*Research Article*

# Smart Walking Stick for Visually Impaired People

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**Abstract:** Detecting obstacles is always a difficult task for visually impaired people when they move. External guidance such as human, trained dogs, or white cane, hence, a blind stick plays an essential role in the decision making of blind people. Due to its low cost, the white cane is often used by visually impaired people. However, traditional white canes cannot accurately detect obstacles above the knee level or at a distance beyond the white cane's length. Our goal is to create an affordable, smart blind stick that can help blind people to navigate. The device consists of an ultrasonic sensor and infrared sensors to detect obstacles in front of the blind user and a vibration motor + buzzer for alarm. One of the biggest challenges for blind people when they move inside the house is to go up and downstairs. We aim to address the challenge by integrating into the blind stick a function that alarms users in the staircase presence. Moreover, this device also has a built-in GPS module that allows the device's and its user's location to be tracked and displayed on a smartphone app, a desirable feature for many families of blind people. Ultrasonic and infrared sensors allowed the smart blind stick to detect obstacles at a distance from 5 to 150 cm from the user. Moreover, with a built-in GPS module, it was easy to identify the stick-on smartphone location, which made the searching location of a blind user much easier. This paper presented a design and implementation of an intelligent blind stick for blind people with several advantages, including low cost, capability to detect obstacles above knee level, staircase detection, location tracking via smartphone, etc. However, more tests need to be conducted to determine its accuracy and reliability in real-world settings.

**Keywords:** smart blind stick · smart white cane · ultrasonic sensor · GPS module· location tracking

## I. Introduction

According to the global prevalence estimates for blindness and vision impairment ofthe World Health Organization (WHO), visual impairment and blindness accounted forat least 2.2 billion people worldwide in 2019, and this number is continuing to increaseas time passes. Approximately half of the visually impaired people suffered from un-addressed refractive error, cataract, diabetic retinopathy, and other severe optical prob-lem [1, 2]. As some leading causes of blindness are eye infection and cataract [3] whichis easily found in developing countries and due to the geographical variations, distancevision impairment is found more often in low- and middle-income regions than in thehigh-income areas. Because of the vision loss, obstacles, which is sometimes annoyedthe non – visually impaired people, become a huge problem with the nonvisual people.Hence, external guidance such as humans, trained dogs, or special devices like whitecane, for example, plays an important role in the decision-making of blind people [4]. Although there are several psychological and social benefits for having a guided dog [5], the training cost is not affordable. An investigation for Nonvisual Navigation shows thatthe blind preferred to have the detail of the direction and travel independently [6]. Dueto those reasons, white cane or blink stick is mainly used by the person who has aproblem with visuality [7, 8].Since the visually impaired people have a high demand for efficient mobility ser-vices [9], many developments applying the new technologies to increase the priority ofwhite – cane – liked devices for obstacle detection and navigation. The significant ad-vances are the devices that maintain the shape of the traditional white cane and add thesensors and sounds system for supporting mobility which is generally known as Elec-tronic Travel Aids (ETAs) [10]. This device has the function of realizing the surface ofthe road so that it can detect the position of the congestion in an unknown place [11].Guide cane [12] and Borenstein and Ulrich's innovation, which attached an array of theultrasonic sensor at the end of the stick to detect hindrances. Another type of ETA is pre-sented by Mahmud et al. [13]. This device is used the PIC microcontroller (PIC16F90)to command the ping sonar sensor, proximity sensor, and other equipment. However, acontroversial problem occurred that whether a person with no usable eyesight can inde-pendently and safely move to a new place without any monitoring or not [14]. Hence,this paper proposed to make a Smart Blind Stick that can (1) detect and alarm obstaclesas well as the upward and downward stairs, (2) utilize the design of the stick to helpblind people find it easier to move, (3) send the temperature, humidity, location andspeed of the user to another smartphone via GPS to let the relatives keep in touch withthe blind people condition and (4) be low cost, low power consumption.

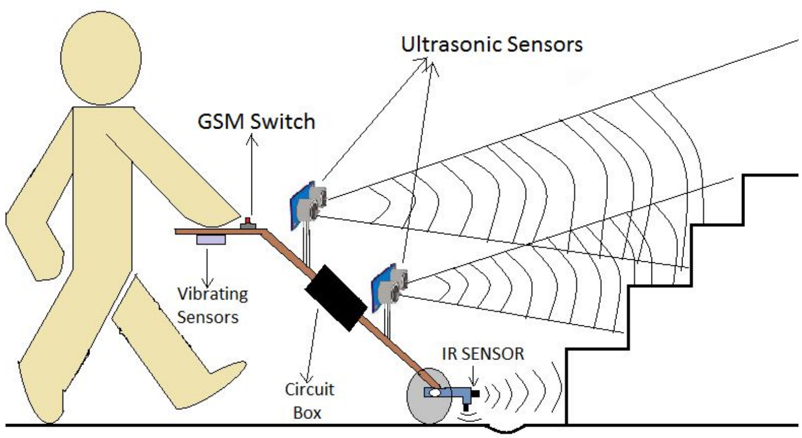


Fig. 1: A sketch of the proposed system

**II. Materials and Methods**

This proposed smart blind stick contains two main characteristics, which include ob-stacle detection and location tracking. In terms of detecting hindrance, the ultrasonicsensor was used thanks to its wide range of detection based on ultrasound wave trans-mission and detection [15]. For keeping track of the user, the GSM module and tem-perature sensor provide the user's location and information to another person, like arelative, by transfer to a smartphone via SMS messages.

Fig. 1 illustrates the mechanism of the smart white cane. The structure includes threeultrasonic sensors, two of which are placed at the cane's bottom for detecting obstaclesin the nearest range of 2 – 10 cm. One ultrasonic sensor mounted on the control boxranges from 30 - 150 cm (set to different ranges), which can detect things placed in thehigh position. A push-button (GSM switch) enables the user to send current status to amobile application via SMS text messages. The control box contains all the sensors incharge of controlling the systems.

**II.1 Stick construction:**

According to the Ministry of Health, Vietnam, the average height of Vietnamese people163.7 cm for men and 153 cm for women. Thus, to make it easier to handle for bothgenders, this stick's height was determined to approximately one meter. In choosingthe material for the stick, a plastic rod made from polyvinyl chloride was used. Thiscompound is lighter and more durable than metal, as well as withstand harsh weatherconditions. The hollow rod allows reducing the weight and makes room for the wiringsystem. At the end of the stick, the 3D plastic box was designed to fix the stick at an an-gle of 60 – the degree to the ground and avoid damaging internal electronic components.There is a control box printed to cover the ultrasonic sensor, GSM module, and Arduinoin the middle of the stick. On the top of the white cane, the handle makes it possiblefor the person to hold the stick firmly. Besides, there is also a push-button to send anSMS message containing the location, coordinate, speed (m/s) of the person holdingthe stick. The following figure illustrates the technical drawing of our prototype. The first and second sketch shows the prototype's front and side view, respectively, while the final one illustrates the whole system.

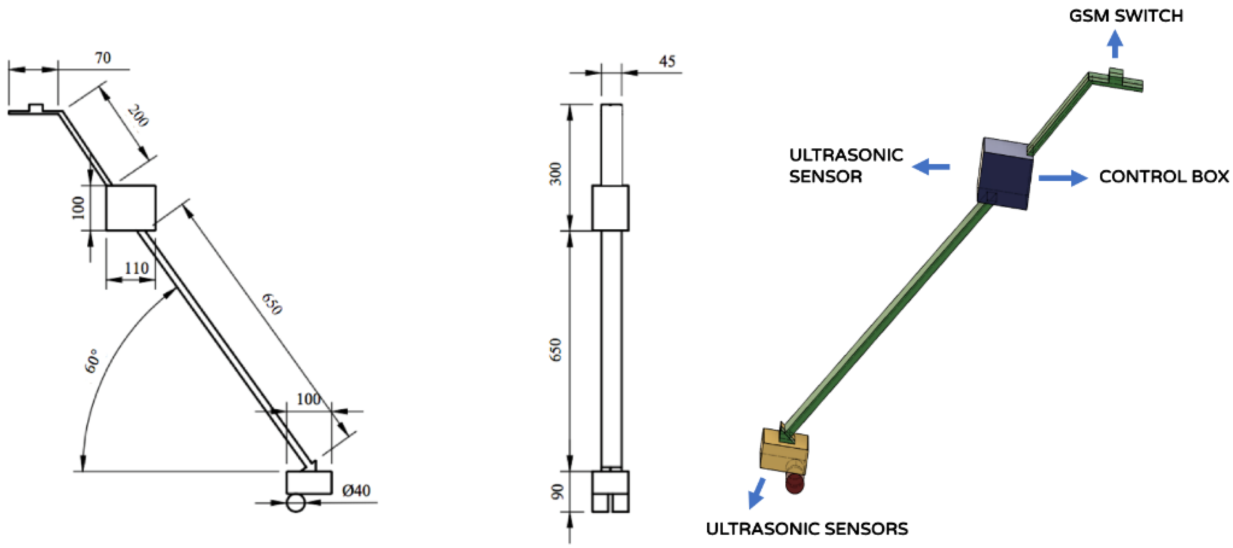


Fig. 2: The structure of the prototype of smart white cane

**II.2 Detecting and Alarming system:**

For distance detection and alarming types, two ultrasonic sensors are responsible for thefull front view; the two sensors will always cross-checking to give an accurate result ofdetecting obstacles. There are various types of alarming for the wide range detection;we aim to the warning by two senses of human: touch (vibration) and sound (buzzer) - the closer the obstacle, the higher frequency of alarms. Besides, the last sensor is usedfor detecting downstairs with the highest repetition.For alarming, we want to warn not only by sound but also by vibration. Therefore,buzzer and vibrate motor are ideal things that help blind man can recognize the dangerin two senses: touch and sound. Fig. 4-a presents the workflow of the whole system.

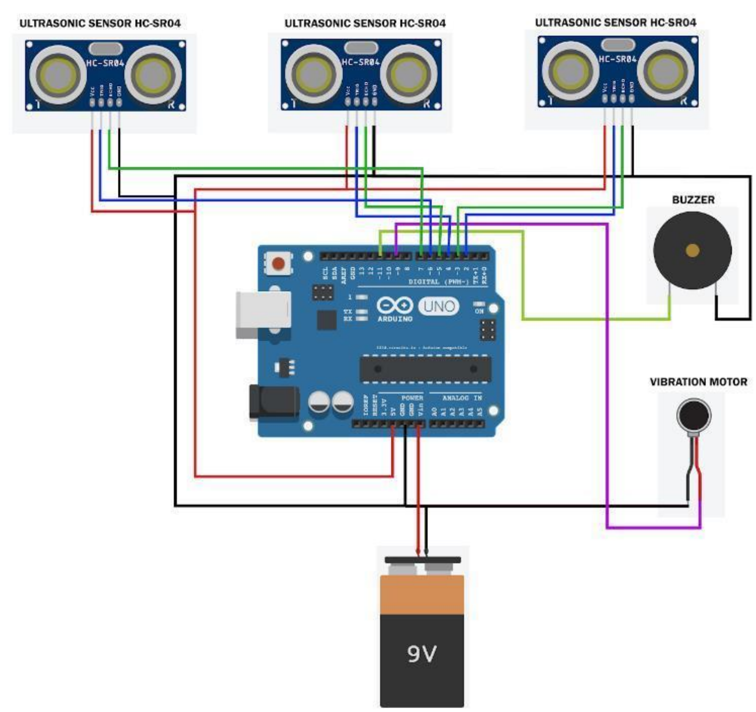


Fig. 3: Wiring diagram of the detection module

**II.3 Data transmission**

For communication between the visually impaired people and their caretakers and loca-tion tracking, a GSM-based data transmission system was proposed in this work. Whenthe user pushed the button on the handle, the temperature sensor (DHT11) and GPSmodule collected information on the user's speed, temperature, humidity, and location.Then, those data were coded in an SMS text message and send to the caretaker phonenumber. A specific Android-based application was used to read this code as well asvisualize those data. The workflow in this step is summarized in the following figure(Fig. 4-b).

**Android Application**: The application was made on MIT App Inventor [18, 19], whichis a visual programming platform for designing applications for Android smartphones.This program was formerly provided by Google and promptly maintained by the Mas-sachusetts Institute of Technology (MIT) App Inventor allows us to create Android-based applications on smartphones via coding and implementing on a web browser, theconnected phone, or an emulator. By using the block programming language, we canfind it efficient to perform a project on this platform. After finishing the work, we canpackage our app and produce a standalone application to install on the smartphone. Theapp is defined to receive text messages only from the smart white cane; thus, any otherSMS will not affect the App. Regarding the function of the Application, since we gotthe information on location, speed, temperature, and humidity from the GPS module, we let the App show three variables: location, speed, and temperature. In terms of loca-tion tracking, there are two different types to show the location of the blind on the map.For people who prefer to use Google Maps for searching the location, we link the BlindStick App and automatically send the latitude and longitude of the blind to located onMaps. The second type of map is the map created from the map function of the AppInventor (BS Map), people can search the location together with other variables.

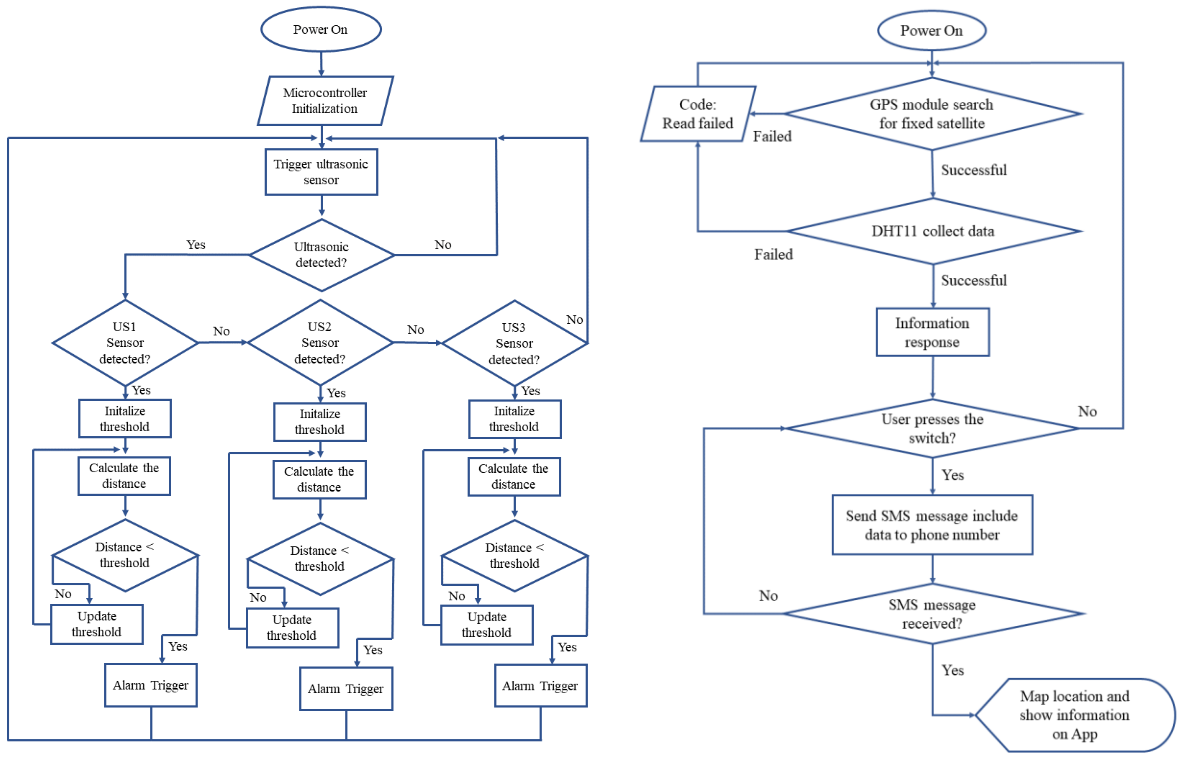


Fig. 4: a) Flow chart of the obstacle detection system b) Flow chart of Data Transmission System

**III. Results and Discussion:**

First, we experimented to determine the accuracy of the HC-SR04 sensor's ability tomeasure distances. For system testing, a steel scale is used to measure the actual dis-tance in centimeters. Room walls are used as the object from which the system willmeasure the distance. The system is designed to be moved from the wall and then theactual distance is measured in steel ladders in centimeters. The distance measured bythe development system will be shown on the serial monitor screen from the ArduinoIDE. We conducted experiments based on experiments that

[20] performed. To evalu-ate the performance of the system designed, we took 14 sample distances within thedesired distance. For each sample, we conduct experiments three times to compute themean value of each sample at each fixed distance, so that we can compute the stan-dard deviation of each sample at each fixed distance. We also analyzed the percentageof errorfor each sample. In all distance measurements, the error percentage is lessthan 1 and so is the average. Fig. 6 shows the experiment results, we can see that thefarther the distance from the object to the sensor, the greater the percentage of errors is increased. Moreover, the percentage of errors can still be affected by external en-vironmental conditions (i.e. Temperature, Humidity, Materials, etc.). Since then, weproposed the measurement distance for our system should be in the range of (0-100cm), in order to provide the most accurate results as well as minimize the percentage oferrors that may occur when operating under conditions outside the environmental. Thatwill help the user experience of the blind be better as well as ensure user safety.

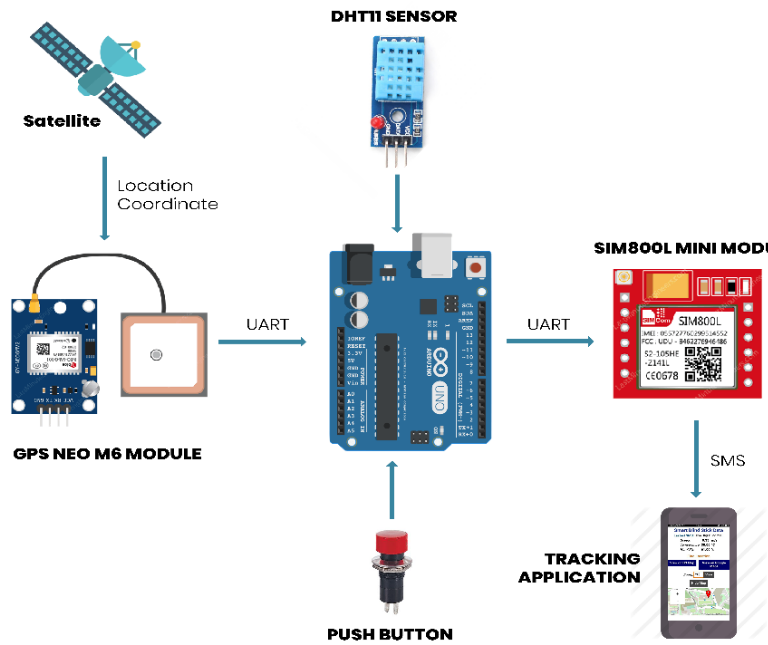


Fig. 5: Block diagram of the transmission system

We also plotted the graph to visualize the relation of fixed distance (Dm) with dis-tance measured with HC-SR04 (Ds). From the plot, we obtained a regression equationwhere regression coefficients are obtained as 9.2833 and 0.9996 respectively using Mi-crosoft Excel software, as shown in Fig. 6 below:

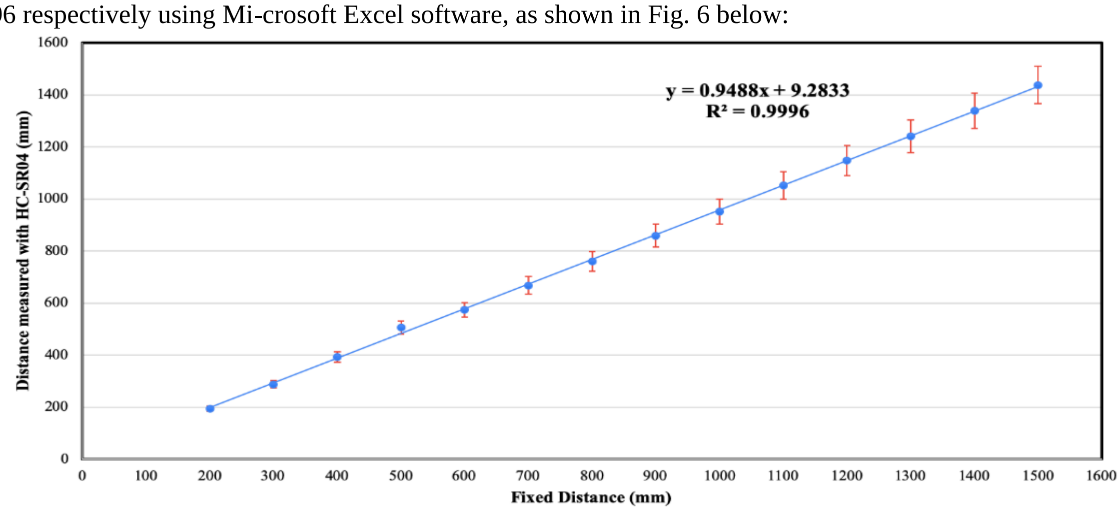


Fig. 6: Plot of the fixed distance versus measured distance by the system

The value of coefficient of determination (R2) is 0.9996 as extracted from MicrosoftExcel software, and the slope of the regression line (i.e. regression coefficient, a0) isalso 0.9996, which signifies that all the data of measured and sample test distancesalign with each other, and hence the system is performing very well. In addition, weconducted experiments to measure the difference of voltage with distance to the object.We reuse the system proposed in the experiment, then use the voltmeter to measurevoltage measured from the ECHO pin of the ultrasonic module (HC-SR04). Accordingto the working principle of the sensor, it acts as a transducer when receiving echo ultra-sonic waves from the object will convert to a voltage signal and gain from the ECHOpin. As seen in Fig. 7, we can estimate that the larger the distance, the more measuredvoltage will increase.

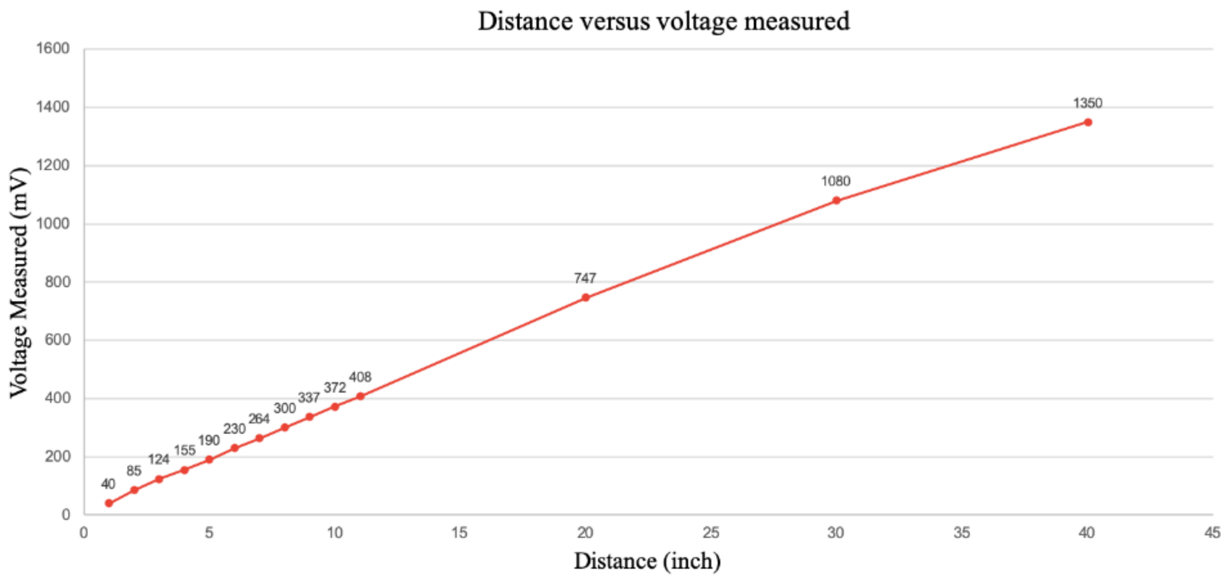


Fig. 7: Distance versus voltage measured plot graph

**IV. Conclusion:**

This proposed method comes up with designing and implementing a smart walkingstick for the visual impairment in developing countries that can send the information atthe current place to another one. This device shows its effectiveness and safety for thecustomers. This paper offers a low-cost, reliable, and robust system for navigation andlocation tracking. However, the materials for building the circuit and the weight of thestick should be improved for better application.

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