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Low Cost GPS and GSM Based Navigational Aid for Visually Impaired People

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Abstract Mobility for the blind can be defined as the ability to move independently through the environment with ease, speed and safety. With an estimate of 7 million people going blind each year, the numbers of visually impaired people are expected to be double by 2030. This work presents a prototype development of a low cost GPS and GSM based navigational aid device called smart white cane for assisting visually impaired people to navigate easily. This device integrates smart sensors and wireless technologies GPS and GSM to assist the user in safe indoor and outdoor navigation. The major phases of this prototype development are obstacle detection, depth detection, water detection and finding location. A GSM module has been incorporated in this prototype so as to make blind people capable of sending an SOS message to a family member in critical situations. The smart white cane is a small, cheap and easily operated navigation aid for the blind and visually impaired people.

Keywords Global system for mobile communications (GSM) · Global positioning system (GPS) · Electronic travel aids (ETA) · White cane · Automatic playback recorder (APR9600) · Infrared radiation (IR) · SOS

1 Introduction

According to World Health Organization (WHO) report [1] in 2010, 285 million people across the world are visually impaired out of which 36 million are blind and 230 million are visually impaired; 65 % of the visually impaired and 82 % of the blind people are

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50 years or older. The Fig. 1 shows global causes of blindness as percentage of global blindness in 2010. The most common causes of blindness are glaucoma, cataracts, age-related macular degeneration (AMD), trachoma or corneal opacity, and diabetic retinopathy, amongst other cause like blind since birth or involved in an accident [1].

For the proficient reintegration of the visually impaired in the family and society and for them to lead a happy and an independent life, we need to find ways to support their damaged vision. Thus, engineers and technology enthusiasts are committed to develop assistive devices which can be used by blind and visually impaired people to improve their living standards. The biggest hurdle for the blind is navigation at unfamiliar places. Visually impaired people make use of their tactile senses for movement, and thus they are unable to move freely in new environment. The usual and old mobility aids like simple white cane, guide dogs have lot of drawbacks. Firstly, white canes have limitations such as the information is gained only by touching the object with the cane. Secondly, use of guide dogs can be a costly affair and they are useful for only about 5–6 years. This makes navigation technology applications in unfamiliar places a useful asset for the visually impaired. Such smart assistive devices and systems are result of integration of several current technologies such as position identification, obstacle or hazards recognition.

The research focus in this paper is to design a low cost smart white cane embedded with wireless technologies such as GPS and GSM for visually impaired people. Research focuses on obstacle/hurdle detection, pit detection, water detection and finding location in order to reduce navigation problem for blind people. In critical conditions, a blind person would be able to send an SOS message to a family member. The prototype comprises of IR sensors, a water detection circuit which includes two electrodes, a global positioning system module, a global system for mobile communications module, stepper motor and drivers, APR9600 voice synthesizer, speaker, components and power supply batteries.

2 Previous Work

Electronic travel aids (ETAs) for the blind have two broad categories-clear-path indicators and environmental descriptors. Clear-path indicators warn the user of hazards or obstacles which present somecollision threat. Environmental descriptors fetch requisite information about neighbouring objects through sensory substitution and warn the user. This work falls

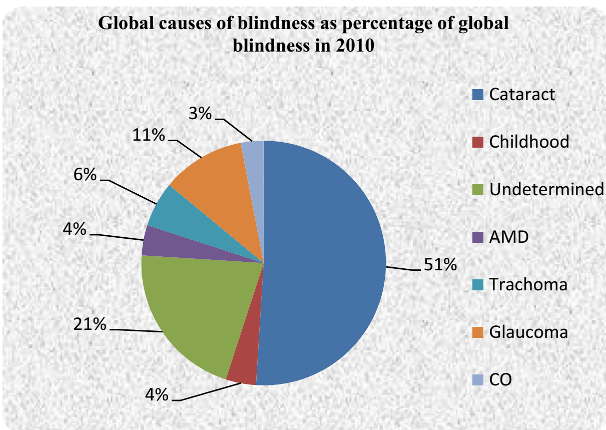

Fig. 1 World health organization blindness index [1]

in the category of clear-path indicators. Over the past few decades, lot of research efforts are going on to develop novel and reliable systems for visually impaired people to detect obstacles and warn them of unsafe places. Some navigational aids have been developed to assist the blind and visually impaired, but they have some deficiencies. The following researchers made significant contribution in this field.

Yusro et al. [2] presented concept and design of a smart environment explorer stick (SEES). They proposed a SEES as an enhanced white cane which assists a visibly impaired person using GPS technology. This system is possible only with the help of multi-sensor context-awareness concept. It aids the visually impaired people to move safely and easily in indoor or outdoor places. Jameson et al. [3] developed a wearable collision warning system for blind. The system alerts the blind user well in advance to avoid the obstacle at head level. In comparison to existing sophisticated ETAs, this device simply generates an alert signal (in acoustic and/or tactile form) when a hazard is detected. Two ultrasonic transducers are used for obstacle localization, can be mounted on one's shirt pocket or disguised as a brooch. Much attention is devoted to optimize the performance of the device in terms of range accuracy and detection of false alarm rate and to minimize form factor and power consumption. Laurent et al. [4] introduced a sonar system modeled after spatial hearing and echo locating bats for blind mobility aid. It comprises of three transducers, one transmitter which plays the role of mouth of the bat that transmit echo location signal and two receivers located near the left and right ear respectively to mimic human ears configuration.

Koelsch et al. [5] analyzed possible multimodal interaction with wearable augmented reality systems. The main aim of the study was to provide workers with specialized equipment to visualize effectively in their jobs and improve their situational awareness. The authors proposed that the convicting goals of device size and interface area could be met by expanding the interaction area beyond the device dimensions. Loomis et al. [6] investigated the use of audio interfaces in a navigation system for the blind as a viable solution for communication between the consumer and program. In this study, blind test subjects were given a backpack mounted computer each with GPS capabilities and a set of headphones with a motion sensing device attached to follow head movements. This research gave valuable insights about how to integrate GPS and auditory user interfaces. Krause et al. [7] examined different ways for a system to adapt to its user's performance. Novel software was developed using a twofold input–output system integrating sensor data with user inputs to categorize and learn user performance. The data was collected through a series of three experiments. The researchers used a large amount of hardware, more than desired for their product, and the delay time were still around 10 s. Fancy et al. [8] presented electronic travel aid (ETA) to help visionless people move freely by detecting obstacles while travelling and to aid visually impaired people in new environment. Infrared proximeter and teletact, which is a laser telemeter, is used to detect the object.

Debnath et al. [9] presented an electronically guided stick for the blind which uses sonic path finder, sonic torch and that can be used conveniently inside closed premises. Ross et al. [10] designed navigational aids for blind people both for indoor and outdoor navigation. The study's purpose was to identify the best types of user interfaces for navigational aid systems. Authors evaluated the efficiency of such interfaces by measuring the number and type of user errors and the speed of the devices. Liarokapis et al. [11] proposed a method to represent a combination of GPS devices with computer vision techniques to create an augmented reality interface. This research suggested that a combination of GPS and computer vision system would be feasible as a blind navigation tool if an interface can be designed for it. Also several aspects of design and development of navigational aids for visually impaired can be found in [12–24].

Thus, keeping in view the merits and demerits of various techniques and technologies used in devices and systems previously developed for assisting blind people, a novel, low cost and reliable smart white cane equipped with modern technologies need to be designed and developed.

3 Specific Requirements

The proposed ETA device is meant as a safeguard for a blind person during navigation. It should warn the person on any obstacle/hurdle detection in time to evade a collision. It can be considered as a secondary ETA to avoid the use of a guide dog or a long cane. The presence of a nearby obstacle should activate a warning mechanism when it is detected within precisely defined boundaries. Ideally, the device should be hand-held and easy to use. Also, all the sensors and components of the system must fit within a single piece. ETA must have a lithium polymer battery with long back-up to avoid the need of recharging or replacing it frequently. Finally, the complete development cycle must facilitate easy bulk production and marketing at an affordable cost.

4 Range and Obstacle Detection

The developed ETA prototype performs range measurement by means of infrared radiation reflection technique. Following are two important aspects of the system:-

4.1 Object Detection

Two IR sensors are mounted on shaft of stepper motor such that they are 120° apart. References of both the IR sensors are different from each other to detect the different positions of object. Since step size of a normal person is 2 feet max and for a blind person it would be even less; so, a detection range of 1 m has been chosen to alarm the person about the obstacle well in advance [25]. In case of detection of an obstacle, the stepper motor will stop and controller will decode the position (distance in feet) and direction (left, right and front) of sensors. Figure 2 illustrates the obstacle detection mechanism.

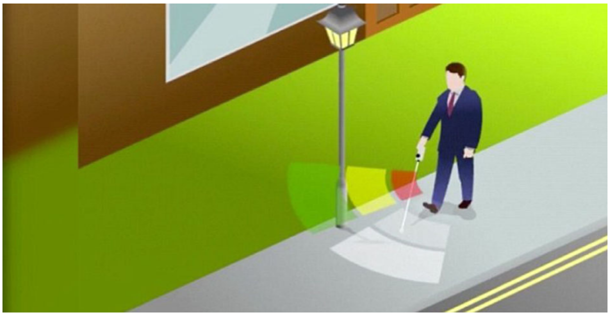

Fig. 2 Obstacle detection mechanism [25]

4.2 Pit Detection

In pit detection circuit, the receiving module detects the reflected IR from any depth and gives a signal to the micro-controller which further signals the automatic playback recorder to play the recorded message to make blind person aware of some pit on the road. Minimum possible depth covered by pit detection is 1/2 feet.

4.3 Ergonomics Design

It is basically the functional design of equipment e.g. interface design-display and controls, safety maintainability and handling. It makes the system user friendly. For designing of the smart white cane the following ergonomics design steps have been followed:

- SOS switch is placed on top of the device for sharing location of the person in case of emergency and for mode select.
- Microcontroller, sensors and speaker are mounted on the front side of the white cane. On/Off switch and battery are also provided on the white cane.

5 Hardware Description

This section describes various sensors and other modules used in development of this prototype device.

5.1 ATMEL (AT89S52)

The AT89S52 belongs to the 8051 family of microcontrollers which have low power idle and power down mode, and are high performance computing devices. It works at crystal frequency ranging from 0 Hz to 33 MHz and executes most of complex instructions in a single clock cycle. It has 8 KB of ISP flash memory, 256 bytes RAM, 32 I/O programmable lines, full duplex UART serial channel, a watchdog timer, power off flag and two 16 bit timer/counters. It is used to interface various sensors and modules like GPS, GSM and IR sensors. This microcontroller initiates all these modules and sends the location of the person through message by GSM module [26].

5.2 IR Technology (GP2Y0A02YK)

Infrared light is basically an electromagnetic radiation which has more wavelength than visible light. It has a frequency range of 1–400 THz. Sharp GP2Y0A02YK IR sensor is used in this research work [27]. Sharp IR sensor provides the following standard features: detection range of 20–150 cm and an analog output. The sensor output can be directly connected to controller or ADC.

5.3 GPS Technology

The global positioning system (GPS) is a satellite based navigation system that can be used to track longitude and latitude. It utilizes a constellation of 24/32 active satellites orbiting the earth that transmit an accurate microwave signal. A GPS receiver requires at least three or four satellites to calculate the distance and direction as shown in Fig. 3. It can calculate two dimensions, that is latitude and longitude or three dimensions that is latitude, longitude, and altitude positions [28]. Figure 4 shows the GPS module.

5.4 GSM Technology

GSM stands for global system for mobile communication and is an open, cellular technology used for transmitting mobile data services or voice calls. GSM module shown in Fig. 5 is a device which acts as a mobile phone and it accepts any network operator and SIM card with its own unique phone number. This SIM900AGSM modem can be used for communication and developing embedded applications for SMS based communications, for example, to send and receive message and for voice calls. GSM systems use radio frequencies between 890 and 915 MHz for receiving and between 935 and 960 MHz for transmitting [29].

5.5 Automatic Playback Recorder (APR) and Speaker

APR9600 is an automatic playback recorder IC which is used to record and play recorded audio data. Recording capability of APR9600 is 60 s on eight different channels. Recorded data is retained even if power supply is switched off. APR9600 and speakers will be embedded on white cane and when any signal of depth, hurdle or water is received by

Fig. 3 GPS signal working

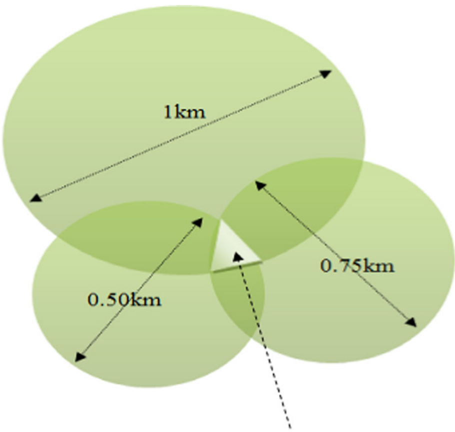

Fig. 4 GPS module [28]

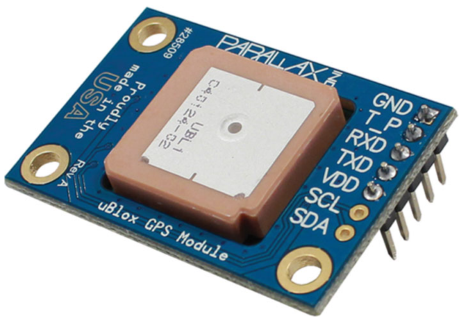

Fig. 5 GSM module [29]

Table 1 Different warning sounds produced by APR 9600

No.	Signatures	Signals	Audible/warning
1	Object detection	Object detected	On half feet, one feet, two feet
2	Pit detection	Pit detected	–
3	Water detection	Water detected	–
4	Position detection	Position detected	Right side, Front side, Left side

controller, the microcontroller sends a signal to APR, which is audible through speakers [30]. Table 1 lists different warning sounds produced by APR9600 IC.

6 Device Architecture

The device architecture of smart white cane is based on AT89c52 controller unit and suitable electronics for signal conditioning. The microcontroller unit provides an interface and manage signals coming from different sensors and modules in order to control the actuator on the basis of the obstacle location. The device architecture of smart white cane consists of a simple stick with a stepper motor attached to it. On the shaft of the stepper motor, a pair of IR sensors is mounted such that it covers an angel window of 120° during rotation. With this configuration the location of obstacle in three (left, right and front) can be decoded. Also an IR sensor is mounted at the bottom of the stick to detect depth of the surface. The stick also contains a water detector circuit. The outputs from IR sensors and water detector are fed to microcontroller mounted on the stick. There is an APR circuit attached with the controller which plays the alarm signals about obstacle detection, obstacle direction, obstacle distance, depth detection and presence of water. The device also incorporates GPS and GSM modules. There is an SOS key mounted at the handle of the stick, which when pressed transmits the current location co-ordinates of the blind person wirelessly. Figure 6 represents the device architecture.

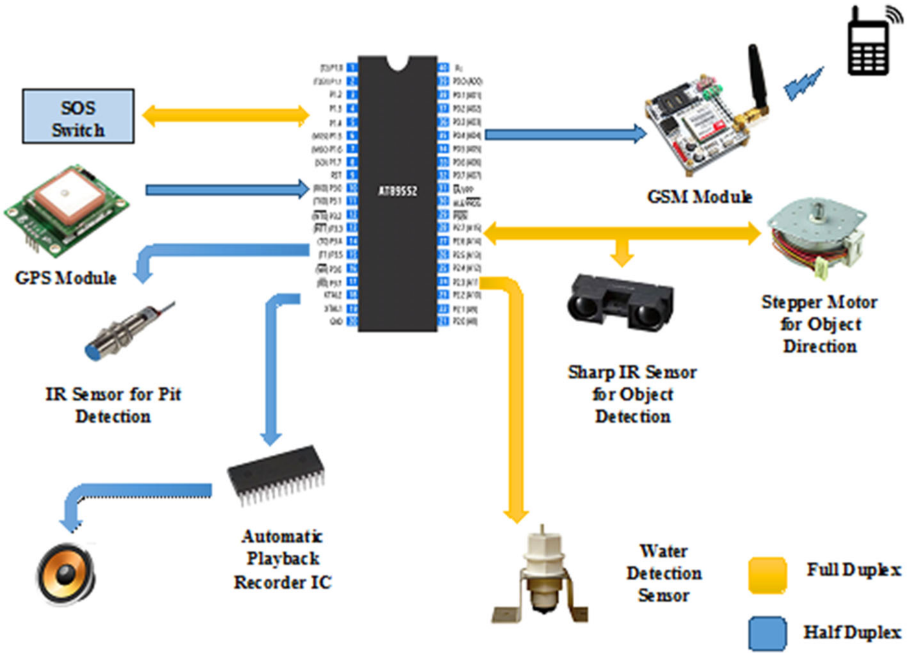

Fig. 6 Architecture of device

7 Device Operation

The programs for complete operation of device are written in assembly language. µvision tool has been used to compile the assembly source files. Figure 7 describes the flowchart for device operation. The various steps involved in its operation are as follows:

- Visually impaired person holds the stick in his hand and turns on the device by pressing the "Power ON" key. The alarm from buzzer indicates that the device has started operating.
- The device continuously monitors the obstacle's direction and distance, presence of pits and presence of water on the surface, and alerts the user by audio message playback. For example, in case an obstacle gets detected at 2 feet ahead in the left side, The APR circuit plays the audio message "OBJECT DETECTED", "LEFT SIDE", "TWO FEET". There is time gap of 2 s within each audio playback. In case some pit is recognized by the device, The APR circuit plays "PIT DETECTED". In the scenario of presence of water on the surface, APR will be playing the audio message "WATER DETECTED". Figure 8 describes the system response in case of obstacles located in different position in respect to the user path.
- In case the blind person finds himself in any kind of trouble or unease situation, he needs to press the SOS key. This would send location coordinates of the person wirelessly with some pre decided mobile number.

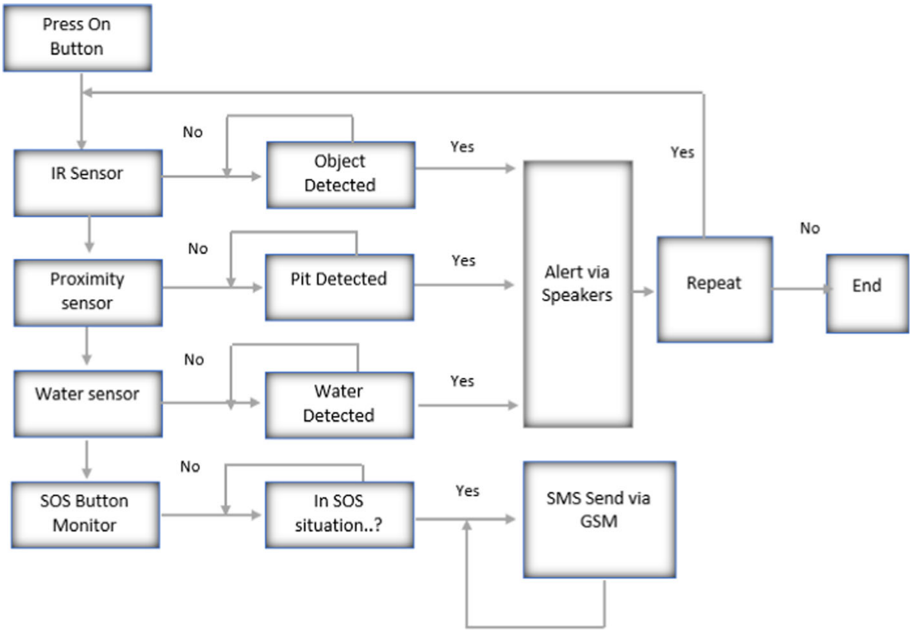

Fig. 7 Flow chart for device operation

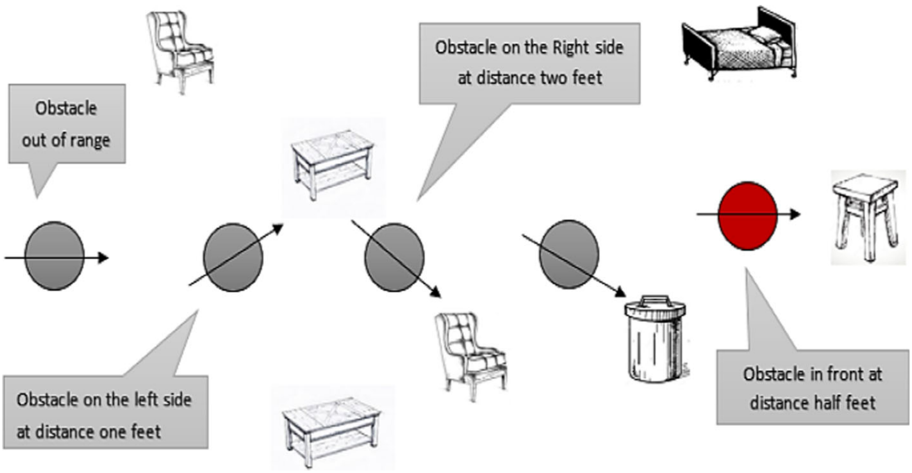

Fig. 8 Description of the system response in case of obstacles located in different position as respect to the user path [31]

8 Results and Discussions

During this evaluation, the smart white cane was tested in practical and real time conditions. It is also evaluated by blind person. Three different conditions on three different routes have been chosen to test the performance:

8.1 Route A

Location of first route was on first floor of laboratory building. In this route, a dummy wall was placed as obstacle. The blind person was unfamiliar with this place. First, blind person used the normal white cane on this route and then smart white cane.

8.2 Route B

In this route, a congested street was selected and different obstacles were placed on the way chairs, blocks, poles and pits were included in obstacles. The smart white cane and normal white cane was tested in four different scenarios.

8.3 Route C

In third route, it was only for GSM and GPS module testing. When blind person pressed the SOS switch, the text message containing location coordinate was delivered to pre stored number via GSM module. Text message is "user needs help" with location coordinates of user 30.7021052N, 76.850094E.

Comparative performance of normal white cane with smart white can for three different routes has been summarized in Table 2. Collision detection performance of normal and smart white canes has been summarized in Table 3.The Table 4 illustrates the testing of measured GPS location coordinates with the location coordinates on Google and the error in GPS coordinates.

8.4 Obstacle Detection Output

Experiments were conducted to evaluate the performance of the proposed method. The obstacle detection circuit has provided an accuracy of approximately 1 m. Data collected from ADC output of IR sensor is given in Table 5.

Table 2 Comparative performance of normal & smart white cane

Route	Route length (m)	Normal white cane		Smart white cane	
		Time (s)	Speed (m/s)	Time (s)	Speed (m/s)
A	28	77	0.37	42	0.69
B	14	21	0.66	16	0.86
C	27	52	0.52	35	0.77

Table 3 Collision detection performance of normal and smart white cane

Obstacle	Normal white cane No. of collisions	Smart white cane No. of collisions	Reduction in collisions (%)
13	10	2	80
10	7	1	85.7
17	13	2	84.6
7	4	1	75 %

Table 4 Testing of prototype at different locations

Subjects with diseases	Coordinates via smart cane (Lon, Lat)	Comparison with google map	Exact name of location	No. of error (in meters)
1	30.7021052, 76.850094	30.7021049, 76.850191	Industrial area, Phase-1, Chandigarh	2
2	30.71447700, 76.7148930	30.71448800, 76.7148927	Phase-5, Mohali (Punjab)	0
3	30.719425700,76.781259600	30.7193256,76.781259600	Sector-20, Chandigarh	7
4	30.739833900, 76.783207999	30.739833980, 76.783207999	Sector-17C, Chandigarh	0
5	30.708171000, 76.718559000	30.708171000, 76.718559000	Phase-3B2, Mohali (Punjab)	2
6	30.681173000,76.746737800	30.681173300,76.746737900	Phase-11, Mohali (Punjab)	11

Table 5 ADC output data from IR sensor

Distance (feet)	Output (ADU)
0.5	152
1	71
2	38
2.5	23
3	11

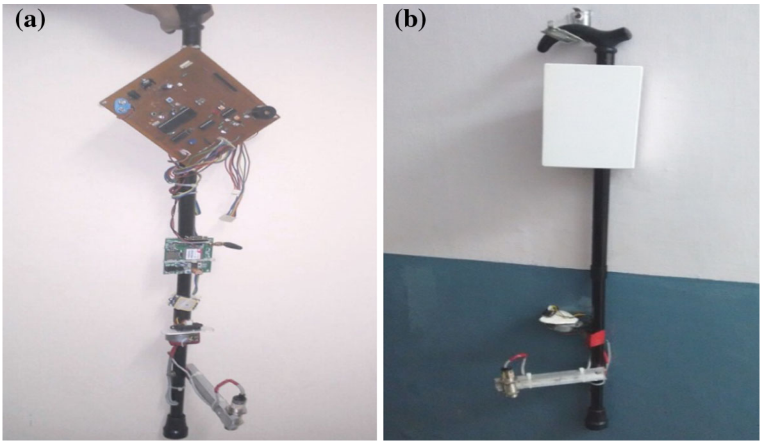

Fig. 9 **a** Smart white cane prototype with all sensors and modules mounted and **b** Final prototype of device

The indigenous developed white cane overcomes the limitations of costly commercial devices available in the market at much lower cost and with enhanced set of features. Some smart cane vendors charge extra monthly rental for using their online application services to access the GPS location, while some others charges activation fee to activate the device. Also many of the existing devices do not include utilities like SOS button, water detection and pit detection. The main advantage of developed device is that it provides the facility to trace the location of person in emergency condition and to find out the direction as well as distance of obstacles. The Fig. 9a shows the development stage of the device with all sensors and components mounted on the device and The Fig. 9b shows the final prototype of device.

9 Conclusion and Future Scope

This work proposed the development of a low cost GPS and GSM based navigational aid device called smart based white cane for assisting visually impaired people. The device costs lesser compared to other such devices available in the market. It is a real time system which detects the obstacle's position and direction, monitors the location coordinates of the person, presence of pits and water on the surface. The total development cost of this prototype development is under $60. So, this low cost smart white cane can be easily afforded by affected people in developing countries. Another aspect of the project was to develop an electromechanical design of the system. Our proposed methodology gives a new opening for the expansion of the field of operational devices for the visually impaired people, taking outside world as functional area. Our idea helps to remove the restrictions that the blind people suffer from. The further extension to this work would be to improve the range exploring other transducers and to incorporate the health monitoring modules for measuring various health parameters of the person holding white cane.

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