Online-Journals.org

iJOE International Journal of Online and Biomedical Engineering

iJOE | eISSN: 2626-8493 | Vol. 20 No. 8 (2024) | OPEN ACCESS

https://doi.org/10.3991/ijoe.v20i08.49343

PAPER

Development of a Prototype Global Positioning System Based Stick for Blind Patients

Ramesh Kumar[1], Mohammad Aljaidi[2](✉), Manish Kumar Singla[1], Anupma Gupta[1], Ahmed Mershed Alhomoud[3], Amjad A. Alsuwaylimi[4], Sami M. Alenezi[4]

[1]Chitkara University Institute of Engineering and Technology, Rajpura, Punjab, India

[2]Department of Computer Science, Faculty of Information Technology, Zarqa University, Zarqa, Jordan

[3]Department of Computer Science, Faculty of Computing and Information Technology, Northern Border University, Rafha, Saudi Arabia

[4]Department of Information Technology, College of Computing and Information Technology, Northern Border University, Arar, Saudi Arabia

mjaidi@zu.edu.jo

ABSTRACT

This paper presents a novel vision impairment assistive device to improve mobility and independence. This device consists of Arduino Nano microcontroller technology that powers the Satellite/GPS-based stick, which tracks and navigates in real-time. Arduino Nano's adaptability and compactness enable our portable, affordable white cane replacement. Satellite signals let the stick locate the user, compute the best routes, and provide aural navigation cues through speakers or headphones. The obstacle detection sensors notify users of adjacent risks, improving safety. The proposed device is a stable and user-friendly technology that delivers a potential answer to visually impaired navigation issues after rigorous development and testing.

KEYWORDS

blind stick, Arduino Nano, satellite/global positioning system (GPS), lithium-ion battery

1 INTRODUCTION

Nowadays, the social development of blind people relies less on visual cues, such as touch, hearing, and descriptive language. They excel at using nonverbal cues like tone of voice and body language. Social interaction can be fostered through games designed for tactile or auditory input, building confidence and fostering strong connections [1]. The proposed work is inspired by the challenges faced by visually impaired individuals in navigating and experiencing their surroundings [2, 3]. They often have limited interaction with their environment and struggle to move independently [4, 5]. The main goal is to develop an efficient navigation aid, in the form of a smart walking stick that empowers them with a sense of "vision" by providing information about their surroundings and nearby objects. While the current smart walking stick is a simple and portable combination of mechanical and electronic components for obstacle detection, its effectiveness is limited by its size, production cost, and design and assembly time [6].

Kumar, R., Aljaidi, M., Singla, M.K., Gupta, A., Alhomoud, A.M., Alsuwaylimi, A.A., Alenezi, S.M. (2024). Development of a Prototype Global Positioning System Based Stick for Blind Patients. *International Journal of Online and Biomedical Engineering (iJOE)*, 20(8), pp. 21–36. https://doi.org/10.3991/ijoe.v20i08.49343

Article submitted 2024-02-03. Revision uploaded 2024-03-19. Final acceptance 2024-04-02.

Vision plays a crucial role in how we gather information from the world. This information is then processed by the brain. Unfortunately, individuals with visual impairments face significant challenges in their daily lives and social interactions due to the loss of sight. This condition, affecting millions of people globally, can range from partial vision loss to complete blindness [7]. As a result, the demand for assistive devices remains ever-present, aiming to support individuals with visual impairments in navigating their lives. While a variety of navigation systems and tools are available to support individuals with visual impairments, the need for solutions that effectively detect and identify obstacles remains a critical area for continued development. Individuals with visual impairments face challenges in interacting with and experiencing their surroundings. Their ability to move independently and engage with their environment is often limited. While the traditional white cane remains the most widely used tool for navigation, it has limitations in detecting all types of obstacles and potential dangers [8, 9].

This work presents a novel assistive stick designed to aid blind and visually impaired individuals in independent navigation and mobility. The key contributions of this research are as follows:

- **i)** Design and development of a portable, low-cost smart cane prototype that integrates Global Positioning System (GPS) technology and obstacle detection sensors.
- **ii)** Implementation of an Arduino Nano microcontroller as the core computing unit, leveraging its compact size, low power consumption, and ease of programmability.
- **iii)** Real-time tracking and navigation capabilities enabled by GPS allow the smart cane to determine the user's location, plan optimal routes, and provide audio guidance through speakers or headphones.
- **iv)** Incorporation of obstacle detection sensors to enhance user safety by alerting them to potential hazards in their immediate surroundings, reducing the risk of collisions or falls.
- **v)** User-friendly interface and operation, ensuring the device is accessible and easy to use for individuals with varying levels of technical proficiency.
- **vi)** Extensive testing and evaluation of the prototype, demonstrating its reliability, accuracy, and effectiveness in assisting blind and visually impaired users during indoor and outdoor navigation tasks.
- **vii)** Presentation of a cost-effective solution that addresses the mobility challenges faced by blind and visually impaired individuals, promoting greater independence and improved quality of life.

This research contributes to the field of assistive technologies for individuals with disabilities, specifically addressing the navigation and orientation needs of the blind and visually impaired community. The developed prototype offers a promising foundation for further refinement and commercialization, potentially improving accessibility and inclusivity in various environments.

2 LITERATURE REVIEW

The blind stick, also known as a white cane, is an essential mobility aid used by many blind and visually impaired individuals. Traditionally made of lightweight materials like aluminum or fiberglass, the blind stick helps detect obstacles and dropoffs in the path ahead through subtle tapping motions. Basic white canes are rigid and straight, while longer varieties can fold up for easier transportation. More advanced models may incorporate technologies like sensors or GPS to further aid navigation [6]. Properly using a blind stick requires specialized training to interpret the cane's inputs and navigate safely. Despite its simple design, the white cane allows many visually impaired people to travel independently with increased confidence and freedom. It has become one of the most recognizable symbols of blindness and visual impairment around the world.

In order to develop a comprehensive and effective Smart Stick for the Blind using Arduino Nano, a thorough literature review is crucial. This review involves studying relevant research related to the project, allowing for a deeper understanding of the technical aspects involved. This chapter serves as an introduction to the research area by presenting a concise analysis of existing solutions and identifying key challenges related to providing smart electronic aids for blind people. These aids aim to offer features like artificial vision, object detection, and real-time assistance through the use of Arduino technology [11, 12].

3 THEORETICAL BACKGROUND

The proposed system consists of four functional modules i.e. Ultrasonic Sensor, Microcontroller, GPS Module and GSM Module. All the components are described below.

A) Ultrasonic Sensor

Ultrasonic sensors utilize sound waves beyond human hearing range (ultrasonic) to measure the distance of objects. They work by emitting these sound waves using piezoelectric crystals in a transmitter and then detecting the reflected sound with a receiver. Since the speed of sound is known, the sensor can calculate the distance to the object based on the time it takes for the sound to travel back and forth [13]. Afterward, to determine the distance between the sensor and the object, the sensor measures the time it takes for the sound wave to travel from the transmitter, bounce off the object, and return to the receiver. This round-trip travel time is then used in the following formula to calculate the distance, as per Figure 1.

$$D = \frac{1}{2} T \times C \quad (1)$$

Where, D is the distance,
T is the time,
C is the speed of sound ~ 29 meters/second.

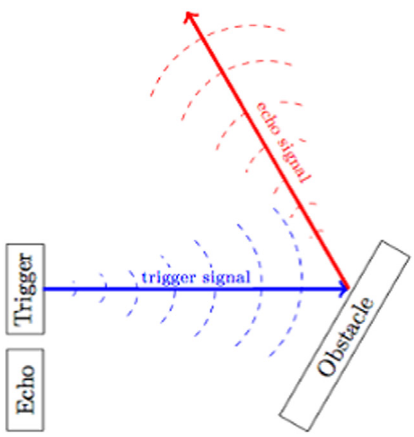

Fig. 1. Working of ultrasonic sensor

B) Microcontroller

The Arduino Nano, designed by Arduino.cc, is a compact and versatile microcontroller board built around the same Atmega328 microcontroller as the Arduino Uno. Unlike the Uno, the Nano lacks a dedicated power jack, opting instead for a mini USB port for both power and programming. While similar in functionality to the Arduino Duemilanove, the Nano's smaller size and USB-powered design make it a popular choice for projects requiring a more portable form factor [14].

C) GPS Module

Imagine a network of over 30 satellites constantly circling Earth, each broadcasting its location like a celestial lighthouse. The phone's GPS receiver picks up these signals and, by measuring the distance to at least four of them, can pinpoint your exact location on Earth, such as shown in Figure 2.

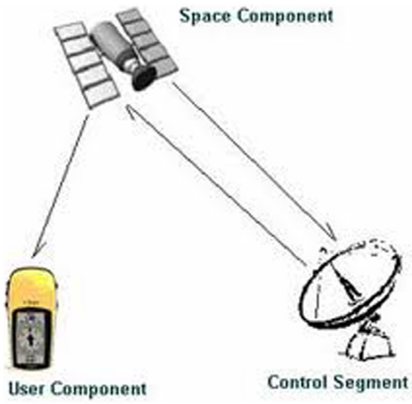

Fig. 2. Working of GPS module

GPS is a system. It's made up of three parts: satellites, ground stations, and receivers. Satellites act like the stars in constellations, also know where they are supposed to be at any given time. Ground stations continuously verify the position of GPS satellites using radar, ensuring their accuracy. Meanwhile, receivers in devices like phones or car navigation systems actively search for signals from these satellites. By measuring the distance to several satellites, and calculating the distance to at least four of them, the receiver can pinpoint your precise location on Earth [15].

D) GSM Module

This specially designed GSM module enables wireless radiation monitoring via SMS. It connects to radiation monitoring instruments like survey meters and area monitors, collecting their data, such as shown in Figure 3. The module then transmits this data as text messages (SMS) to a central server for remote monitoring and analysis.

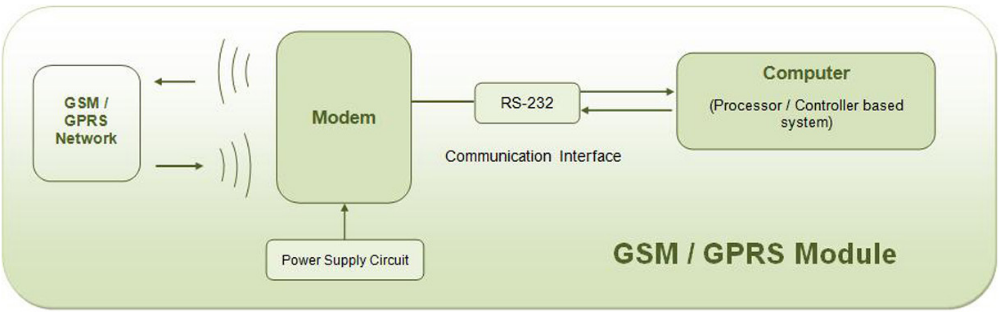

Fig. 3. Working of GSM module

4 DESIGN METHODOLOGY

In this section, the block diagram is of smart blind stick using Arduino. The block diagram of our project is given below. The Li-ion battery gives the constant 3.7 V supply and the power bank module connected with this battery steps up the voltage to 5 V. Here we have used two Arduino Nano. And the DC 5 V is supply is given to the two Arduino Nano boards separately. All the sensors are interfaced with Arduino Nano-1 and Arduino Nano-2.

A) Block Diagram

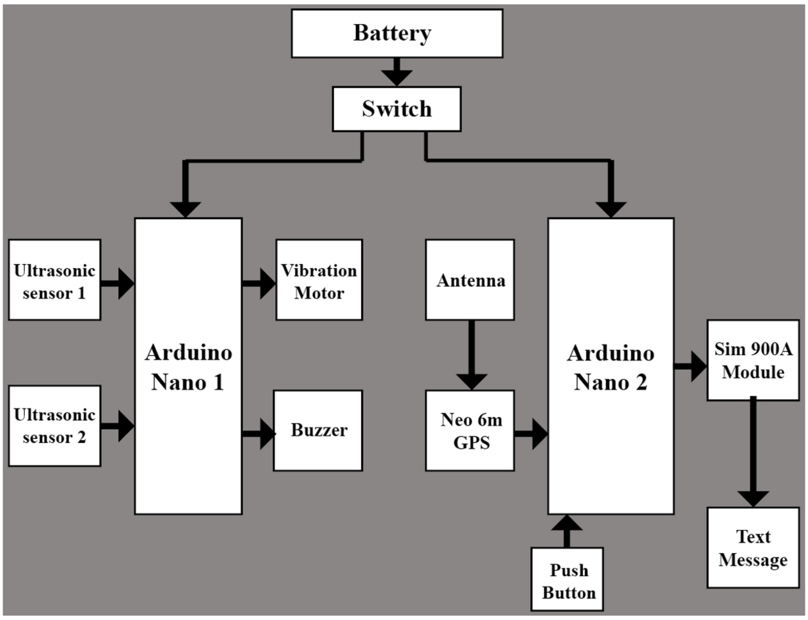

Fig. 4. Block diagram of the proposed model

The two ultrasonic sensors are connected to Arduino Nano-1, which processes this data and calculates if the obstacle is close enough. If the obstacle is close enough, Arduino Nano-1 sends a signal to vibrating motor and buzzer. The GPS module calculates the location and the GSM module sends SMS to the number that is stored in the microcontroller, such as shown in Figure 4.

B) Algorithm for Arduino Nano-1

Step-1: Switching on the Li-ion battery to regulate 5 V supply to the circuit.

Step-2: The ultrasonic transmits a high frequency pulse and receives the signal echo to reflect back. It interfaces with the microcontroller board.

Step-3: The microcontroller then calculates the distance between the object through the signal received from ultrasonic sensors.

Step-4: If the distance is less than or equal to 100 cm, the vibration motor will start to vibrate.

C) Algorithm for Arduino Nano-2

Step-1: The ceramic antenna of Neo 6M (GPS module) receives continues signal from the satellite.

Step-2: The Neo 6M (GPS module) then sends the data continuously to the microcontroller-2.

Step-3: At the pull up condition, the microcontroller sends the message to the receiver through SIM 900A (GSM module).

D) Flow Chart

The proposed device consists of the two Arduinos, one for Nano-1 and the other for the Nano-2 controller. The Neno-1 Arduino is used to measure the distance for blind patients. Nano-2 Arduino is used for the location through the GPS module. Both algorithms of this device have been shown in the flowchart, such as shown n Figure 5. (A) Flowchart for Arduino Nano-1, and (B) Flowchart for Arduino Nano-2.

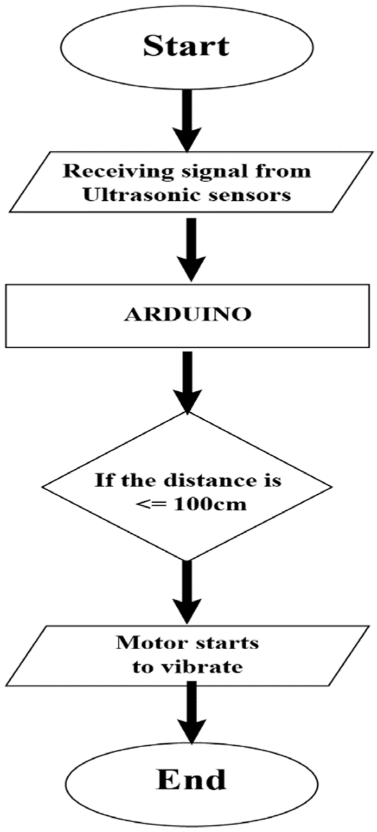

Fig. 5a. Flowchart for Arduino Nano-1

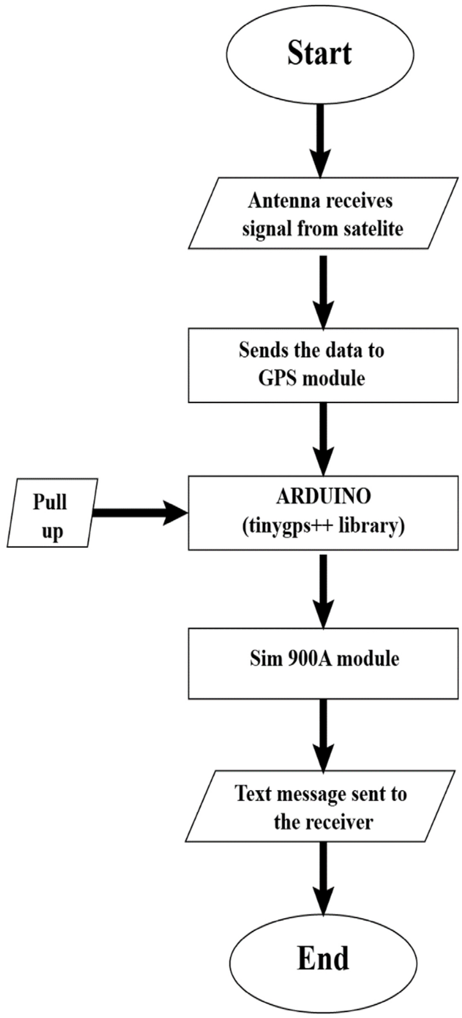

Fig. 5b. Flowchart for Arduino Nano-2

5 DESIGN & IMPLEMENTATION

It delves into the intricate design of each component within the proposed smart blind stick model. It details the specific parts used and their functionalities. Each section comprises various components meticulously connected to generate the intended output. For reference, a complete circuit diagram, serving as the blueprint for fabrication, is provided at the end. Notably, meticulous attention was paid while constructing the circuit to ensure proper connections between each component [16].

A) Arduino Nano Microcontroller

The Arduino Nano, a compact version of the Arduino Uno, packs the same connectivity but in a smaller size. This sustainable and versatile microcontroller board utilizes either the ATmega328P or ATmega628 microcontroller [10]. Like the Uno, it can be programmed using the Arduino Integrated Development Environment (IDE), compatible with various platforms [13]. To get started with the device, the Arduino IDE software is installed and a Mini USB cable transfers code to the Nano board as shown in Figure 6.

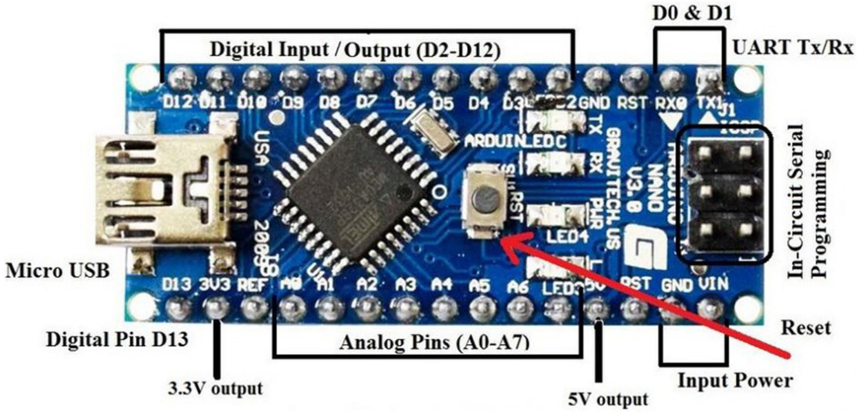

Fig. 6. Arduino Nano

B) HC-SR04 Ultrasonic Sensor

An ultrasonic sensor as shown in Figure 7, unlike traditional distance sensors that use light or lasers, relies on high-frequency sound waves inaudible to the human ear. These sound waves, emitted by a transmitter within the sensor, bounce off objects and are detected by a receiver. By measuring the time it takes for the sound wave to travel to the object and back, the sensor calculates the distance between itself and the object. The device typically has four connection points: Vcc for power, ground, trigger to initiate a measurement, and echo to receive the reflected sound wave.

Fig. 7. Pin description of ultrasonic sensor

C) NEO 6M (GPS Module)

The Global Positioning System (GPS) is a network of satellites that provides free location and time information to anyone with a receiver and a clear view of at least four satellites. By precisely measuring the time it takes for signals to travel from the satellites, a GPS receiver can pinpoint its location. This technology has become ubiquitous, integrated into most smartphones. The GTPA010 module simplifies using GPS by offering both RS232 and USB connections. It operates on a flexible power range of 3.2 to 5 volts, making it compatible with both 3.3 V and 5 V microcontrollers. Most importantly, the module outputs GPS data in a widely used format called NMEA0183. This format uses messages starting with a dollar sign ("$") followed by an identifier, with commas separating each piece of data. This makes it easy to parse and extract the desired information.

Fig. 8. Neo 6M (GPS module)

D) SIM 900A (GSM Module)

GSM, short for Global System for Mobile communication, is the foundation of most mobile networks worldwide. It provides the basic framework for voice calls and text messages. GPRS, or General Packet Radio Service, builds upon GSM by enabling faster data transfer, similar to what you experience on your phone when using the internet. A GSM/GPRS module combines a modem (modulator-demodulator) with the necessary electronics to connect to your computer. It typically offers communication options like USB or serial ports, similar to how you connect a printer or other device. Just like a mobile phone, it also requires a SIM card to identify itself on the network and establish communication as shown in Figure 8.

1. Receive, send or delete SMS messages in a SIM.
2. Read, add, search phonebook entries of the SIM.
3. Make, receive, or reject a voice call.

Fig. 9. SIM 900A (GSM module)

E) Lithium-Ion Battery

The 18650 battery as shown in Figure 9, named for its dimensions of 18 millimeters in diameter and 65 millimeters in length, is a type of rechargeable lithium-ion battery. These batteries are popular in electronics like laptops and flashlights, and even power electric vehicles due to their high energy storage, long lifespan, and slow self-discharge. Some 18650s have additions like a button top or built-in protection circuits, which can slightly increase their length beyond the standard 65 mm. For our project, we specifically used 4200 mAh capacity batteries (shown in Figure 10), offering an operational range exceeding 24 hours.

Fig. 10. Li-ion battery

F) Vibration Motor

Unlike a smooth-running motor, a vibration motor is designed with an unbalanced weight attached to its rotating shaft. This off-center weight creates a wobble, or vibration, as the motor spins. The strength of this vibration can be adjusted by changing the weight's mass, its distance from the shaft, and the motor's speed. This unique design makes vibration motors ideal for various applications, as they can be attached to objects to cause them to vibrate and even move freely (Shown in Figure 11).

Fig. 11. Vibration motor

G) White Cane

The white cane is a crucial tool for many who are blind or visually impaired. It serves two primary functions (Shown in Figure 12).

1. **Navigation:** By sweeping the cane across their surroundings, users can detect obstacles and orientation markers, allowing them to navigate safely.
2. **Identification:** The white color helps others recognize the user's visual impairment, prompting them to offer assistance or be extra cautious.

This specific cane is:

- **Portable:** Made of lightweight aluminum, it folds and unfolds easily for convenient storage in your bag.
- **Durable:** Constructed with high-quality materials, it can withstand daily use.
- **Visible:** Reflective tape on the shaft enhances nighttime visibility, and the 48.82-inch length provides good reach.
- **Secure:** The hook-style tip ensures a firm grip on the ground, secured with an elastic cord.

Fig. 12. White cane

6 HARDWARE IMPLEMENTATION

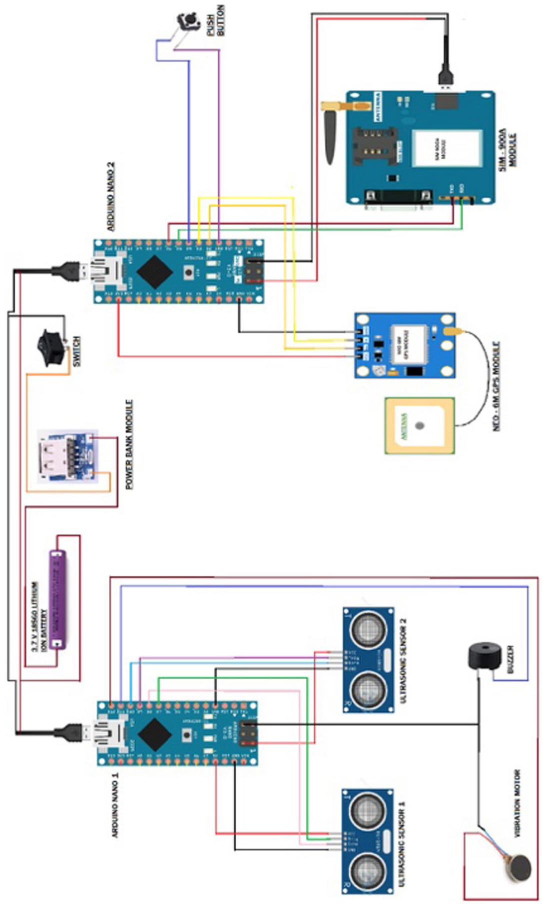

Fig. 13. Circuit diagram for the proposed model of smart blind stick

The circuit consists of 2 Arduino Nanos, 2 ultrasonic sound sensors, a Li-ion battery, power bank module, a switch, a buzzer, a vibration motor a GPS module and a GSM Module. The Li-ion battery gives constant 3.7 V supply and the power bank module connected with this battery steps up the voltage to 5 V as shown in Figure 13. Here we have used two Arduino Nanos. And the DC 5 V is supply is given to the two Arduino Nano boards separately. All the sensors are interfaced with the Arduino Nano-1 and Arduino Nano 2. The two ultrasonic sensors are connected to Arduino Nano-1 which processes this data and calculates if the obstacle is close enough. This circuit provides a stable 5-volt power supply to the system, ensuring consistent operation. It's commonly used in object detection projects with ultrasonic sensors. When an object is present, the sensor measures the distance between it and the user and sends this data to the Arduino Nano. The distance is calculated by measuring the time it takes for a sound wave to travel to the object and back.

$$\text{Distance} = \text{speed} * \text{time}$$

The speed of the sign going through air is 341 m/s. The time is determined between conveying and getting back the message. Since the distance traveled by the signal is double, it is divided by two i.e.

$$\text{Distance} = * \text{Distance}/2$$

It is located on the upper side and the lower side of the stick to detect the object. Arduino measures with this information and computes with the order conditions. If any object is found nearer, it sends the command to the user through the vibrating motor.

The second Arduino board is powered by a 3.7 V battery boosted to a constant 5 V using a voltage regulator. The first ultrasonic sensor also operates on 5 V power, with its Trigger and Echo pins connected to Arduino Nano pins A7 and A8, respectively, as shown in the circuit diagram. Similarly, the second ultrasonic sensor connects to Trigger 2 and Echo 2 on Arduino Nano pins A9 and A10.

The system's output is delivered through a vibration motor and buzzer, both connected to pin 12 of Arduino Nano-1.

The GPS module utilizes a 3 V power supply with its ground pin connected to the common ground. Its Trigger pin connects to pin 2 of Arduino Nano-2, while the Echo pin connects to pin 3.

Finally, the GSM module receives 5 V power with its ground pin grounded. Its Trigger pin connects to pin 5 of Arduino Nano, and its Echo pin connects to pin 6.

In case on emergency when the push button is pressed, this is the pull up condition and the Arduino Nano receives the signal 0 from, which means that it will send the data of that distance to the receiver through Sim900A (GSM module) in the form of a text message. Figure 14 below shows the fabrication of model of smart blind stick.

Fig. 14. Fabrication of model of smart blind stick

7 RESULTS & DISCUSSIONS

The proposed stick is equipped with a functional hardware model for obstacle detection when it encounters any line society people. The proposed blind stick model can assist the user who is virtually disabled by guiding them through various obstacles and terrains. The main benefits are that it is inexpensive, responds quickly, uses little power, is lightweight, and can receive input via an audio buzzer. In addition to using ultrasonic sensors to detect obstacles, it may notify the user by vibrating and sounding a siren while holding it in place. Also, to identify the location through GPS, which is also defined as the way or intimation about the direction of the route for blind people. Additionally, it has a feature that makes communicating in an emergency easier.

The proposed stick is performed as a simple experiment to detect obstacles and calculate the distance. A sensor was used for calculating the distance of the obstacles. Also, a simple analysis was used to assess the error perceentage with respect to the material of oobstacles. In this experiment, many materials are used as per the different obstacle, such as shown in Table 1 and Figures 15 and 16.

Table 1. Identification of distance according to materials

S. No.	Obstacles Material (cm)	Range (cm)	Average (cm)	Standard Deviation	Variance	Error
1	Human	50	45.5	2.66	7.09	42.5
2	Wall	180	175	3.38	11.47	68.6
3	Wood	150	147.5	3.53	12.5	12.5
4	Water	110	105	4.46	22	66
5	Stone	200	193	6.46	41.8	167
6	Plastic	180	175	3.36	13.6	53
7	Tree	140	138	2.86	11.86	62.3
8	Metal	120	108	3.56	12.02	58.23
9	Soil Object	180	174	3.23	12.99	53.3
10	Animal	51	48	2.22	7	41.23

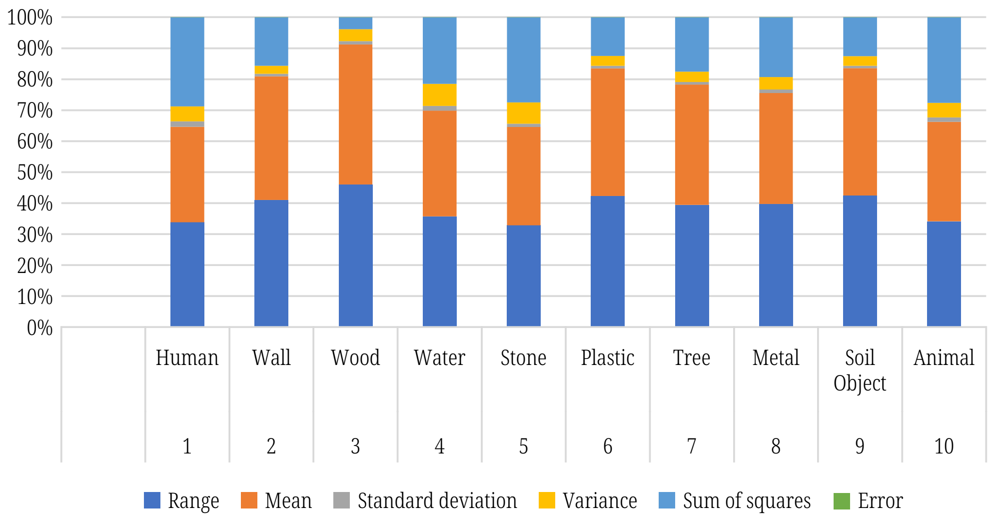

Fig. 15. Materials obstacle analysis in bar graph

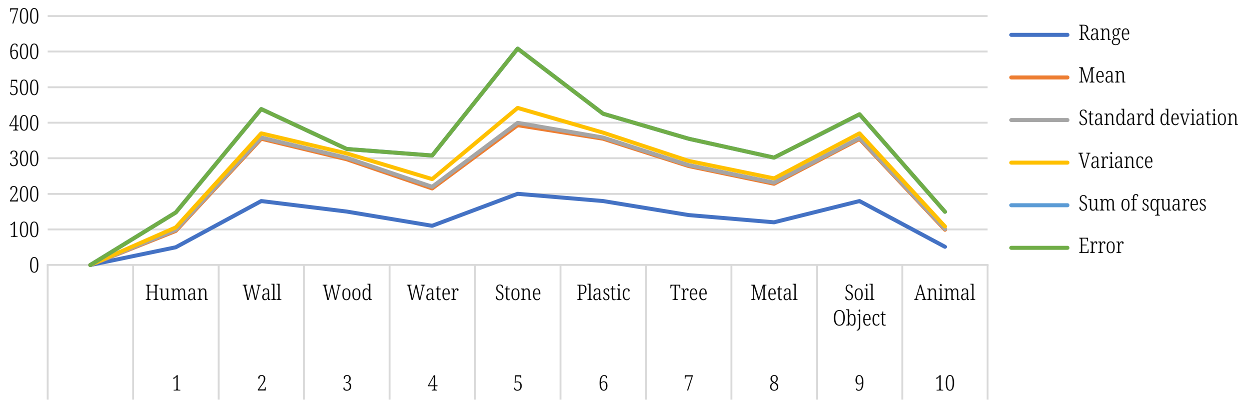

Fig. 16. Materials obstacle analysis in line graph

The system includes a buzzer, vibrator, and emergency alert functionality. Upon being assigned to the starting area, the timer initiates for each participant and stops once they complete the designated route. Table 2 outlines the various signals used to indicate the presence of obstacles, varying terrain conditions, and water hazards along the course.

Table 2. The blind stick process

S. No.	Distance	Used Sensors with Detection View	Signal Process	Response
1	≤80	Ultrasonic Sensor with direct detection	Vibration + Alarm	Fast
2	≤80	Ultrasonic Sensor with miner obstacle	Vibration + Alarm	Medium
3	≤80	Ultrasonic Sensor with water detection	Vibration + Alarm	Slow
4	≤80	Ultrasonic Sensor with moving object	Vibration + Alarm	Slow
5	≤80	Ultrasonic Sensor with stable detection	Vibration + Alarm	Fast
6	≤80	Ultrasonic Sensor sudden detection	Vibration + Alarm	Slow

Additionally, some users' mobility speed exceeded the allotted time frame, while others struggled to accurately differentiate between the various warning signals corresponding to obstacles, terrain variations, or water hazards detected along their path, likely attributable to their initial system exposure. The sighted partners faced challenges tracking their blindfolded counterparts, stemming from unfamiliarity with advanced mobile device usage or inconsistencies in app utilization. These factors underscore the need to enhance training sessions for improved user experience, such as shown in Table 3.

Table 3. Volunteer response

User No.	Time Response	Alarm	GPS	Location	Map	Tracking Voice	Emergency Features
1	5.6s	Yes	Yes	No	Yes	Yes	Yes
2	6.5s	Yes	Yes	No	No	Yes	No
3	6s	Yes	Yes	Yes	No	No	No
4	5.1s	Yes	Yes	Yes	Yes	Yes	No
5	7.3s	Yes	Yes	Yes	Yes	Yes	Yes
6	7s	Yes	Yes	Yes	No	Yes	No
7	6.0s	Yes	Yes	Yes	No	Yes	Yes
8	7s	Yes	Yes	Yes	No	No	No

In the future, the proposed model can be modified in better ways, initiating with the addition of a Bluetooth module for proper on and off functioning. A GPS module will be integrated for detecting the user's location in case of an emergency. The GPS module will be integrated in combination with the Bluetooth Module of an Arduino Nano, connecting it to a mobile phone for better and smoother location detection. Besides, a soil moisture detector can be implemented for detecting the amount of moisture in the soil, providing safer access along paths for the user. Lastly, to improve sound notifications, a sound module will be implemented which will give instructions in voice form. The stick system presented uses artificial intelligence along with various sensors in real-time to help visually disabled people navigate their environment independently. Image recognition, collision detection, and obstacle detection are the three tasks performed by the system.

8 CONCLUSION

This work introduces a novel design for a smart electronic guiding stick aimed at assisting visually impaired individuals. This stick would help them navigate various terrains and avoid obstacles, enhancing their independence and safety. One key advantage is its potential to be a highly affordable solution for millions of blind people worldwide. By combining different components, the system offers real-time user location monitoring and provides dual feedback navigation, making it more reliable and secure. Furthermore, the stick has the potential for future improvements. Integrating a wider range of sensors could equip it with enhanced decision-making capabilities, making it suitable for diverse applications. Ultimately, this project strives to address the challenges faced by blind individuals in their daily lives and contribute to their overall well-being.

9 ACKNOWLEDGEMENT

The authors extend their appreciation to the Deanship of Scientific Research at Northern Border University, Arar, KSA for funding this research work through the project number "NBU-FFR-2024-1182-01". The authors also extend their appreciation for filing the Japanese Utility Model Patent, Application Number: 2024-000986.

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11 AUTHORS

Ramesh Kumar, Chitkara University Institute of Engineering and Technology, Rajpura, Punjab, India (E-mail: rameshkumarmeena@gmail.com).

Mohammad Aljaidi, Department of Computer Science, Faculty of Information Technology, Zarqa University, Zarqa, Jordan (E-mail: mjaidi@zu.edu.jo).

Manish Kumar Singla, Chitkara University Institute of Engineering and Technology, Rajpura, Punjab, India (E-mail: manish.singla@chitkara.edu.in).

Anupma Gupta, Chitkara University Institute of Engineering and Technology, Rajpura, Punjab, India (E-mail: anupmagupta31@gmail.com).

Ahmed Mershed Alhomoud, Department of Computer Science, Faculty of Computing and Information Technology, Northern Border University, Rafha, 91911, Saudi Arabia (E-mail: ahmad.alhomoud@nbu.edu.sa).

Amjad A. Alsuwaylimi, Department of Information Technology, College of Computing and Information Technology, Northern Border University, Arar, Saudi Arabia (E-mail: amjad.alsuwaylimi@nbu.edu.sa).

Sami M. Alenezi, Department of Information Technology, College of Computing and Information Technology, Northern Border University, Arar, Saudi Arabia (E-mail: sami.m.alenezi@nbu.edu.sa).