# A Mobility Support Device (Smart Walking Stick) for the Visually Impaired

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***Abstract*—- Visually impaired persons experience difficulty while moving around in their environments. Most working sticks currently in use are not smart, and have no intrinsic ability to detect danger. An attempt to solve this problem is the involvement of orientation and mobility specialists who help the visually impaired, by training them to move on their own independently and safely depending on their other remaining senses. Also guide dogs are used to help them navigate around obstacles. These methods have limitations including the inability of these dogs to understand complex directions, the cost of hiring a specialist, and maintenance of these trained dogs is very high. The "Smart walking stick" has therefore emerged as a viable solution to the above observed challenges. The "Smart walking stick" is a functional mobility aid with the abilities to detect and alert the user about obstacles above ground level and pits using ultrasonic sensors; identify that its user has suffered a collision and initiate a call to his/her relative that can be of help; and also call the user's mobile phone if misplaced. A test case was carried out using some visually impaired persons and the success rate was 95%.**

***Keywords-visually impaired; sensors; micro-controller; GSM/GPRS; buzzer; arduino IDE; vibrator***

## I. INTRODUCTION

When a physiological or neurological occurrence leads to the lack of visual perception, the affected person is said to be visually impaired or blind. Partial blindness signifies the lack of integration in the growth of the optic nerve or visual center of the eye and total blindness is the full absence of the visual light perception. According to [6], as at the year 2010, 285 million people were estimated to be visually impaired worldwide: 39 million were blind and 246 million had low vision.

Visually impaired and blind people experience difficulty while moving around in their environment. In many occasions, they need help for mobility. One of the ways currently used to solve this problem is orientation and mobility specialist who helps the visually impaired and blind person and trains them to move on their own independently and safely depending on their healthy sense organs. Another method is the guide dogs which are trained specially to help the blind people on their movement by navigating around the obstacles to alert the person to change direction. However, these methods have some limitations including; inability to understand complex directions by these dogs, and they are only suitable for five years. The cost of these trained dogs is very high and they have to be cared for by the same person that needs help with mobility.

This research work involves the creation of a smart walking stick based on embedded systems technology that reduces the dependence of the visually impaired/blind on other mobility aids. Over the years several attempts have been made to deliver support systems for the visually impaired persons. Such systems have engaged Bluetooth technology, Wi-Fi, Infrared and ultrasonic sensors. However, none has been able to adopt a mini-telephone to enable a call to someone who can help in an emergency situation. The smart walking stick is therefore designed and implemented to send and receive calls to and from designated telephone numbers. As a result of this GSM inclusion, it can also be used by the visually impaired person to search for their personal phone whenever it is misplaced.

Some systems already developed for the visually impaired which are mentioned in the related works need improvement. As a major factor in our consideration and a strong motivation is the depression that visually impaired people are susceptible to when they have to depend so much on other people for daily life. We have attained this independence for the visually impaired by incorporating phone functionalities in the device.

Later, we described related approaches to creating a support system for the visually impaired and distinguished ours from the works already done. Followed also is a detailed description of the various materials and methodology we used to achieve our objectives. The result of our implementation is explained followed by a discussion and conclusion section.

## II. RELATED WORKS

Several approaches have been used to arrive at devices that can aid navigation and co-existence for visually impaired persons. Some of the recent once are described thus:

Ultrasonic navigation system for the visually impaired & blind pedestrians was developed by [2]. Their work was to expand the electronic travel aid for the blind and visually impaired pedestrians using the ultrasonic technology. In a place of high level of noise, the visually impaired person may be unable to hear the buzzer's sound distinctively and is left without any other chance of getting directed since there is no vibration actuator.

Ref. [1] developed a smart infrared microcontroller-based blind guidance system which overcame the use of guide dogs and the unintelligent white cane. A head hat and a pen-like tool were the two components of the device that work together to guide the user. Although the device was very helpful in guiding the user, the head hat defaces the user's appearance, while the use of more than one part increases the chances of loss of a part.

Ref. [3] developed the non-intrusive somatosensory navigation support for blind pedestrians which uses haptic approach to provide continuous and non-intrusive navigation information. The system has five parts; electronic compass, three vibration output, PDA and GPS receiver make up this system and each must be tightly attached to the body. This can create discomfort for the user.

Ref. [4] developed "An Indoor Navigation System for the Visually Impaired". Their objective was develop an indoor navigation system for the visually impaired which maximize the requirement of usability. They were motivated by the fact that most of the existing indoor navigation systems involve an important deployment effort or use artifacts that are not natural for blind users. The several components such as: mobile phone, computer running the controlling application, infrared cameras embedded in the compound communication means which includes infrared, Bluetooth and Wi-Fi reduces the fault tolerance of the system thereby increasing the chance of failure. Also it is limited to indoor usage.

Ref. [5] developed an Embedded Home Automation For The Visually Impaired. Their objective was to develop an embedded system which is used to control the home appliances through voice and mobile for the visually impaired people and also for the physically challenged people. However, the use of infrared highly limits the flexibility in terms of distance in controlling the appliances and it is not much suited as mobility aid.

## III. MATERIALS AND METHODS

### A. *Materials*

The following hardware and software tools were used; a stick, Seeduino micro-controller, ultrasonic sensors, base shield, GSM and GPRS module, buzzer, button, vibrator, light sensor, and Arduino IDE with a code written in C programming language.

### B. *Software Technology*

Arduino IDE: The Arduino Software Integrated Development Environment (IDE) is an open-source software that makes it easy to write code and upload it to a microcontroller. It runs on Windows, Mac OS X, and Linux. The environment is written in Java and based on Processing and other open-source software. It was used to write the code for the operation of our visually impaired support system and to upload the code into the microcontroller. A few sample code segments for the system are shown below. The entire source code has about 442 lines of well documented codes.

### C. *Hardware Technology*

The hardware used in the development of the system include: a microcontroller, Sensors, Actuators, Rechargeable power source, Buttons and GSM Module.

Microcontroller: A microcontroller is a small computer (SoC) on a single integrated circuit containing a processor core, memory, and programmable input/output peripherals. Program memory in the form of Ferroelectric RAM, NOR flash or OTP ROM is also often included on chip, as well as a typically small amount of RAM. Microcontrollers are designed for embedded applications, in contrast to the microprocessors used in personal computers or other general purpose applications consisting of various discrete chips. It will suffice to say that a microcontroller is a self-contained system with peripherals, memory and a processor that can be used as an embedded system. The microcontroller used in this device is Seeduino GPRS. Seeduino GPRS is an IoT panel that can connect to the internet through GPRS wireless network. It can make and answer voice calls as much as it sends and receives SMS. It also supports FM Radio function and Bluetooth communication. Seeduino GPRS is based on ATmega32U4 and SIM800H. ATmega32U4 is a microcontroller compatible with Arduino. SIM800H supports Quad-band 850/900/1800/1900MHz. It can transmit voice, SMS and data with low power consumption. SIM800H also brings some extra features like Bluetooth and FM Radio. Its low power design results in a current as low as 0.1mA in sleep mode.

Figure 1. Microcontroller Seeeduino GPRS

GSM/GPRS: GSM/GPRS module is used to establish communication between a computer and a GSM/GPRS system. Global System for Mobile communication (GSM) is an architecture used for mobile communication in most countries. Global Packet Radio Service (GPRS) is an extension of GSM that enables higher data transmission rate. The GSM module in this project is onboard the microcontroller.

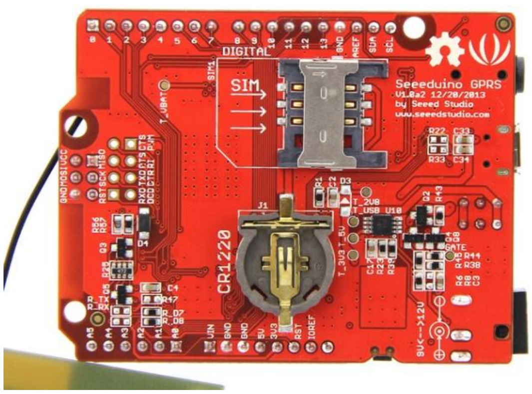


Figure 2. Seeeduino microcontroller showing the SIM card slot

Sensors: A sensor is a device that detects and responds to some type of input from the physical environment. The specific input could be light, heat, motion, moisture, pressure, or any one of a great number of other environmental phenomena. The output is generally a signal that is converted to human-readable display at the sensor location or transmitted electronically over a network for reading or further processing. In selecting the sensors for this work, we considered accuracy, environmental condition, range, calibration, resolution, cost and repeatability. Sensors used for this device are ultrasonic and light. Active *ultrasonic sensors* generate high-frequency sound waves and evaluate the echo which is received back by the *sensor*, measuring the time interval between sending the signal and receiving the echo to determine the distance to an object. Ultrasonic sensing technology is based on the principle that sound has a relatively constant velocity. The time for an ultrasonic sensor's beam to strike the target and return is directly proportional to the distance to the object. Consequently, ultrasonic sensors are used frequently for distance measurement applications such as level control.

Ultrasonic sensors are capable of detecting most objects - metal or nonmetal, clear or opaque, liquid, solid, or granular - that have sufficient acoustic reflectivity. Another advantage of ultrasonic sensors is that they are less affected by condensing moisture than photoelectric sensors. We used ultrasonic sensors for obstacle and pit detection.


Figure 3. Ultrasonic Sensor

Light Sensor: A *Light Sensor* is something to detect the current ambient *light* level - i.e. how bright or dark it is. There are a range of different types of *light sensors*, including Photo resistors, Photodiodes, and Phototransistors.

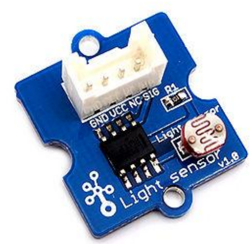


Figure 4. Light sensor

Collision Sensor: A collision sensor equips a device with what appears to be an awareness of its surroundings and a capability to react to collisions within those surroundings. Traditionally, collision sensors have been used to detect or "sense" an actual collision between a vehicle and an object of any kind. We have been able to employ it in the smart walking stick to sense harmful level of impact and trigger or makes a call to the preprogrammed telephone number.

Actuators: An actuator is the mechanism by which a control system acts upon an environment. It is often part of a computer control system. The actuator is a mechanical device or motor which carries out the action or decision made by the control system. For example the lens of a digital camera moves in and out according to how much zoom is wanted. This movement is controlled by an 'actuator'. In this case it is a tiny electric motor that is controlled by a computer control system within the camera. Whatever the size of an actuator the basic function is to allow a computer to control movement or action.

Pushbutton: Pushbuttons are used to give a digital user input to pins. In implementation, push buttons are used to put the device on as well as to make and receive a call.

Figure 5. Push button

Microphone and Speaker: Microphone is an instrument for converting sound waves into electrical energy variations, which may then be amplified, transmitted, or recorded. *Speakers* are one of the most common output devices used with computer systems. Regardless of their design, the purpose of *speakers* is to produce audio output that can be heard by the listener. In the smart walking stick the microphone and speaker are used to facilitate communication via GPRS. A dual function tool that has a mouthpiece which receives voice and an earpiece which delivers sound has been used in this project.

Vibrator: The vibrator is an electric motor that spins with such a high revolutions per time as to cause sufficient vibration that can be felt throughout the smart walking stick. It is used to signal the presence of obstacle in the path of the visually impaired person.

Figure 6. Vibrator

Buzzer: A *buzzer* is a mechanical, electromechanical, magnetic, electromagnetic, electro-acoustic or piezoelectric audio signaling device. A piezo electric buzzer can be driven by an oscillating electronic circuit or other audio signal. A click, beep or ring can indicate that a button has been pressed. Here, the buzzer has been designed to signal a change in ambient light.

Figure 7. Buzzer

Rechargeable Power Source: Power source is a component that supplies power to at least one electric load. Typically, it converts one type of electrical power to another, but it may also convert a different form of energy - such as solar, mechanical, or chemical - into electrical energy. A power source provides components with electric power. The power source used in our implementation is rechargeable to ensure mobility of the system.

### *D. Sub Systems Functions*

The hardware used in the development of the system include: a microcontroller, Sensors, Actuators, Rechargeable power source, Buttons and GSM Module.

The specific actions performed within the entire system framework are listed below:

1. connect to power source - device powers on, all ultrasonic sensors begin transmitting signals to detect obstacle, collision sensor is collecting the value of the pressure acting on it and light sensor is also constantly collecting ambient light value.

2. if the microprocessor receives a value beyond threshold from the top ultrasonic sensor, it sends a command to the buzzer to beep continually, one beep per time. Microcontroller stops beep when the value from the sensor falls below threshold

3. if the microprocessor receives a value beyond threshold from the middle ultrasonic sensor, it sends a command to the buzzer to beep continually, two beeps per time. Microcontroller stops beep when the value from the sensor falls below threshold

4. if the microprocessor receives a value beyond threshold from the middle ultrasonic sensor, it sends a command to the buzzer to beep continually, three beeps per time. Microcontroller stops beep when the value from the sensor falls below threshold

NB: the microprocessor is constantly comparing the values obtained
with the threshold value to dictate a response to actuator

5. if the value from the light sensor rises beyond threshold signifying darkness, the microcontroller sets the vibrator to "vibrate if obstacle found". This makes the device vibrate and beep when an ultrasonic threshold value is exceeded.

6. Button 1 - sends a " send call to emergency telephone number" command to microcontroller. Microcontroller then fires a call through GPRS to the preset emergency telephone number. Speedily double-tapping Button 1 ends a call.

7. Button 2 - sends a redialled" send call to user's telephone number" command to microcontroller which then fires a call through GPRS to device user's phone. The call is redialled if not answered. Double-tapping Button 2 stops the redial

8. The microcontroller responds to an incoming call by instructing the buzzer with a rhythmic beep. The call is acceptable using the button on the earpiece.

## IV. SYSTEM DESIGN

The system is designed with three ultrasonic sensors to detect the obstacles towards which the user is approaching, a light sensor to perceive ambient light, buttons for control, buzzer and vibrator for feedback to user, the GSM module which is responsible for telephone calls, the microcontroller, the software component and a walking stick. In the visually-impaired support system, each of the three ultrasonic sensors are designed to have a fixed orientation. The first ultrasonic sensor named “top” has a line of sight which is perpendicular to the ground and is located 83cm above ground level. The second ultrasonic sensor named “middle” has a line of sight which is 60° to the vertical and located at a distance of 53.5 cm above ground level. The third and last ultrasonic sensor is positioned to have a line of sight that vertically downward and located at a distance 19cm from ground level.

### *A. System Architecture*

The architecture of the visually-impaired support device (see Fig. 8) has the following features: the software which is loaded into the Microcontroller, the hardware features includes; the sensors: ultrasonic, light and collision sensor, the actuators: buzzer and vibrator, then there are two buttons for system control, a power source and the GSM module for mobile communication.

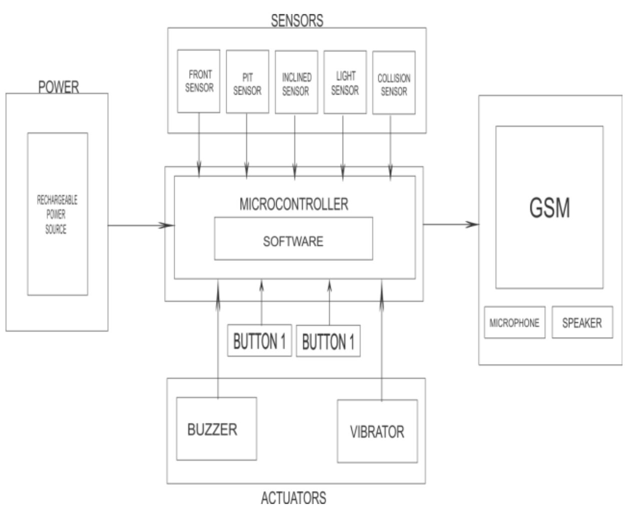


Figure 8. System Architecture

### *B. System Use Case*

The use case contains all system activities that are significant to the users. A use case can be thought of as a collection of possible scenarios related to a particular goal.

TABLE I. USE CASE FOR THE SMART WALKING STICK

| ***Serial No.*** | ***State*** | ***Trigger/Action*** | ***Result/Goal*** |
|---|---|---|---|
| 1 | Device is powered off | press power button | Device powers on |
| 2 | Device is powered on | top obstacle detected | Device beeps once |
| 3 | Device is powered on | middle obstacle detected | Device beeps twice |
| 4 | Device is powered on | down detected | Device beeps three times |
| 5 | Device is powered on | Ambient light changes significantly | Device Immediate three output above accompanied by vibration. |
| 6 | Device is powered on | Excess impact on device | Device buzzes for 5 seconds. If button is pressed between 0-5 seconds, buzzing stops. If button is not pressed between 0-5 seconds a call is sent to a preset number for assistance. |
| 7 | Device is powered on | Button is pressed | Prevents a false automatic emergency call |

## V. SYSTEM TESTING AND DISCUSSION

In testing the visually impaired support system, a room was arranged with different objects of varying heights to serve as obstacle for the three ultrasonic sensors. To test the performance of the light sensor, another test was carried out at 7:15pm when the ambient light in the room was very low. Once the device is turned on, the user experienced a vibration of the device signifying that it is dark and precaution should be applied, the vibration continued until the user pressed the stop button.

The middle ultrasonic sensor is fixed with an orientation of 60° to the vertical at a distance of 53.5cm to the bottom of the stick.

Figure 9. Showing the middle ultrasonic sensor

The top ultrasonic sensor is fixed perpendicular to the vertical with a perfectly horizontal line of sight. It is located 83cm from the bottom of the stick.

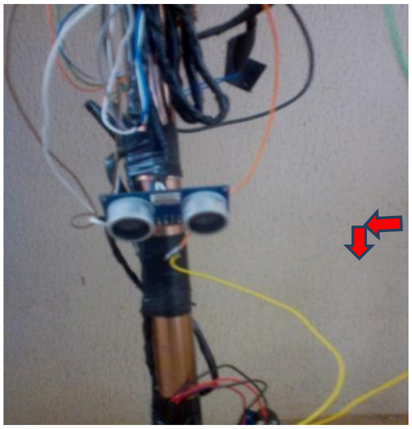

Figure 10. Showing the top ultrasonic sensor

The Seeduino GPRS microcontroller is powered, controlling the entire system as shown in Fig. 11.

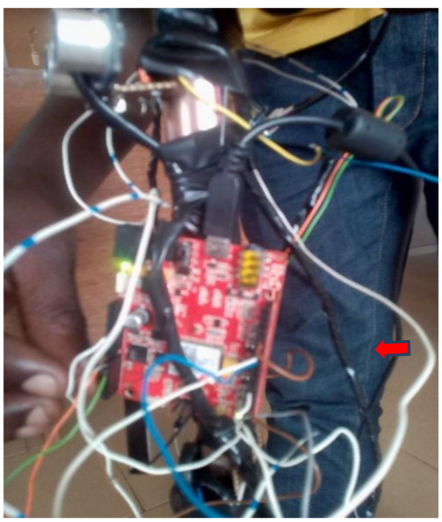

Figure 11. Shows the Seeeduino microcontroller at work

The buzzer begins to beep upon detection of obstacle. When depth is increased a continuous triple beep is heard until the depth reduces to preset ground level. When an obstacle is detected by the middle ultrasonic sensor, a continuous double beep is heard until the obstacle is no longer present. The beep heard is a single continuous one if an obstacle is detected by the top ultrasonic sensor.

Figure 12. Shows the Buzzer at work

Fig. 13 shows the two push buttons in the system. The upper one sends a call to a helper. The lower one ends the device's attempt to make a call.

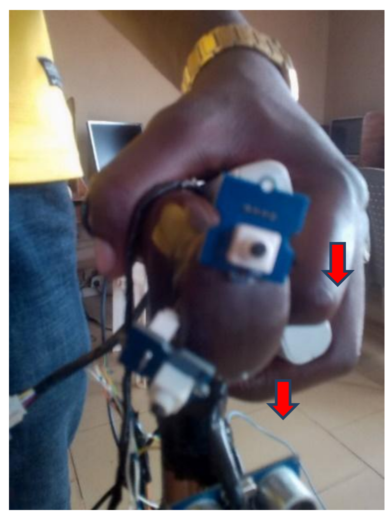

Figure 13. Shows the push buttons

Fig. 14 shows that the Light sensor is ready to detect darkness. When it does, every buzzer reaction to obstacle and depth is accompanied with vibration of the stick.

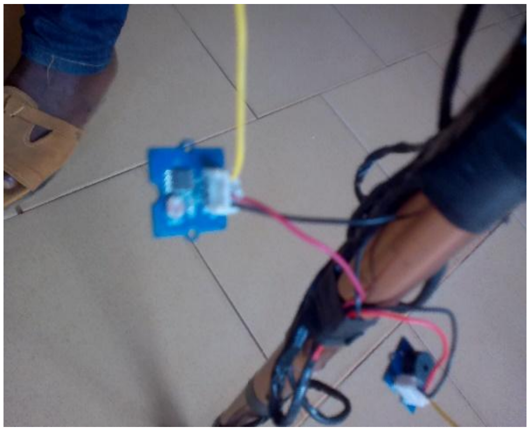

Figure 14. Light Sensor

Fig. 15 shows that the lights on the microcontroller indicating that the device is powered and working.

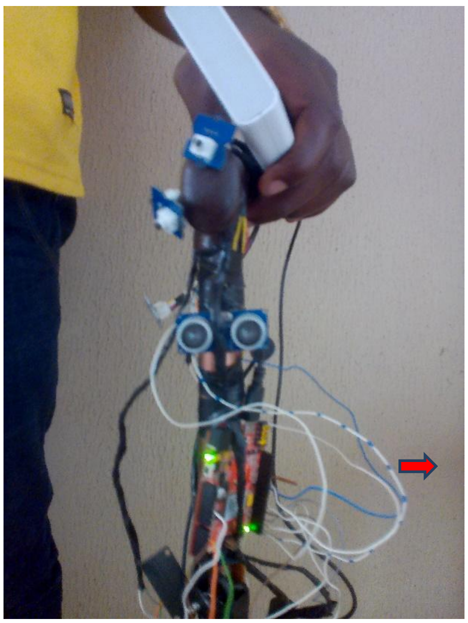

Figure 15. Showing that the device is powered

## VI. CONCLUSION

This work reevaluates the necessity of maximizing the exploits of information and communication technology for improving life lived by the visually impaired. Mobility is essential for the blind, even more, safe mobility. This and more are the things we have focused on in this work. In addition to safe mobility we have integrated mobile telephone in the system, thereby reducing the dependence of the visually impaired. We believe that the adoption of our research would improve daily living for the visually impaired and by extension provide a base of research for the development of systems that will address the needs of persons with physical impairments other than vision.

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