Design of an Intelligent Navigation System for the Blind

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Abstract*—The Intelligent Navigation System is a powerful tool helpful for visually impaired persons in achieving fully independent navigation for those with vision loss and blindness to move freely, and safely with less cost implication. This paper is made up of three sections, which are the Sensory Unit, the Wireless AC Detector Unit, and the Retrieval Unit (RF Unit). The Sensory Unit comprises of three ultrasonic sensors, fire sensor, smoke sensor, and water sensor are all mounted in a box close to the tip of the stick and receives their power supply from the Arduino UNO board, acting as the brain of the device. The AC Wireless Detector uses a 555 Timer IC with a buzzer and an LED as indicators connected to a 9volts dc battery. The receiver and transmitter module are connected to their respective ICs and antennas with a 9volts battery supply to each of them separately. All the sensors performed as expected with the ultrasonic taking readings from 0 – 70cm and at exactly 50cm the ultrasonic sensors detected obstacles in their respective directions. The water sensor taking its reading from 3-5cm of depth. At 3cm the water level sensor detected water. The AC wireless detector buzzed as the LED turned on as it approached a livewire within the range of 1 – 50cm in its direction. Specifically, at 30cm the wireless detector detected a livewire

***Indexed Terms*—Blind, Microcontroller, Navigation system, Sensors**

I. INTRODUCTION

Human beings receive about 80% of information from the environment via sight. According to the World Health Organization (WHO) 285 million people [1] are visually impaired (VI) worldwide. Among these 39 million are blind and 246 have low vision [2]. About 90% of the world's VI live in developing countries [3]. Normally, Visually Impaired Persons (VIPs) rely on an assistance to reach their required location. They cannot find their way by their own if the area is unknown or the path is closed due to some mountains or unavoidable circumstances. They need help in all their daily works, whether they are inside or outside their boundaries. To overcome such challenges, there are several methods used by these VIPs such as white cane, dog guidance, human guide and Navbelt [4] But these methods are ineffective and unreliable. With the rapid advancement in modern technology, both hardware and software have brought about the potentials to provide smart aid for VIPs.

Currently, VIPs use a traditional walking stick as a tool for directing them when they move from one place to another [5]. Traditional, VIPs use common white stick and it works manually. However, research has made it possible for detection of hurdles by using ultrasound sensor system (USS), Global System for Mobile Communication-Global Positioning System (GSM-GPS) system which will send a message to the VIPs guardian in the case of an emergency [6]. This existing system can be improved if the variables used as guide for the visually impaired person (VIPs) are increased.

In this paper, a design has been developed and constructed to provide navigation for the visually impaired persons using an ultrasonic sensor that will detect obstacles in the path of the visually impaired person, a smoke detector in case of a fire threat, a fire sensor in case where the smoke detector fails and a water level detector that detects a certain water level which could be a possible threat to the VIP.

II. MATERIALS

The major materials used were a mix of passive and active electronic components comprising of Arduino microcontroller (uno r3), ultrasonic sensor (HC-RS04), fire sensor/smoke dectector (MQ2), Moisture level sensor (HW-080), sound buzzer, batteries (9v) with clips, transmitter (13.560 TX) and receiver (6.7458 RX) modules, integrated circuit (TD8 2003), HT-12D decoder, HT-12E encoder, capacitors, resistors, op amp (NE555), light emitting diode (5mm), liquid crystal display (16x2), wooden stick, Jumper wires and insulated casing. The design was based on the availability, reliability, efficiency, and maintainability of the materials used.

III. SYSTEM DESIGN AND IMPLEMENTATION

In this research, the design and implementation were done in three approaches. The block diagram, flowchart and circuit design. The block diagram in -Fig 1, describes the basic principle of operation of the Intelligent Navigation System. The flowchart in -Fig 2, gives an overview of the wireless AC detector as well as sensors attached to the Arduino in -Fig 3. The code written was uploaded onto the Arduino uno microcontroller to implement the circuit design.

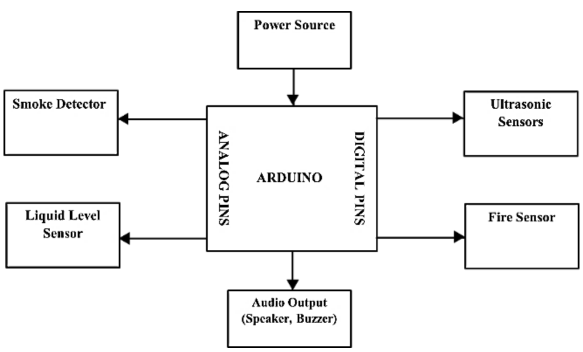

Fig 1. Block Diagram of the Intelligent Navigation System.

3.1. Wireless AC Detector

Magnetic fields are created as electrons move through the wire. On a straight wire, the magnitude of the magnetic field is inversely proportional to the distance from the wire. Electric fields are also proportional to the distance to the wire.

$$Magnetic\ Force\ for\ a\ Sphere\ = [(Magnetic\ Constant\ x\ Current)/ Circumference] \quad (1)$$

Or more specifically, Magnetic field around a current-carrying wire

B perpendicular = $\mu oI\ (2\pi r)$

B, magnetic field strength, measured in Tesla μo, permeability of free space = $4\pi\ x\ 10-7\ Tm/A$

I, current flowing through the wire, measured in amps

r, distance from the wire, measured in meters

Enclosures that are square or other unusually shaped objects the force field will change shapes accordingly. Therefore, to use the tester correctly you must place the tester as close as possible to the suspect area and move the tester across the surface from corner to corner searching out the magnetic waves.

A. Flow chart for Wireless AC detector

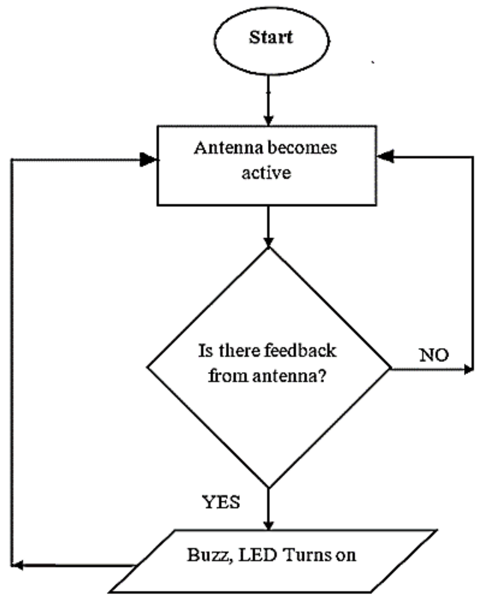

Fig 2. Flowchart for Wireless AC Detector

3.2 Sensors on Arduino

It starts by putting on the system which is represented by the START. The front, left, and right ultrasonic sensors have their trigger pins on by the Arduino UNO and for any obstacle detected a reflected is sent to the echo pin and a voice notification is heard. The Fire Sensor, Liquid Level Sensor, and Smoke Detector also have voltages supplied to them when the device is switched on and a voice notification is heard by the visually impaired person with regards to the threat ahead.

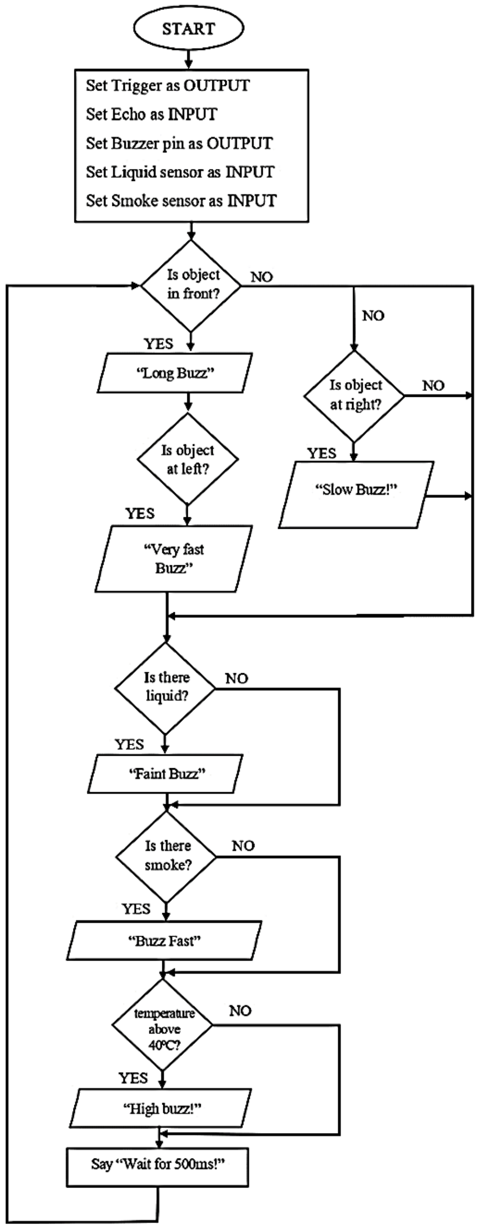

Fig 3. Flowchart for sensors on Arduino

3.3. Intelligent Navigation System

The Arduino code was written to control both input and output response from all the sensors used. The front, left, and right ultrasonic triggers are declared to pin 7, 5 and 3 respectively and the front, left, and right echoes to pin 6, 4, and 2 respectively. The Fire sensor was declared to pin 10 and the buzzer to pin 11. The water sensor was declared to analog 0 and the smoke detector was declared to analog 1. Also, a function is defined to calculate the distance to the nearest obstacle. This function works by sending a digital LOW signal level to the ultrasonic Trigger pin for two microseconds, then a digital HIGH signal level for ten microseconds, and the LOW again. This impulse signal transmits sound waves from the trigger pin.

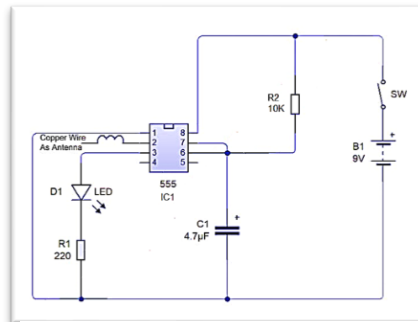

Fig 4. Circuit diagram of wireless AC

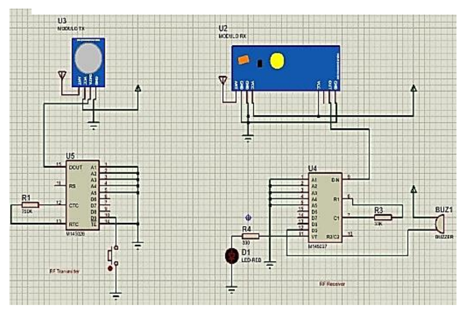

Fig 5. Circuit diagram of Radio Frequency

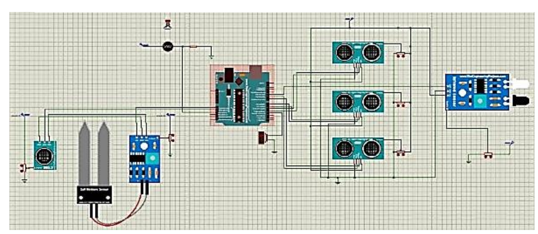

Fig 6. Circuit diagram of the Intelligent Navigation System with sensors.

IV. TESTS AND RESULTS

The whole system was tested with the use of Proteus software sensory components and Radio Frequency (RF) module components to check the behavior of the circuitry system when it's being used by the visually impaired person. When the ultrasonic sensor comes across an obstacle, a signal is sent back to the sensor and the alarm was heard as expected. Also, when there was a presence of smoke the smoke detector detected it, and an alarm was heard as expected. When the Fire Sensor detects a high temperature, which was calibrated from 40^{o}C and above, an alarm was heard as expected to show that there is a fire alert. When the moisture level sensor was put into water of about 5cm in depth the alarm was heard as expected.

Also, when the AC Wireless Detector was brought close to a livewire, at about 80cm, an alarm was heard from the buzzer as the LED also turned on and when the Wireless Detector was put some distance away (>80cm) from the livewire, there was no response. This shows that the desired result of the research was achieved.

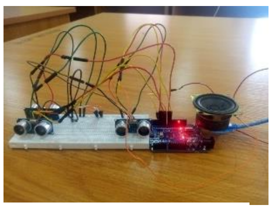

Fig 7. Front, left and right ultrasonic sensors under test.

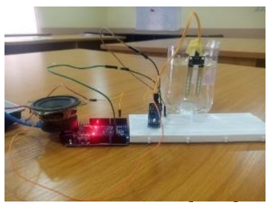

Fig 8. Moisture level sensor under test.

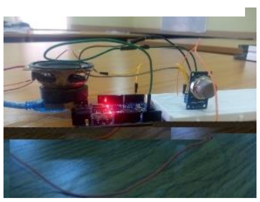

Fig 9. MQ2 smoke detector under test.

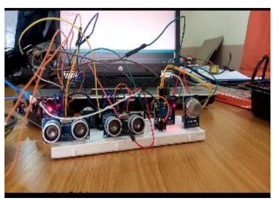

Fig 10. All sensors connected to Arduino under test.

Fig 11. Introducing and explaining the functionalities of the device to Emmanuel Zwalnan, a 200 level Visually Impaired Student (University of Jos).

Fig 12. Visually Impaired Student using the device by himself with the guidance Mr. Yahaya M. Maren (Chief Technologist, Electrical and Electronics Department, University of Jos).

Fig13. The Visually Impaired Person identifying obstacles in his path.

Fig 14. Getting feedback from the Visually Impaired Person after his first-time experience with the device.

A. Radio Frequency (RF) Module

The Radio Frequency (RF) module’s transmission frequency is 433MHz but on testing, 433.92MHz at 1kb data rate was realized. The Radio Frequency (RF) module operated within the range of +4.48v – +8.50v. Table I and -Fig 15 show the signal communication relationship between the transmitter and receiver of the RF module when there is an antenna attached.

Table I Transmitter with Antenna

Range	Signal Communication
10cm	Present
20cm	Present
30cm	Present
40cm	Present
50cm	Present
60cm	Present
70cm	Present
80cm	Present
90cm	Present
100cm and above	Absent

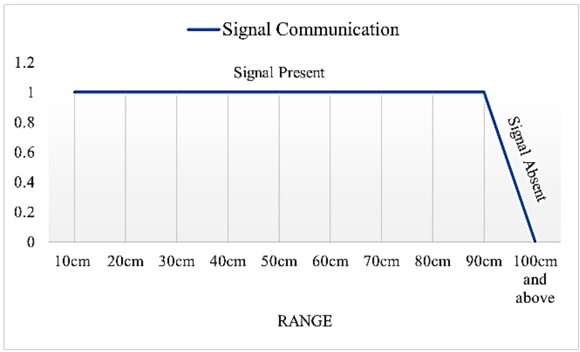

Fig 15. Graph of signal communication against distance

B. Sensory Stage

i. Ultrasonic Sensor

A LOW level signal was sent to the trigger pin and after 2 microseconds, a HIGH level signal is sent to the trigger pin. After 10 microseconds, a LOW level signal is sent again. This sensor is operating at a frequency range of 30 – 500kHz. The result of this pulse signal was observed as shown in - Fig 16

Table II Range of Operation of Ultrasonic Sensors

Range	Signal response
10cm	Present
20cm	Present
30cm	Present
40cm	Present
50cm	Present
60cm	Present
70cm	Present
80cm	Present
90cm	Present
100cm and above	Absent

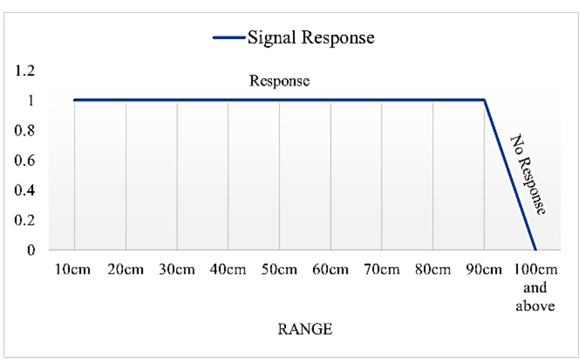

Fig 16. Graph of signal response against distance

II. Moisture Level Sensor

It was observed that the resistance is inversely proportional to the available amount of water. That is, the higher the concentration of water, the lower the resistance. The probe was measured to be about 3cm in height. Table III shows the relationship between the water level and the approximate resistance.

Table III: Relationship Between the Water Level and Resistance

Water Level	Resistance (Ω)	Signal Reading
1cm	8.65	Low
2cm	2.51	Low
3cm	0.19	High
4cm	0.8	High
5cm	0.5	High

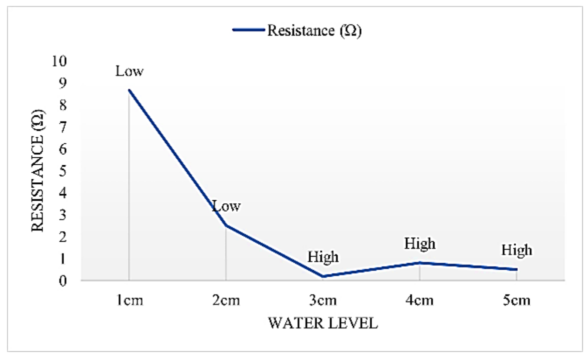

Fig 17. Graph of water level against resistance

C. Wireless AC Detector

For the wireless AC Detector, it was observed that the antenna was sensitive between the distance 1cm – 80cm and insensitive between distances of 80cm and above.

Table IV: Relationship between Range and Output of Wireless AC Detector

Range	Response (LED & Buzzer)
10cm	Active
20cm	Active
30cm	Active
40cm	Active
50cm	Active
60cm	Active
70cm	Non-active

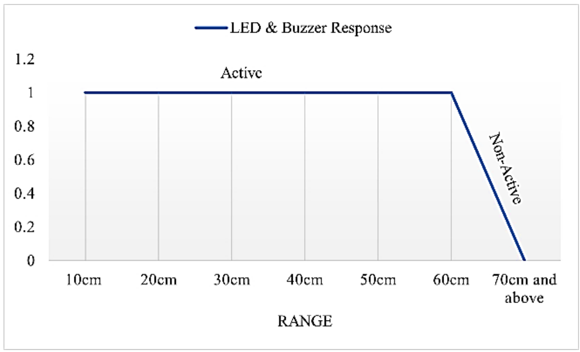

Figure 18. Graph showing active and non-active region of wireless AC detection.

V. DISCUSSION OF RESULTS

From the tests and results observed, the Ultrasonic Sensor can only be functional within the range of 0cm – 50cm. Any range above that, the Ultrasonic Sensor will not detect any obstacle. In addition, obstacles in the front, left, and right directions of the Ultrasonic Sensors give out random output signals. So, the visually impaired person is advised not to be found in places where there can be obstacle in multiple directions.

Drawing from the feedback gotten from the Visually Impaired Person (Mr. Emmanuel Zwalnan), the weight of the wooden stick was considerably light but the length was very short for him to use, therefore, the device could be further improved in such a way it can be comfortable for different lengths of Visually Impaired Persons. “Usually, the length of the device is according to one’s discretion, he added”. He also suggested that a plastic stick could be implemented due to its lesser weight compared to the wooden.

It was further observed that the Visually Impaired Person was able to distinguish the different threats and their buzzing sounds very easily. He said that memorizing the different buzzing sounds from the device wasn’t an issue.

It was also observed that the buzzing sound was loud enough to be heard even amid crowds and for further modifications, a speaker or any other form of voice recognition method could be employed. He commended the technological approach to aid Visually Impaired Persons, especially in this age of technological advancement. He also advised that researches like this should be commercialized and made available to aid the navigation and confidence of Visually Impaired Persons within the society.

CONCLUSION

The idea of an Intelligent Navigation System for visually impaired persons has been designed and implemented. As the system is completely automated, it avoids manual errors and thus provides a degree of safety to visually impaired/blind persons. With this mechanism, the rate of blind people colliding with obstacles, falling ditches and water bodies and exposure to life threatening scenarios like electrocution because of contact with livewires will be greatly minimized. The presence of human guide, guide cane, watchdogs would be limited as independent navigation systems using the developed device. The design of various circuits within the system was based on the specifications determined from already established parameters in assistive navigation technology systems. The actual implementation of the system, test, observation, and analysis yielded excellent results conforming to the design predictions and the set objectives.

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