with microcontroller to inform the blind person of obstacles
4. Water Sensor – Connected at bottom of the stick to sense water on walking surfaces

There are four ultrasonic sensors attached to the navigation-aid stick to detect various obstacles at different heights. The top sensor is used to detect obstacles that are at a height of more than 62 centimetres from the surface of the stick on which it is resting. The top sensor is generally used to detect obstacles above the visually impaired person's knee-length.

The down sensor is installed on the stick at a height of 33 centimetres from the stick's bottom. It is utilised to detect uneven surfaces. It protects the blind person from falling due to elevation or low surface.

The middle sensor is installed just above the down sensor at a height of 40 centimetres. It is installed just above the down sensor to detect any obstacles which come at the knee length of the blind person. As the down sensor faces downwards to detect any uneven surfaces, it cannot detect obstacles ahead. So as a result, the middle sensor will protect the down sensor from smashing against the obstacles. The bottom sensor is installed at the bottom of the stick at a height of 6cm to detect objects on the ground. Figure 3 shows how each ultrasonic sensor interacts with the microcontroller and how the speaker activation takes place. The speakers are interfaced using the Talkie library on the Arduino UNO R3. All the programming and interfacing of the sensors for this sub-system is done using the Arduino IDE.

3.2 Location Tracking Sub-system

The primary function of the Location Tracking System on the stick is to track the blind person everywhere. It provides live tracking of the blind person on the Blynk Application. The stick also incorporates an emergency button, which will give a call to a relative of the blind person when pressed. The central brain of the location tracking system is ESP 8266 NodeMCU WI-FI Module. The hardware requirements of this sub-system include the following:

1. ESP 8266 NodeMCU WiFi module – Complete TCP/IP stack and MCU unit.
2. GPS module – to determine exact geographical positions
3. Push buttons – IFTTT key for actions set

The software used for this sub-system is BLYNK application (IOS/Android) for controlling Arduino and Raspberry Pi with Internet connectivity. The Blynk application fetches the data from the system's GPS module and provides live graphical tracking to the user. It will assist the relative of the blind person to track the blind person when the emergency button is pressed [15].

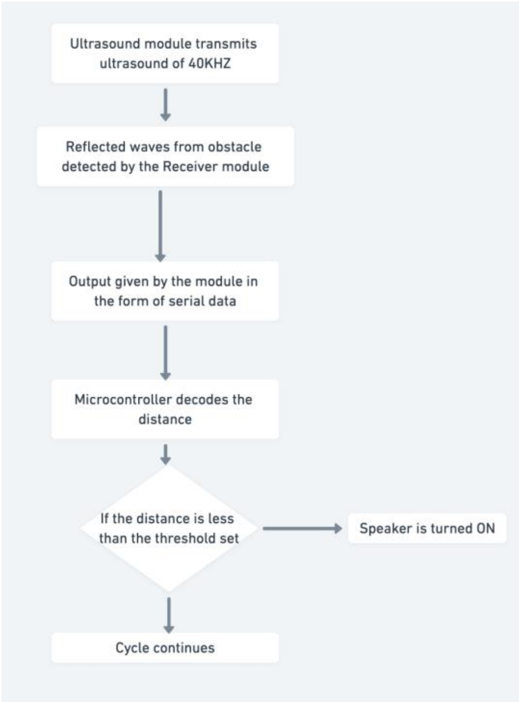

Fig3: Interaction of each Ultrasonic Sensor

IFTTT is a famous trigger-activity programming platform of applets that can automate more than 400 IoT and web application administrations [16]. As soon as the blind person presses the emergency button, the ESP 8266 NodeMCU Wi-Fi module receives the signal from the button and runs the action already set on the IFTTT platform using a specific key, the IFTTT platform. As soon as the IFTTT application is called using a specific key, the following action will be carried out already set against the key. The action set against the key is that it will call on the app of IFTTT using Webhooks.

The complete setup of the navigational aid is as shown in figure 3. It highlights all the sensors that are installed on the stick. The sensors and the wires used in the blind stick are kept open in the prototype. So, if the stick falls on the ground, then the sensors might break, and as a result, it might not work correctly. So, the sensors can be properly protected from a fall by placing them inside a protective box. Even the wires can be protected by making the wires pass through inside the rod. Finally, give the stick a finishing touch to be commercially presented in the market. To commercially present the smart stick in the market, the stick must go through six stages of a new product development process – 1. Concept, 2. Feasibility study and design planning, 3. Design and development, 4. Testing verification, 5. Validation collateral production, 6. Manufacture.

In the current stage, the smart stick has been developed up to Testing & verification stage. In future, the smart stick must go through Validation and Manufacturing stages before getting introduced in the market.

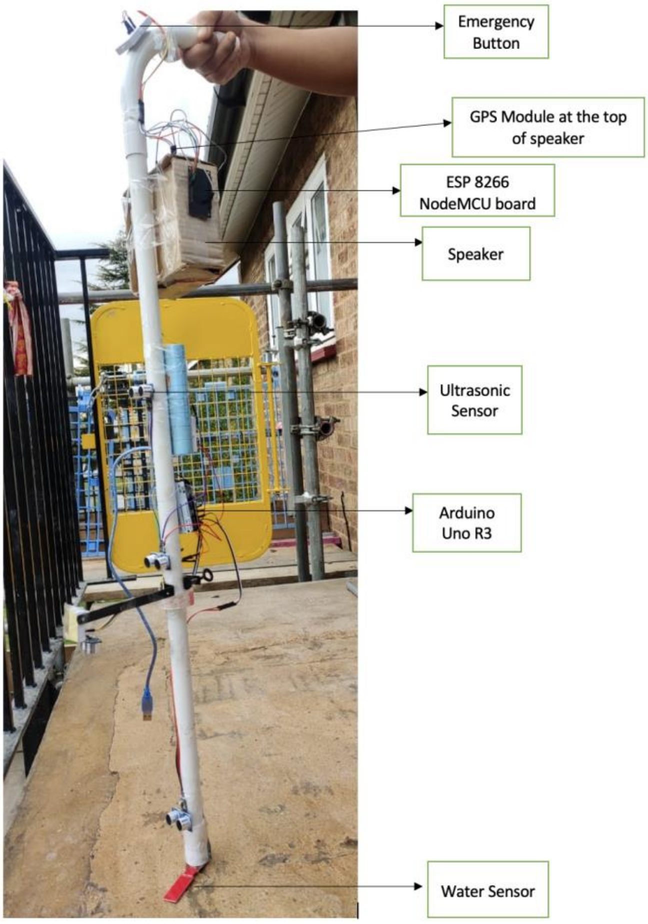

Fig3: Complete IoT-based Smart Navigation-Aid for Visually Impaired

3.3 Results and Evaluations

To test the effectiveness of the overall smart navigation-aid, several tests were performed. These tests were divided into the two sub-system responses. The results for the obstacle detection sub-system are as shown below in table 1. Furthermore, the determination of the speaker output is based on a pre-determined threshold, whether the object is climbable, needs to be avoided (not climbable), or if the water sensor picks up water presence, then wet surface detection. Figure 4 presents the water detection sensor, picking up the wet surface. It is also observed that the down sensor is receiving the reading of 33, thus, there is a low surface ahead, which also confirms that the wet surface may be caused by a puddle, because of an uneven surface.

Table 1. Obstacle Detection Sub-system evaluation

Distance between Object and Top, Middle, Bottom and Down Sensors (cm)	Threshold Distance (cm)	Speaker Output
9, 139,125, 33	80	Obstacle Ahead Not Avoidable Change Direction
2163, 141, 3, 31	80	Obstacle Ahead Not Avoidable Change Direction
2, 138, 2, 31	80	Obstacle Ahead Not Avoidable Change Direction
3, 5, 122, 32	80	Obstacle Ahead Not Avoidable Change Direction
126, 2, 2, 30	80	Obstacle Ahead Not Avoidable Change Direction
5, 3, 1, 29	80	Obstacle Ahead Not Avoidable Change Direction
136, 5, 100, 32	50	Elevated Surface Ahead, Go Slow
129, 155, 125, 8	23	Uneven Surface, Go Slow
146, 143, 142, 54	50	Low surface ahead, Go slow

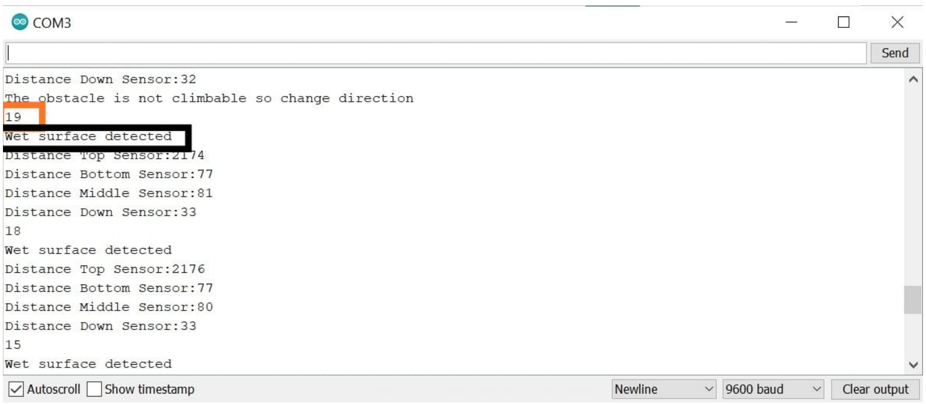

Fig4: Wet Surface Detection

For location tracking, two things were verified: One, whether the system can determine the exact location of the smart stick and second, whether the outdoor connectivity is achieved or not. As soon as the NodeMCU ESP8266 board is powered, it gets connected to the network and starts fetching latitude and longitude coordinates from the Neo 6M GPS Module. The Blynk application can track the system at the current position. In figure 5, the arrow indicates the correct location of the smart stick.

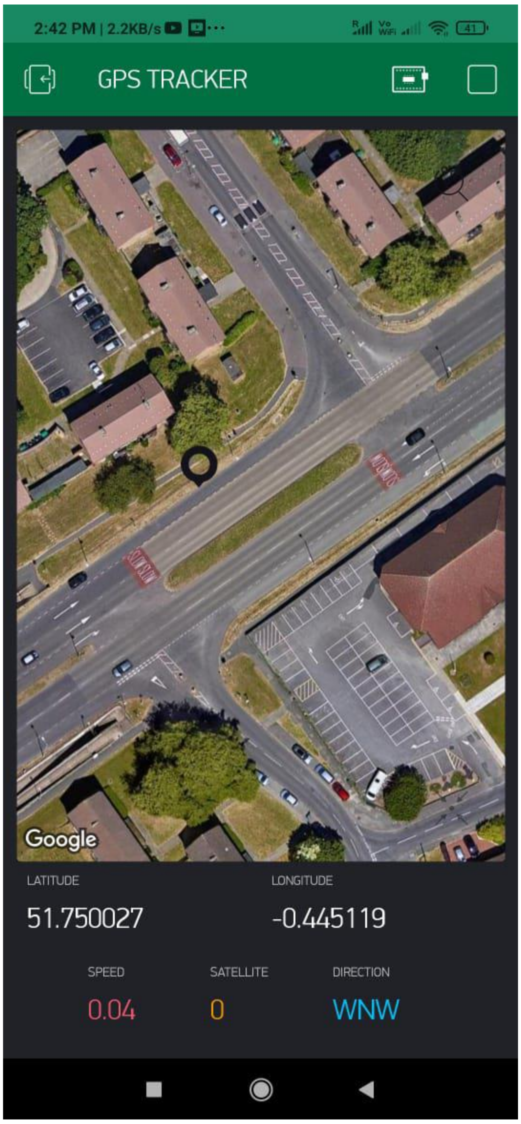

Fig5: Location Detection sub-system operation

The IFFFT application operation is also verified in case the emergency button is pressed by the user. This directly makes a VoIP call and leaves a message asking for help. This is as demonstrated in figure 6.

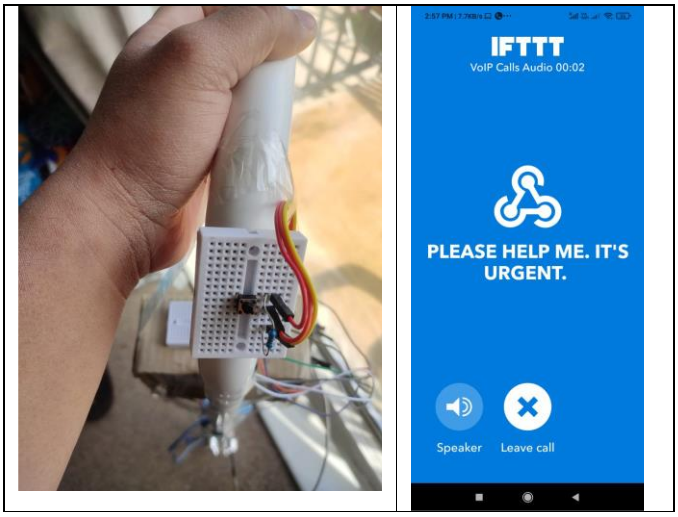

Fig6: Location Detection sub-system operation

4 Conclusions and Future Enhancements

It is worth noting at this stage that the study's primary goal, which was to develop and incorporate a smart walking stick for the blind, was fully met. The Smart Stick serves as a foundation for the next phase of assistive technologies to help the visually impaired navigate both indoor and outdoor environments. It is both efficient and cost-effective. It achieves successful results in detecting obstacles in the user's path within one meter. The detecting range of the stick can be changed as per user requirements. This device provides a low-cost, dependable, compact, low-power, and robust navigation solution with a noticeable fast response time. The machine is light in weight despite being hard-wired with sensors and other parts. Wireless interaction between device components can increase other facets of the system, such as increasing the range of the ultrasonic sensor and integrating technology for calculating the speed of approaching obstacles.

Visually disabled and blind communities in all developing nations were at the forefront of the mind while developing such an inspiring approach. The stick uses a speaker to alert the blind person of the various obstacles they encounter. The stick can detect uneven surfaces such as elevation and low surfaces. It can also detect wet surfaces and alert the blind person of the wet surface to protect the blind person from slippery surfaces.

With the smart stick's help created using this design, every movement of the blind person can be tracked via an app. Also, the stick provides an emergency button to the visually impaired person. If the blind person finds himself/herself in danger, he/she can press the emergency button and call a relative notifying that he/she is in danger.

4.1 Future Scope for Enhancements

The current smart stick's potential scope includes guiding the visually impaired person in independent navigation effectively while maintaining the person's safety.

- The Braille input system allows the blind person to provide the destination address for navigation in a simple manner.
- The programmable wheels will guide the stick away from potential hazards while simultaneously guiding the blind person to their destination.
- The Internet of Things (IoT) is a popular term that allows one smart stick to connect with another smart stick (PC or mobile device) nearby and use the functionality of the other stick when one stick's functionality fails.
- The stick should also connect with the tra_c lights on the road so that it will be easy for the blind person to cross the road without any assistance.
- Solar panels can be used in place of the battery to power this optimised package of hardware. A solar panel is more beneficial when it recharges itself using sunlight, a readily available green energy source.

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