Smart Ultrasonic Walking Stick with Voice Guidance for the Visually Impaired

Dr Velayudham A [1], Haswanth S S [2], Hariharan P [2], Hariprasath S [2], Dhivakar M [2]

[1]*Professor & Head, Department of C.S.E, Jansons Institute of Technology, Coimbatore, India*[1]

[2,3,4,5] *UG Students, Department of C.S.E, Jansons Institute of Technology, Coimbatore, India*[2]

***Abstract*—The Blind Stick Robot is a high-tech mobility aid that was created to improve the movement and safety precautions taken by blind people. The traditional white cane has low capabilities because it can only give some touch information for any hindrance. Nevertheless, such canes lack the ability to alert users before times of hazards or help in communication during emergencies like wet floors. With the advancement in technology, there has been an increased use of intelligent devices such as sensors and communication modules which are all aimed at ensuring that the user gets everything, he needs from the environment around him in an efficient way. The incorporation of IoT technologies into this inventive aid is intended to promote self-reliance and positivity among visually impaired persons.**

The essentiality of this intelligent Stick lies under the ESP32 micro-controller which acts upon various input signals, processes data, and communicates messages properly. It includes a sensor that uses sound waves to determine if there are any obstacles ahead of someone moving with the stick (HC-SR04). This feature helps in the real-time processing of information so that users may easily follow through the provided audile cues and move with confidence even in unknown areas. Also, an additional sensor for detecting the presence of water has been included for identifying slippery surfaces hence improving user security by giving alerts on risky environments.

Another important aspect inherent in this innovation is the fact that it speaks; it possesses voice guidance facilitated using some equipment. A combination of these devices with the inclusion of GPS module (NEO-6M) and GSM communication kit (SIM800L) allows for location tracking as well as emergency alerts by the stick. When there is danger around them, they will be able to act by either sending SOS messages or calling particular numbers which will assure them of getting quick help when required most. These functionalities boost its support to users especially in new or hostile environment. It utilizes power from a 12V lithium-ion battery which is not only light but also durable thus making its energy efficient. This design incorporates an LM2596S voltage regulator for maintaining uniform voltages across all parts of the system. As a result, this effective power system not only increases the stick's working hours but also makes it reliable everywhere.

I. INTRODUCTION

Safe and independent movement is very important in our day-to-day living. The Blind Stick Robot has been designed for this reason, as it comprises certain features that help in addressing some of these issues. For instance, the device is able to detect any impediment on its way due to the sensors contained in it. Also, it can be used to send out distress messages when there is an emergency.

The core operations of the smart stick rely on input data analysis by ESP32 microcontrollers obtained through sensors and communication modules. An ultrasonic sensor (HC-SR04) is used to determine distances by emitting ultrasonic waves that bounce off nearby objects; this can then be relayed through noises or words if necessary for safety measures taken seriously by those around us too! On top of that, detecting whether floors are more slippery than usual could now also easily done using newly added technology called “water detection sensors.” To make navigation easier and more comfortable, there is a voice guide in the Blind Stick Robot. It consists of three main parts: a speaker, a recorder (ISD1820), and a microphone – everything one may need for providing audible signals concerning obstacles around, the direction of movement at the moment as well as any other vitally important data during the navigation process itself! GPS (NEO-6M) and GSM (SIM800L) modules have also been included for tracking position in real-time and sending out distress calls/messages when such need arises from users' end side hence making sure that timely help can easily reach them when required. Designers consider energy consumption very important while developing this project Smart Stick Robot. The power system depends on a 12V LiFePO4 battery which is light; hence it has high energy density with low self-discharge rate thereby ensuring a longer lifespan of your device. It also includes an LM2596S voltage regulator that evenly supplies power to all units prolonging its activities under various conditions across any place where one may find himself or herself at a given moment.

The main goal of the Blind Stick Robot is to provide a sophisticated, user-friendly solution for all. It can be carried easily because it is light and portable hence; this enables the users to move with them from one point to another in the course of their daily activities. Also, it does not burden users much as they do not have to think too hard about using it, and includes some kind of sound that helps them know where they are going so that they can move about with ease and without fear or doubt.

In addition to its primary function, the Blind Stick Robot can also work with smartphone applications and other IoT platforms for monitoring purposes as well as offer additional personalized navigation aid options. If such progressions were made, then it would improve what the device can do and create space for custom-made assistive devices for blind people in the future.

II. RELATED WORK

In the last few years, many researchers have been interested in creating tools that can help people who cannot see well. A lot of research as well as technological advancement has been focused on developing ways to enhance movement, security as well and self-reliance issues among this population. Over the years, various studies and technologies have been developed aimed at enhancing the mobility, safety and independence of visually impaired individuals. First of all, it is important to mention some related works that were essential for the creation of intelligent moving devices for blind people and then discuss what hi-tech features were integrated into Blind Stick Robot.

III. METHODOLOGY

A. Ultrasonic Sensor-Based Smart Walking Sticks:

The efficiency of ultrasonic sensors in helping blind individuals sense hurdles has been proved through various academic undertakings. In their work, Singh et al. (2021) made a stick for the blind with ultrasonic sensors that could sense if there is any obstacle three meters from them. This stick was designed in such a way that it could provide information to the user about the presence of any obstacles. On their part, Kumar and Sharma (2022) came up with a model having several ultrasonic sensors for identifying blocking at different positions. Although these systems enhanced obstacle detection, they had some weaknesses in terms of environmental factors like high rainfall or crowded places.

B. Water Detection Systems in Assistive Devices:

The safety of visually impaired people is greatly compromised by smooth surfaces. According to Chen et al. (2020), an exploration was done on how effective are the water detection sensors when incorporated into the mobility aid for preventing slip accidents. The device they developed could identify wet surfaces by taking conductivity measurements, and it would vibrate to warn the user of an impending slip on such surface. Nevertheless, the solution could not effectively tell apart harmless dampness from unsafe spilt moisture.

C. Voice Assistance Technologies for Navigation:

In a study done by Ali et al. (2019), it was found that voice guidance systems are very crucial in making assistive tools more usable. The results indicated that among visually impaired users, real-time audio feedback was much better at helping them navigate than either the tactile/vibration-based systems.

D. Proposed System Overview:

An innovative assistive device called The Blind Stick Robot was created in order to conquer the weaknesses of the usual walking stick which is meant to help blind people alone. The device is made up of certain features such as immediate obstacle identification, a GPRS system, an emergency call facility by GSM technology, and spoken instruction packaged into an intelligent and compact user-friendly approach. This project intends to offer visually impaired individuals' better ways of moving around safely on their own; hence it should provide them with a comfortable travelling experience.

Through this proposed system, the blind stick robot takes advantage of up-to-date IoT systems and effective power management units for consistency both indoors and outdoors. Equipped with sensors, communication modules, microcontrollers, etc., it can sense the environment around it just like humans do in order to follow a particular direction while keeping track of any upcoming dangerous situation for the users.

IV. EXISTING SYSTEM

In the past, visually impaired people used to move around by using simple things like white sticks, and guide dogs which would help them know where they are going. Although these have been helpful, they only offer limited help because they cannot work well in every environment. With time, however, there has been progress in this area as can be seen by the evolution of simple gadgets into complex ones comprising; sensors, auditory feedback, and GPS among others. This part explores some of the available designs for assisting the blind in moving from one point to another with emphasis on what they can do, their weaknesses, and areas left for advancement. Be that as it may (despite all these), there are still a number of issues that continue to pose challenges even with the advancement in technology, and these

Include:

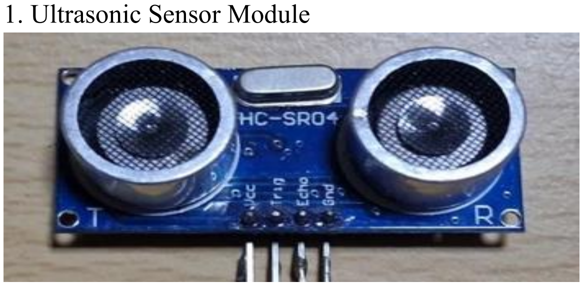
The systems lack wide area coverage as most of them can only identify obstacles that are very close without detecting those on the sides too.

Some devices do not have efficient ways of helping users send out distress calls when the need arises.

V. PROPOSED SYSTEM

A. Module Description:

1. Ultrasonic Sensor Module



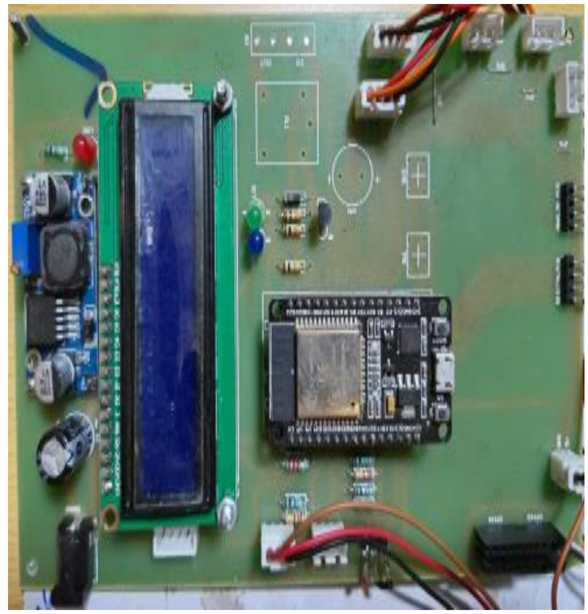
❖ Specifications:

- Operating voltage: 5V
- Range: 2 cm to 400 cm
- Resolution: 0.3 cm
- Accuracy: ± 3 mm
- Angle of Detection: Approximately 15 degrees

Details:

It detects any objects nearby which may obstruct the user. Real-time information is given to help avoid obstacles. The module sends distance data to the ESP32 so that it can decide when to warn about obstacles. The time difference between sending and receiving the signal allows the sensor to calculate the distance to an object with high accuracy.

2. ESP32 Microcontroller Module



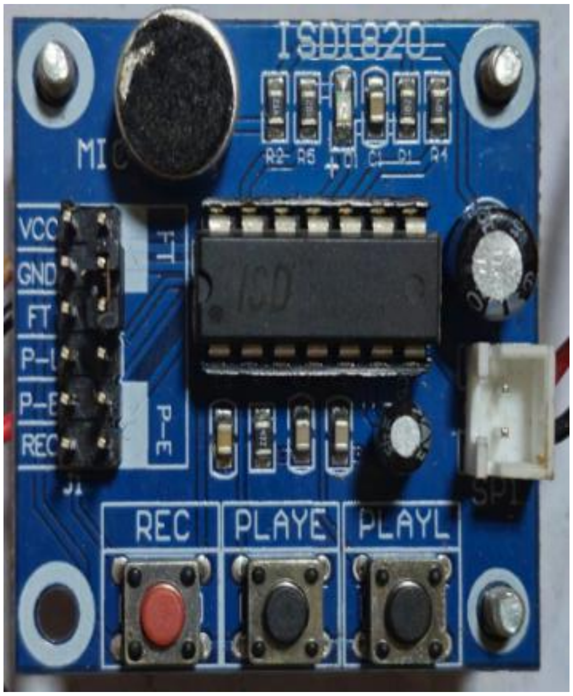
❖ Specifications:

- Processor: Dual-core Ten silica LX6 CPU, operating up to 240 MHz
- Memory: 520 KB SRAM
- Wi-Fi: 802.11 b/g/n
- Bluetooth: v4.2 BR/EDR and BLE
- Operating Voltage: 3.3V

Details:

The ESP32 is a powerful and versatile microcontroller that is meant to carry out various functions in the IoT environment. This Espresso Systems designed device has dual Ten silica LX6 microprocessors that can be controlled up to 240MHz and supports Wi-Fi 802. 11 b/g/n/e/i(2. 4GHz)/WPA/WPA2, Bluetooth/BLE, and other communication technology. The microcontroller also has many features that are important for wireless communication and processing at the periphery.

3. Voice Recording Module (ISD1820)



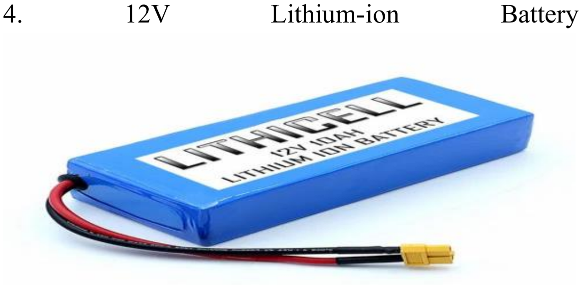
❖ Specification:

- Operating Voltage: 3V to 5V DC
- Maximum Recording Time: 10 seconds
- Audio Sampling Rate: 3.2 kHz (approx.)
- Microphone: Built-in Electret Condenser Microphone
- Storage: Non-volatile storage for audio

Details:

This is an audio recording module that is easy to use and can be easily integrated into embedded systems for various applications. It allows users to record, store, and play short sound bites or messages (not more than ten seconds long). To facilitate direct voice input, the onboard electret microphone is linked with auxiliary speaker output through amplifiers.

4. 12V Lithium-ion Battery



❖ Specifications:

- Voltage: 12V
- Capacity: 2200mAh to 5000mAh
- Charging Voltage: 14.4V
- Charging Current: 1A

Details:

To ensure that the wheelchair moves as expected and all the systems work efficiently, there is a 12V battery that powers them. The wheelchair movement as well as overall system function require certain energy which is provided by this 12V battery pack. The appropriate capacity of a battery should be determined depending on how long it is expected to be used.

5. Water Sensor

❖ Specifications:

- Operating Voltage: 3.3V to 5V DC
- Operating Current: ≤ 20 mA
- Sensor Type: Resistive
- Size: 60mm x 20mm

Details:

It operates through sensing of water contact between two parallel copper strips. The more strips are touched by water, the higher resistance is recorded by the sensor and therefore generates a linearly varying analog output voltage proportional to this value. Additionally, it produces digital outputs of either high or low depending on whether the water level exceeds a threshold determined by means of the associated potentiometer.

6. GPS Module (GY-GPS6MV2)

❖ Specifications:

- Receiver Type: 50-channel GPS receiver
- Operating Voltage: 3.3V to 5V

- Communication Interface: UART (TX/RX)
- Baud Rate: Default 9600 bps (adjustable)
- Antenna: External active antenna with high sensitivity
- Position Accuracy: ±2.5m
- Cold Start Time: < 38 seconds
- Hot Start Time: < 1 second

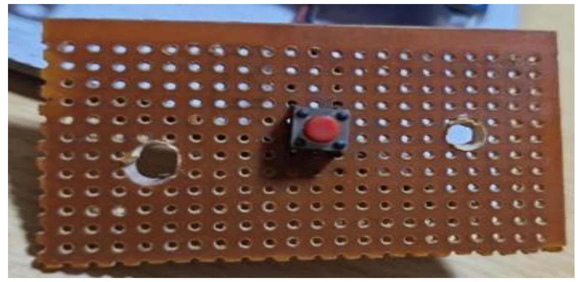
Details:
A high-quality GPS module referred to as GY-GPS6MV2 is applied in live tracking systems. This module communicates to the microcontroller and gives data about the position (latitude and longitude). The presence of an external active antenna improves signal reception thereby guaranteeing precise positioning. This device can be used to monitor wheelchair movements and communicate any changes in location during emergencies such as (i.e., Fall detection).

7. GSM SIM 800

❖ Specifications:
- Operating Voltage: 3.4V to 4.4V DC
- Operating Temperature: -40°C to +85°C
- Internet Connectivity: TCP/IP, HTTP, FTP
- SIM Interface: 1.8V / 3V SIM card support

Details:
GSM communications technology has found a new friend in the form of SIM800 GSM/GPRS modules which offer worldwide network coverage for data, SMS, voice, and MMS functionalities. Global System for Mobile Communication (GSM) / General Packet Radio Service (GPRS) technology-based devices are now possible thanks to quad-band feature inclusion into this module hence it can operate anywhere in the world due to its universal frequencies compatibility.

8. Emergency Button Module



❖ Specifications:
- Operating Voltage: 3.3V to 5V DC
- Switch Type: Push-to-make (normally open)
- Contact Resistance: ≤ 50 mΩ
- Insulation Resistance: ≥ 100 MΩ at 500V DC
- Mechanical Life: > 100,000 operations

Details:
This module is called an emergency button it is used in safety systems where immediate manual action may be necessary. It contains a big red push button that is very easy to see and press and typically covered with a bright red cap for visibility.

9. Connectors and Wires

❖ Specification:
- Voltage: Rated for 5V to 12V circuits
- Type: Jumper wires, DuPont connectors, JST connectors (depending on components)
- Insulation: PVC or Teflon insulation for durability

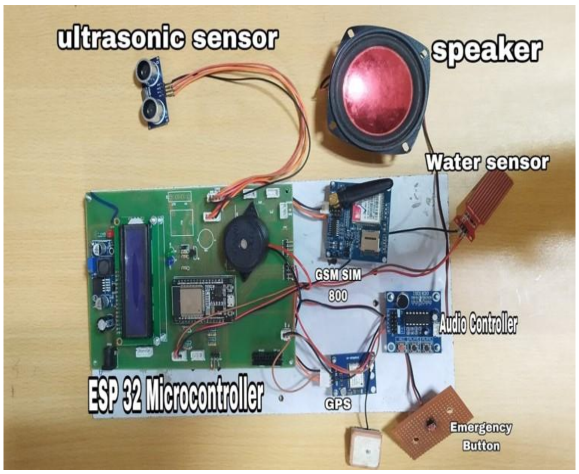
Details:
Wires and connectors are used for connecting various components, including motors, sensors, and controllers. Proper wiring ensures secure connections and avoids short circuits, ensuring the safe and stable operation of the system.

VI. METHODOLOGY:

Data gathered continuously by the sensors of the Blind Stick Robot is used in monitoring the environment. The system is composed of an ESP32 microcontroller which processes incoming data from various sensors such as ultrasonic, water detection as well and emergency push button sensors. The collected data makes it possible for the system to take appropriate measures like; giving out sound warnings, turning on GPS, and sending emergency messages via the GSM module.
It is independent and gives assistance without using

hands. The combination of a speaker with a voice recording module produces alerts while GPS and GSM modules help in determining location and sending emergency messages. A 12V lithium-ion battery powers the whole system and the LM2596S voltage regulator guarantees even distribution of power among all components.

VII. RESULT AND DISCUSSION



A. Obstacle Detection Performance:

With a range of 50 cm, obstacles were detected by the ultrasonic sensor (HC-SR04) in real-time. The audio alerts of the system facilitated timely responses that helped users steer away from hitting other objects such as walls, furniture, and pedestrians. From the test, it was noted that: It had a high accuracy in detecting stationary obstacles and very few false alarms.Although more improvements could be made to its sensitivity or additional sensors, it worked reasonably well in detecting moving obstacles.

B. Results of Water Surface Detection:

During testing, the wet and slippery surface detector worked effectively. Users would prevent entering dangerous places by receiving audio caution from the instrument concerning any change noted in surface properties or rather, its conductivity level. From the experiment, it was seen that: The sensor was able to detect all wet surfaces created by spilled liquids or rain water.On different floors like tiled or concrete floor, it did not fail at any point and performed consistently throughout.

C. GPS Tracking Reliability:

Observations from testing the NEO-6M GPS module outdoor performance indicated that it indeed gave accurate real-time position information as expected. Here is what we found out during the tests. The GPS coordinates were being updated fast with only slight deviations experienced within town areas due to construction. It had enough accuracy to determine the user’s location within several meters of distance.

D. Emergency Communication Functionality:

During the tests, the SIM800L GSM module was able to send SOS messages and make calls using distinct voice channels as intended. Emergency messages were delivered instantly to set numbers as planned. Voice calls went through clearly across different signal strengths on all tested networks used for communication.

E. Power Management Evaluation:

An extended evaluation period indicated that the 12V lithium-ion battery-powered system consumed power efficiently. LM2596S voltage regulator facilitated the equal distribution of stable power amongst devices connected to it. Testing The battery lasted for many hours without needing a recharge while in operation continuously for long periods. Efficient processing by the ESP32 microcontroller ensured low power consumption.

F. Feedback from Users regarding its Usability and Functionality:

Opinions were sought from people, particularly the visually impaired, on the usefulness of the Blind Stick Robot after which it was tested It turned out to be user-friendly as it is not heavy for them to lift and take with ease when walking using their hands just like on a stick alone; therefore, they could now travel solo even in very dark conditions. The device had an additional feature compared to the usual white stick and modern smart canes – Emergency Communication Functionality.

VIII. CONCLUSION

The Blind Stick Robot is an advanced and complete answer for the movement issues experienced by blind persons. It makes users be able to move around safely and at ease by incorporating some sophisticated features like ultrasonic obstacle detection, GPS tracking, water surface sensor, GSM-based emergency communication, and voice guide in the device. To operate in all environments well, there is proper power management done on the system as it is being handled or controlled using ESP32 microcontroller which is very effective. Its lightweight and ease of carriage allow for comfortable use indoors or outdoors. The positive outcome of putting this into practice and carrying out tests shows that it helps minimize navigation risks, increasing safety awareness as well as facilitating emergency assistance to disabled people. This equipment is efficient and friendly; hence it provides significant progress compared to the conventional means of transportation available for this group. Nevertheless, there are still many things left undone with all these accomplishments.

IX. FUTURE WORK

A. Wearable Module Integration:
Wearable modules including haptic belts, smart bands, or glasses could be added to the system. As a result, it will give vibration and visual/audio indication for navigation which will allow one to operate it without using hands.
B. Machine Learning for Intelligent Obstacle Recognition:
The Blind Stick Robot can be able to differentiate various obstacles which may include moving and still objects once integrated with machine learning algorithms. Specifically, it would be easier for the robot to know when there is a car nearby, or it is passing behind a pedestrian, walking along a wall and so on.

REFERENCES

[1] M.A. Rahman, M.A. Islam, S.R. Chakraborty, and M. Hasan, "Development of a Smart Stick for Visually Impaired People using Ultrasonic Sensors," International Journal of Advanced Computer Science and Applications (IJACSA), Vol. 10, No. 9, 2019.

[2] B. S. Manogaran, S. K. Pradhan, and K. V. Rajesh, "Blind Stick with Alert System Using Arduino," International Journal of Electronics and Communication Engineering (IJECE), Vol. 6, No. 7, 2017.

[3] J. K. R. T. Waseem, M. A. M. Khan, and N. S. Khan, "Design and Implementation of a Blind Stick with Global Positioning System (GPS) and Emergency Communication System," Journal of Engineering Science and Technology, Vol. 12, No. 5, 2017.

[4] Mohamed Elhoseny, Albert Y. Zomaya, and Sherali Zeadally, Smart Assistive Technologies for Visually Impaired Individuals, Springer International Publishing, 2020.

[5] S. Sharma, P. K. Sahu, and S. Chatterjee, "Assistive Devices for Visually Impaired People: A Review," Procedia Computer Science, Vol. 85, 2016.

[6] K. S. Rao, P. Kumar, and R. Swain, "Design and Implementation of Smart Cane for Visually Impaired Using IoT," International Journal of Engineering Trends and Technology (IJETT), Vol. 68, No. 2, 2020.

[7] Ramesh, A., and M. Priya, "Smart Navigation System for Visually Impaired Using GPS and GSM Modules," International Journal of Scientific Research in Computer Science, Vol. 9, No. 3, 2021.

[8] Gupta, N., Sharma, A., and Patel, R., "ESP32-Based IoT Applications for Assistive Devices," Advances in Embedded Systems and Applications, 2022.

[9] P. Chen, H. Zhang, and L. Liu, "Sensor Technologies for Enhanced Mobility Devices: A Review," Journal of Sensor Applications, Vol. 15, No. 1, 2020.

[10] Ali, H., and Farooq, S., "Voice Assistance Technologies for Smart Navigation: A Comparative Analysis," Proceedings of the 2019

International Conference on Assistive Technologies, 2019.
[11] Tiwari, A., and Verma, D., "Innovative Power Management Solutions for IoT-Driven Devices," Energy and Power Systems Review, Vol. 11, No. 4, 2023.
[12] IEEE Standards Association, "Guidelines for Designing Assistive Technologies for the Disabled," IEEE-SA Publication, 2021.
[13] World Health Organization (WHO), "Assistive Technology Development: Vision and Mobility," Technical Report, 2020.
[14] N. Singh and S. Kumar, "Ultrasonic Sensors and Real-Time Navigation Systems," Embedded Systems Journal, Vol. 14, No. 7, 2021.
[15] Waseem, J. K. R. T., Khan, M. A. M., & Khan, N. S. (2017). "Design and Implementation of a Blind Stick with Global Positioning System (GPS) and Emergency Communication System," Journal of Engineering Science and Technology, 12(5).