Journal of Multidisciplinary Engineering Science Studies (JMESS)
ISSN: 2458-925X
Vol. 11 Issue 1, January - 2025

Third Eye: An Assistive Technology for Visually Impaired with Sound and Vibration Capabilities

Titilayo A. Ogunjobi and Kazeem B. Adedeji

Department of Electrical and Electronics Engineering, Federal University of Technology Akure, Ondo State, Nigeria
Email: ogunjobititilayo2@gmail.com, kbadedeji@futa.edu.ng

***Abstract*— In recent years, the development of assistive technology to aid visually impaired individuals is gradually increasing. Various systems, including traditional white canes, guide dogs, sonar systems, ultrasonic sensors, and other internet of things (IoT)-based devices, have been developed to assist people with visual disabilities. Some of these systems, however, possess some drawbacks such as low response time and high cost. In this study, a wearable device in the form of a glove with both sound and vibration features was developed. The system employs a combination of ultrasonic sensor technology and vibration feedback, to notify the user about the forthcoming obstacle. The vibrating section was mounted on the glove while the sound mode is through an earpiece. For the sound mode, an LM386 amplifier was also equipped to handle noise cancellation. The system was also equipped with a charging unit via a universal serial board (USB) cable. The developed system was demonstrated using five test users. Thereafter, the performance of the system was assessed based on its response time to detect obstacles. The results show that the system has a superb response time when the obstacle is 1 m away. Additionally, the response time of the system was analyzed as the distance to the obstacle varied from 1 m to 0.1 m. It was observed that as the distance between the obstacle and the glove reduces, the response time also decreases rapidly. This behavior indicates that the system is well-suited for detecting objects at close range, which is essential for real-time interaction and the safety of the visually impaired.**

Keywords—assistive technology; obstacle detection; ultrasonic glove; vibration feedback system; wearable devices

I. INTRODUCTION

Blind and visually impaired individual often miss out on crucial environmental cues that sighted individuals can easily access, which significantly impacts their quality of life. These individuals tend to rely heavily on alternative senses like hearing, touch, and smell, which provide a much lower perception bandwidth compared to vision. This lack of access to visual information poses significant challenges, hindering mobility, environmental access, and safety [1]. The dangers become more prominent when accidents occur, like bumping into misplaced furniture, or navigating structural failures in buildings. According to the WHO [2], millions globally are affected by these impairments, making it necessary to develop assistive technologies that can help improve their mobility and safety. To meet this growing need, state-of-the-art sensor technologies have emerged, providing solutions that can record and interpret details of the surrounding environment, which facilitates smoother navigation for visually impaired individuals. While existing assistive devices such as long canes [3-5] and guide dogs [6, 7] (Fig. 1) have proven helpful, they also come with significant limitations. For example, guide dogs are typically available only to a selected group of users in first-world countries due to high costs. Although, long canes are more accessible, only ground-level obstacle detection can be achieved. It is impossible to protect against upper body obstacles like hanging objects [8]. Additionally, effective use of a long cane requires training in mobility and orientation skills, which could sometimes be socially awkward or inconvenient. To overcome these limitations, this study proposes a solution based on ultrasonic technology paired with haptic feedback to offer a more user-friendly and efficient alternative.

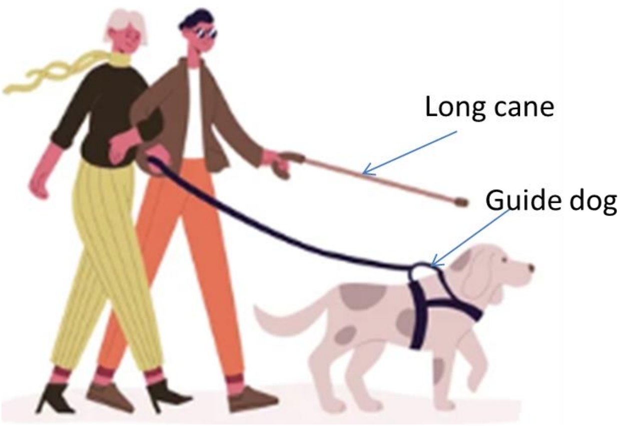

Fig. 1. *A sample of long canes and guide dog used for assitive technology.*

II. LITERATURE REVIEW

There have been several studies that focused on the development of obstacle detection systems and navigation aids for the blind and visually impaired. These systems can be generally categorized under four headings namely: ultrasonic sensor technology, IoT-based navigation systems, IR sensors, and Artificial Intelligence (AI) use cases.

A. Obstacle Detection based on Ultrasonic Sensor Technology

Ultrasonic sensor technology often employs microcontroller boards such as Raspberry Pi or Arduino. For example, Elsonbaty [9] developed a smart blind stick prototype (Fig. 2) that incorporates an Ultrasonic ESP826 sensor, a water sensor, and three thumb-operated push buttons. These features enable blind users to send general messages to a saved cell number or call for assistance. The system also includes vibrating motors and a buzzer, which activate when the stick is approaching an obstruction. The developed system has been used for accurate distance measurement achieved through the combination of micro-controller circuitry.

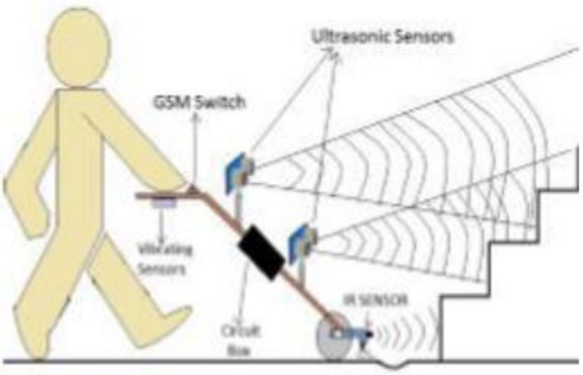

Fig. 2. *Smart electronic stick [9].*

In Patil [10], a NavGuide system was developed. The system uses ultrasonic sensors to classify obstacles and environments. This device is capable of detecting obstacles at knee and floor levels, as well as wet flooring. However, it may not detect pits or downward slopes. In real-world test situations, 70 blind participants from the "school and home for the blind" evaluated the NavGuide's performance. Advancing research in this domain, Parikh *et al*. [11] developed an ultrasonic sensor-assisted navigation jacket (Fig. 3) that aids in detecting obstacles higher than waist level. This system uses vibration motors and auditory feedback via a buzzer or speech mechanism.

Fig. 3. *Ultrasonic sensor-based assitive navigation jacket.*

B. Obstacle Detection based on IoT

IoT has also been incorporated into navigation systems for the blind. These systems use smart devices to interact with physical objects and provide real-time feedback. Kallara *et al*. [12] proposed a hand-held device used in combination with a smart cane that incorporates IoT-based technology, supported by the Android platform. The system can distinguish between people and objects with 80% accuracy and detect obstacles up to three meters away. It provides both audible and vibratory alarms to warn of impending collisions. However, the device may struggle with detecting steps and slopes.

In another study, Vera *et al*. [13] developed a blind guide system that integrates wireless sensors worn on different parts of the body, all connected to a central device (Raspberry Pi). The central device recognizes objects through voice feedback and informs the user of the object's name and distance. One major drawback of this system is that it requires internet access for object identification, which may not always be available in both indoor and outdoor environments.

C. Obstacle Detection based on Infrared Sensors

Infrared ray (IR) sensors are also employed in several assistive devices. Jafri *et al*. [14] developed a system that couples IR data-based technology with the Google Project Tango Tablet Development Kit and Unity SDK as illustrated in Fig. 4. This system reconstructs the user's surroundings in 3D and uses the unity engine to help users navigate by identifying obstacles. The system connects the user to a Unity collider component and alerts them via audio alarms when obstacles are detected.

Fig. 4. *Tango unity SDK-based obstacle detection system [14].*

D. *Obstacle Detection based on AI*

AI is becoming an integral part of navigation and obstacle detection systems for the blind. It is widely employed in fields such as healthcare [15], retail [16], logistics [17], and security [18]. Joshi *et al.* [19] proposed an effective AI-based multi-object detection and smart navigation system, which incorporates computer vision and sensor-based technologies. The system utilizes Convolutional Neural Networks (CNNs) to train algorithms for identifying important objects in the environment for visually impaired people. The results demonstrated a real-time object detection accuracy of 95.19% and object identification accuracy of 99.69%. In Wang *et al*. [20], a smart navigation aids such as smart readers, smart glasses, and smart canes was developed. The study utilized Generative Adversarial Networks (GANs) and transfer learning models in combination with CNNs. These neural network models were used to process images and videos, with the transfer learning aiming to bring computers closer to human-level thinking. This system allows users to apply learned tasks to new challenges and domains, such as reading assistance, object detection, and obstacle navigation systems.

III. MATERIALS AND METHODS

Fig. 5 illustrates the steps required for the development of the vibrating ultrasonic glove system. It has five main stages: circuit sketching, component gathering, system simulation, hardware design and fabrication. Foremost, the circuit was sketched, detailing the key components, including an ultrasonic sensor for obstacle detection, a microcontroller for processing inputs, and a DC motor for haptic feedback. Once the design was finalized, the necessary hardware components were gathered, ensuring each part fulfilled a specific function based on its appropriate specification in the system. Finally, the circuit was simulated using KiCAD before moving to the fabrication phase, where the components were integrated onto a PCB and assembled into the glove.

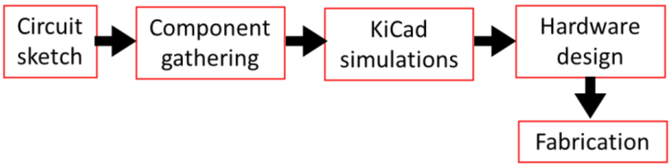

Fig. 5. *Activity diagram.*

A. *System Architecture*

The architecture of the developed ultrasonic glove system can be divided into three core blocks: Input, Processing, and Output. These blocks work together to achieve the desired functionality of obstacle detection and alert mechanisms for visually impaired users. The signal flow of these components are shown in Fig. 6.

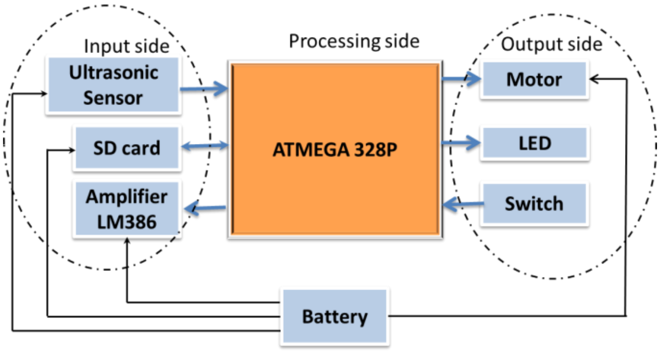

Fig. 6. *Block diagram of the proposed circuit.*

(a) The input block

The input block comprises the ultrasonic sensors (HC-SR04), which continuously monitor the surroundings for obstacles. These sensors measure the distance to nearby objects by emitting ultrasonic waves and receiving the reflected signals. The data from the ultrasonic sensor is sent to the processing unit (ATmega328p microcontroller) where it is evaluated. This block plays a critical role as the eyes of the system, scanning for potential obstacles and converting real-world physical distances into digital data for further processing.

(b) The processing block

The heart of the system is the ATmega328p microcontroller. It is responsible for processing the input from the ultrasonic sensors. The microcontroller operates based on pre-programmed logic, where it evaluates whether the user is approaching an obstacle within a predefined range (e.g., 1 meter). Once an obstacle is detected, the microcontroller decides whether to trigger the vibration motor or send audio cues via the earpiece, depending on the mode the user has selected. The system also includes a switch that allows the user to toggle between vibration mode and sound mode.

(c) The output block

The output block provides feedback to the user in two forms: tactile feedback and audio feedback. The vibration motor provides the functionality for delivering haptic signals when the glove detects an obstacle. In sound mode, the system uses an LM386 amplifier to boost audio signals before sending to the earpiece. The LM386 ensures that the sound is clear and loud enough to be perceived by the user, even in noisy environments. It amplifies the audio signal, and sends the amplified sound to the earpiece. This multi-sensory output approach makes the system adaptable to various user preferences and scenarios.

B. *Component Gathering*

The components used for the design are shown in Table I. The vibrating ultrasonic glove system is powered by an 18650 rechargeable battery with a TP4056 charging module to ensure portability and extended use.

C. Circuit Simulation using KiCAD

To mimic how the system will perform, the components were first simulated in KiCAD. This virtual representation allowed for the testing of each component's functionality within the system. The key components, including the ATmega 328p microcontroller, HC-SR04 ultrasonic sensor, and DC motor, were selected from the KiCad library and connected using the wiring tool to form the circuit as shown in Fig. 7. The ultrasonic sensor's trigger and echo pins were linked to the microcontroller for obstacle detection, while the vibration motor and audio output were configured to respond based on the sensor input. Simulated connections, such as the motor's connection to a current-limiting resistor and the amplifier's integration into the sound system, were tested to ensure proper operation.

TABLE I. LIST AND SPECIFICATION OF THE COMPONENT USED.

S/N	Component used	Qty	Rating
1	ATMega 328p Microcontroller	1	5 V, 20 mA per pin
2	22 pF Capacitor	2	-
3	10 kΩ Resistor	1	-
4	104 Ω Resistor	1	-
5	LM386 Audio Amplifier Module	1	5 V, 140 mA
6	10 μF Capacitor	2	-
7	220μF Capacitor	2	-
8	10kΩ Potentiometer	1	-
9	Switch	2	-
10	BC547 Transistor	1	-
11	18650 Rechargeable Battery	1	3.7 V, 2300 mAh
12	MT3608 Boost Converter	1	5 V
13	TP4056 Battery Charging Module	1	5V
14	DC Motor	1	5V, 100mA
15	LED(Red)	1	3.3V, 10mA
16	Ultrasonic Sensor (HC-SR04)	1	5 V, 20 mA

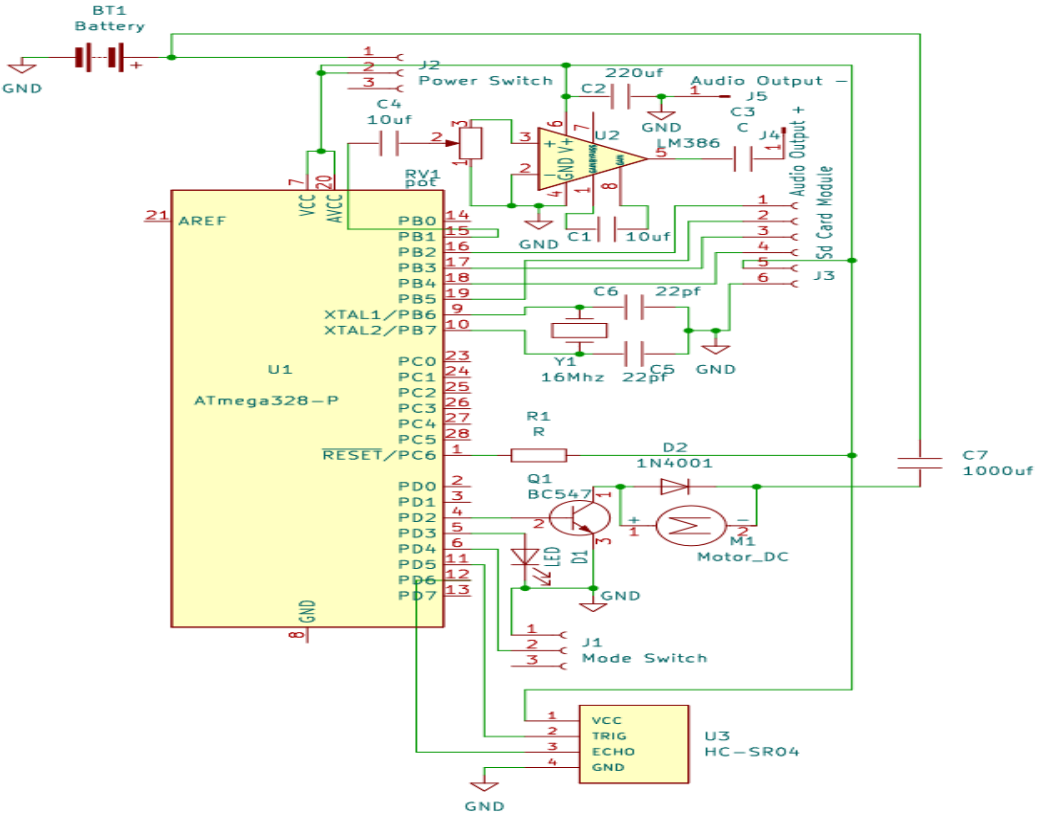

Fig. 7. *Block diagram of the proposed circuit.*

Additionally, the Arduino IDE was used to program the microcontroller, controlling the sensor inputs and switching between vibration and sound modes based on user feedback.

D. Hardware Design and Fabrication

The initial design simulated on KiCad was transferred to a PCB layout to prepare for the fabrication process. The conceptual design of the circuit was first prototyped on a breadboard to validate the connections and component functionality. After the initial testing on the breadboard was completed, the circuit design was printed onto glossy paper, and the PCB was prepared for fabrication. In the fabrication process, the PCB surface was roughened to allow for better adhesion, and the circuit design was transferred from the glossy paper onto the PCB using a heat transfer method. This was followed by an etching process, during which unwanted copper layers were removed, leaving behind the finalized circuit traces. After the etching process, the PCB was populated with the necessary components following the design layout as shown in Fig. 8. Fig. 9 demonstrates the outputs of the PCB fabrication, with all the components successfully placed on the board. Once the PCB assembly was complete, the entire circuit was integrated into the glove.

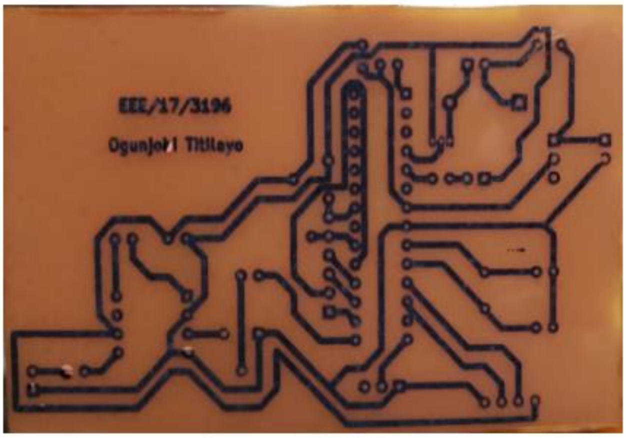

Fig. 8. *The fabricated PCB.*

Fig. 9. *Component placement on the fabricated PCB.*

Fig. 10 illustrates the glove in its OFF (Fig. 10(a)) and ON (Fig. 10(b)) states, respectively.

Fig. 10. *The ultrasonic glove in (a) OFF state (b) ON state.*

Fig. 11 highlights both operational modes (vibration and sound mode) of the glove, demonstrating its versatility in adapting to the user's preference for either vibration or sound-based feedback when navigating their surroundings. In the vibration mode, the system uses a motor to provide haptic feedback whenever the ultrasonic sensor detects an obstacle within a specified distance. Conversely, in sound mode, the glove is connected to an earpiece, and audio cues are provided to the user through a Bluetooth speaker or a standard earpiece.

Fig. 11. *Glove housing the motor for vibration mode.*

E. Performance Metrics

The effectiveness of the developed system was assessed using the following metrics:

(a) Operational time: To estimate the operational time of the vibrating ultrasonic glove under different modes and operating conditions, the following calculations were performed based on the total load current drawn from the components. The operating time (T_{op}) is determined from the supply current (I_s) and the total load current as;

$$T_{op} = \frac{I_s}{I} \tag{1}$$

In vibration and earpiece modes, the total load current due to each mode (I_v) and (I_e) is calculated using (2) and (3) respectively.

$$I_v = I_{us} + I_{AT} + L_{LED} + I_M \tag{2}$$

$$I_e = I_{us} + I_{AT} + L_{LED} + I_M \quad (3)$$

When the glove is idle (not triggered), the total current (*I*) reduced to

$$I = I_{us} + I_{AT} + L_{LED} \quad (4)$$

(b) Response time of ultrasonic sensor: The ultrasonic sensor is a critical component of the glove, as it is responsible for detecting obstacles and relaying the information to the user. The evaluation of the sensor's performance focused on how quickly it could respond when an obstacle was detected within a set range, typically 1 meter. The system employed the time-of-flight principle to measure the distance between the sensor and obstacles. This method calculates the time it takes for a sound signal emitted by the sensor to reflect off an object and return to the sensor.

(c) Vibration motor feedback pattern: This is the effectiveness of the vibration motor (haptic feedback) in signaling the proximity of obstacles to visually impaired users. The glove's vibration motor provides tactile feedback to the user, which is vital for clear communication of the proximity of obstacles. The haptic feedback patterns were designed to be intuitive and easily understandable. When an obstacle was detected, the system emitted a long pulse of sound along with a single-intensity vibration if the obstacle was within 10 centimeters. This simple and effective feedback pattern allowed users to quickly assess their surroundings without confusion.

(d) User feedback and usability assessment: The effectiveness of the vibrating ultrasonic glove system was evaluated not only through its technical performance but also by assessing the overall user experience. User feedback is crucial in determining the real-world usability and practicality of assistive technology for the visually impaired.

IV. RESULTS AND DISCUSSIONS

A. *Operational Time Result*

Table II shows the operational time of the system during both working and idle state considering vibrating and earpiece mode. As can be observed, when the system is fully operational, the system can last up to 12 hrs when the vibrating mode is activated while it lasted 10hrs for earpiece mode. These demonstrate the glove's efficiency in various operating conditions, ensuring adequate battery life for extended use.

TABLE II. THE OPERATIONAL TIME OF THE SYSTEM DURING WORKING AND IDLE STATE.

State	Working State	Idle state
Mode		
Vibrating mode	12 hrs	29 hrs
Earpiece mode	10 hrs	

B. *Results of Response Time of Ultrasonic Sensor*

Fig. 12 provides the response times for distances ranging from 1 meter to 0.1 meters. The quickest response time recorded was 5.83 × 10^{-4} seconds when the obstacle was at a distance of 0.1 meters, while the slowest response was 5.83 × 10^{-3} seconds at a 1-meter distance. This behavior indicates that the system is well-suited for detecting objects at close range, which is essential for real-time interaction and the safety of the visually impaired. The ability of the system to detect obstacles rapidly enhances its usability, especially in dynamic environments where the user needs to navigate around multiple objects. The system's reliable and fast response ensures that users are alerted promptly, reducing the risk of collisions and improving mobility in both open and confined spaces.

C. *Vibration Motor (Haptic) Feedback Results*

The combination of sound and vibration feedback offers a multi-sensory experience, which enhances the user's ability to understand the spatial layout. Test users consistently reported that the feedback mechanisms were easy to comprehend, particularly the vibration signals, which provided a straightforward indication of when an obstacle was near. This intuitive design contributed to the system's overall effectiveness in obstacle detection, making it a practical tool for real-world navigation, even in environments with limited sensory cues.

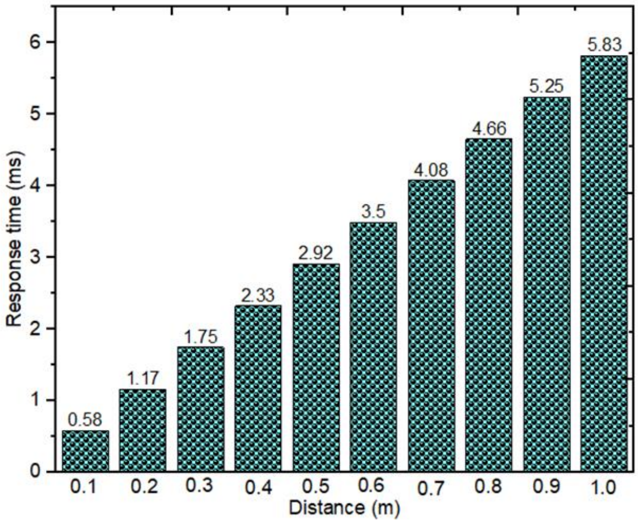

Fig. 12. *The response time of the system.*

D. *User Feedback and Usability Assessment Results*

A total of five test users were engaged in a usability study, during which they were blindfolded and tasked with navigating their environment using the glove. The feedback assessment (Table III) highlights the overall satisfaction and performance of the glove from the user's perspective.

TABLE III. USER FEEDBACK ASSESSMENT (AVERAGE).

Criteria	Assessment
Initial impression	Excellent
Understanding and interpreting feedback	Very Good
Performance and usability	Very Good
Real-world application	Good

(a) Initial Impressions: Upon interacting with the ultrasonic glove for the first time, users conveyed a range of emotions and thoughts regarding its design and usability. One user described the experience as "stepping into a new dimension", wherein they relied solely on touch and sound rather than sight. This reflects the glove's primary design goal of providing an intuitive and straightforward interface for the blind or visually impaired. The simplicity of the device was repeatedly noted. Users highlighted that the design and form factor made the glove easy to wear, and once worn, they felt comfortable navigating with minimal learning time. The attached earpiece was reported as enhancing the overall experience by providing auditory feedback, thus facilitating smooth interaction between the user and the system. The design effectively minimized the need for external assistance, fulfilling the system's objective of making visually impaired users more independent.

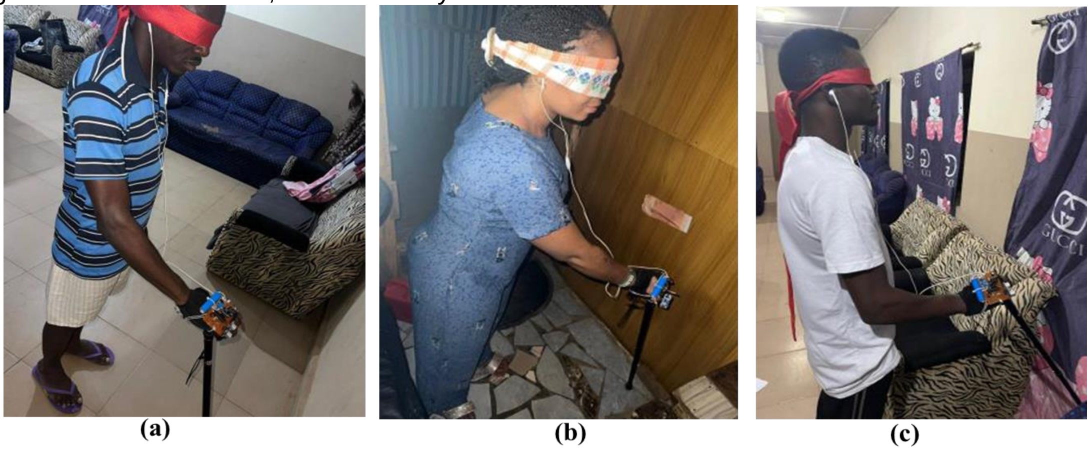
(a) (b) (c)

Fig. 13. *Obstacle detection test for (a) user 1 (b) user 2 (c) user 3.*

(b) Understanding and Interpreting Feedback: The glove's feedback mechanisms, which consist of both vibration and sound cues, were noted for their ease of interpretation. Users found the vibration intensity and sound patterns intuitive, with the single-pattern vibrations serving as clear indicators for obstacles within a set range (typically 1 meter). This aligns with the system's goal of simplicity, ensuring that the feedback was easy to understand without overwhelming the user with complex signals. Notably, users reported no confusion in interpreting the feedback provided by the system. Even when used in conjunction with a walking stick, the forward-facing orientation of the sensor helped ensure accurate functionality, allowing the glove to work seamlessly alongside traditional mobility aids. The glove's simplicity in feedback interpretation was also praised for assisting balance, particularly for beginners who were using the system for the first time.

(c) Real-World Applications: The device allowed users to detect and avoid obstacles, helping them move through environments with reduced reliance on external guidance. However, users suggested that introducing a mode for different environments, such as an adjustable sensitivity mode, would further enhance the glove's functionality, especially in crowded areas.

(d) Performance and Usability: The accuracy of obstacle detection and the prompt alert provided a reassuring sense of awareness during use, which was critical for ensuring safe navigation. While the glove performed well in less crowded spaces, some users did express challenges when using the device in busy or crowded in-door environments, suggesting that a sensitivity control feature could be beneficial in improving performance in such conditions. Despite this drawback, the glove's overall usability was rated as Very Good, with users expressing confidence in its ability to aid navigation.

E. Testing the System with Different Users

The effectiveness of the system was demonstrated on different users. Each users were blinded folded, wear the ultrasonic glove on their right hand, switch on the glove, select mode either vibration or earpiece mode (amplification), hold walking stick for extra aid and positioning of the hand and move towards obstacle and state observation and experience as shown in Fig. 13.

V. CONCLUSIONAND FUTURE STUDIES

This study presents the development and evaluation of an indoor navigation aid for the visually impaired, utilizing an ultrasonic glove system. The system has demonstrated significant potential in assisting visually impaired individuals by providing timely and effective feedback for obstacle detection.

Through user feedback and performance evaluations, the glove's simplicity and forward-facing sensor orientation have proven to be effective in real-world scenarios, enabling users to navigate their surroundings with reduced dependence on external assistance. The system's reliance on a single vibration mode and its challenges in crowded environments highlight areas where further refinement is necessary. Specifically, users reported difficulty in interpreting overwhelming feedback in environments with multiple obstacles, which suggests a need for adaptive sensitivity control. Despite these limitations, the glove has shown promise as an innovative solution for indoor navigation.

REFERENCES

[1] A. Bhowmick, and S.M. Hazarika, "An insight into assistive technology for the visually impaired and blind people: state-of-the-art and future trends," Journal on Multimodal User Interfaces, vol. 11, pp.149-172, 2017

[2] WHO. 2023. Blindness and vision impairment – Online Available from https://www.who.int/news-room/fact-sheets/detail/blindness-and-visual-impairment. [Accessed 10/8/2023].

[3] A.D.P. dos Santos, F.O. Medola, M.J. Cinelli, A.R. Garcia Ramirez, and F.E. Sandnes, "Are electronic white canes better than traditional canes? A comparative study with blind and blindfolded participants," Universal Access in the Information Society, vol. 20, no. 1, pp.93-103, 2021.

[4] C.H.M. Texeira, A.A. Rodrigues, A. Costa, and V.R. Santos, "Wearable haptic device as mobility aid for blind people: Electronic Cane," JOJ Ophthalmol, vol. 9, no. 3, pp. 1-6, 2023.

[5] K.M. Hoogsteen, S. Szpiro, G. Kreiman, and E. Peli, "Beyond the cane: describing urban scenes to blind people for mobility tasks," ACM Transactions on Accessible Computing, vol. 15, no. 3, pp.1-29, 2022.

[6] F. Menuge, M. Marcet-Rius, M. Jochem, O. Francois, C. Assali, C. Chabaud, E. Teruel, J. Guillemot, and P. Pageat, "Early evaluation of fearfulness in future guide dogs for blind people," Animals, vol. 11, no. 2, pp. 1-11, 2021.

[7] L. Florido-Benítez, "The accessibility of beaches for blind people and their guide dogs: Accessible tourism and inclusion in Spain," Tourism Review, vol. 79, no. 3, pp.719-738, 2024.

[8] P. Chanana, R. Paul, M. Balakrishnan, and P.V.M. Rao, "Assistive technology solutions for aiding travel of pedestrians with visual impairment," Journal of Rehabilitation and Assistive Technologies Engineering, vol. 4, pp. 1-16, 2017.

[9] A.A. Elsonbaty, "Smart blind stick design and implementation," International Journalof Engineering and Advanced Technology, vol. 10, no. 5, pp. 1-4, 2021.

[10] K. Patil, Q. Jawadwala, and F.c. Shu. "Design and construction of lectronic aid for visually impaired people," IEEE Transactions on Human-Machine Systems, vol. 48, no. 2, pp. 172-182, 2018.

[11] H. Parikh, J. Gosalia, J. Gosalia, J., and N. Mehendale, "Ultrasonic sensor-assisted navigation for blind individuals using jacket," *SSRN*, p. 4444011, 2023.

[12] S.B. Kallara, M. Raj, R. Raju, N.J. Mathew, V.R. Padmaprabha, and D.S. Divya, "Indriya—a smart guidance system for the visually impaired," In: Proceedings of the IEEE 2017 International Conference on Inventive Computing and Informatics, pp. 26-29, 2017.

[13] D. Vera, D. Marcillo, and A. Pereira. "Blind guide: Anytime, anywhere solution for guiding blind people," In Recent Advances in Information Systems and Technologies, vol. 2, no. 5, pp. 353-363, 2017.

[14] R. Jafri, R.L. Campos, S.A. Ali, and H.R. Arabnia. 'Utilizing the google project tango tablet development kit and the unity engine for image and infrared data-based obstacle detection for the visually impaired," In: Proceedings of the International Conference on Health Informatics and Medical Systems, Las Vegas, Nevada, Vol. 6, pp. 163-164, 2016.

[15] D. Ueda, T. Kakinuma, S. Fujita, K. Kamagata, Y. Fushimi, R. Ito, Y. Matsui, T. Nozaki, T. Nakaura, N. Fujima, and F. Tatsugami, "Fairness of artificial intelligence in healthcare: review and recommendations," Japanese Journal of Radiology, vol. 42, no. 1, pp.3-15, 2024.

[16] D.I. Ajiga, N.L. Ndubuisi, O.F. Asuzu, O.R. Owolabi, T.S. Tubokirifuruar, and R.A. Adeleye, "AI-driven predictive analytics in retail: a review of emerging trends and customer engagement strategies," International Journal of Management & Entrepreneurship Research, vol. 6, no. 2, pp.307-321, 2024.

[17] I. Jackson, M. Jesus Saenz, and D. Ivanov, "From natural language to simulations: applying AI to automate simulation modelling of logistics systems," International Journal of Production Research, vol. *62, no.* 4, pp.1434-1457, 2024.

[18] K.B. Adedeji, S.O. Oladiran, S.V. Abokede, and O. Ogunlade, "Prospect of machine learning scheme for efficient detection of DDoS attacks in IoT networks," Journal of Multidisciplinary Engineering Science Studies, vol. 10, no. 11, pp. 5648-5658., 2024.

[19] R.C. Joshi, S. Yadav, M.K. Dutta, and C.M. Travieso-Gonzalez. "Efficient multi-object detection and smart navigation using artificial intelligence for visually impaired people," Entropy, vol. 22, Nno. 9, pp. 941, 2020.

[20] J. Wang, S. Wang, and Y. Zhang. "Artificial intelligence for visually impaired," Displays, vol. 77, no. 102391, pp. 1-8, 2023.