CONESCAPANHONDURAS2025paper48.pdf

Institute of Electrical and Electronics Engineers (IEEE)

Document Details

Submission ID

trn:oid:::14348:477742797

Submission Date

Jul 31, 2025, 11:47 PM CST

Download Date

Aug 12, 2025, 2:30 PM CST

File Name

CONESCAPANHONDURAS2025paper48.pdf

File Size

408.6 KB

6 Pages

4,349 Words

26,509 Characters

10% Overall Similarity

The combined total of all matches, including overlapping sources, for each database.

Match Groups

- **24** Not Cited or Quoted 8%
  Matches with neither in-text citation nor quotation marks
- **0** Missing Quotations 0%
  Matches that are still very similar to source material
- **8** Missing Citation 3%
  Matches that have quotation marks, but no in-text citation
- **0** Cited and Quoted 0%
  Matches with in-text citation present, but no quotation marks

Top Sources

10% Internet sources

5% Publications

0% Submitted works (Student Papers)

Integrity Flags

0 Integrity Flags for Review

No suspicious text manipulations found.

Our system's algorithms look deeply at a document for any inconsistencies that would set it apart from a normal submission. If we notice something strange, we flag it for you to review.

A Flag is not necessarily an indicator of a problem. However, we'd recommend you focus your attention there for further review.

Match Groups

24 Not Cited or Quoted 8%
Matches with neither in-text citation nor quotation marks

0 Missing Quotations 0%
Matches that are still very similar to source material

8 Missing Citation 3%
Matches that have quotation marks, but no in-text citation

0 Cited and Quoted 0%
Matches with in-text citation present, but no quotation marks

Top Sources

10% Internet sources
5% Publications
0% Submitted works (Student Papers)

Top Sources

The sources with the highest number of matches within the submission. Overlapping sources will not be displayed.

1	Publication	
	Akshay Vijay Munot, Eshaa Niteen Mohod, Sahil Raviraj Hemnani, Kaustubh Nark...	<1%
2	Internet	
	www.coursehero.com	<1%
3	Internet	
	journal.umy.ac.id	<1%
4	Internet	
	www.researchsquare.com	<1%
5	Internet	
	maker.pro	<1%
6	Internet	
	alicia.concytec.gob.pe	<1%
7	Internet	
	upcommons.upc.edu	<1%
8	Internet	
	bmcophthalmol.biomedcentral.com	<1%
9	Internet	
	blog.fundaciononce.es	<1%
10	Internet	
	www.rmo.com.mx	<1%

11 Internet

openscholarship.wustl.edu <1%

12 Publication

Kusnandar, Dwi Nova Anggraeni, Kartaman, Asep Najmurrokhman, Nanang Ism... <1%

13 Internet

jicts.udsm.ac.tz <1%

14 Internet

repositorioinstitucional.buap.mx <1%

15 Internet

www.sciencebuddies.org <1%

16 Internet

pmc.ncbi.nlm.nih.gov <1%

17 Internet

rehab.jmir.org <1%

18 Internet

journal.50sea.com <1%

19 Internet

www.thinkmind.org <1%

20 Internet

mdpi-res.com <1%

21 Internet

repositorio.usp.br <1%

22 Internet

www.researchgate.net <1%

23 Publication

"2020 7th International Conference on Smart Structures and Systems (ICSSS) - Ful... <1%

24 Publication

Carlos Lamuela Orta. "Contradictions and double standards in Helsinki's cycling i... <1%

25 Internet

hpej.net <1%

26 Internet

jnao-nu.com <1%

27 Internet

www.mdpi.com <1%

Wearable Ultrasonic Navigation Aid for Individuals with Visual Impairment

***Abstract*—Visual disability significantly affects the quality of life and independence of affected individuals, highlighting the need for assistive technologies that improve mobility and environmental awareness. This paper presents the design, development, and evaluation of a smart glasses prototype developed for people with low vision. The system integrates an ultrasonic sensor (HC-SR04), an Arduino Nano microcontroller, and a DFPlayer Mini audio module to detect obstacles and deliver auditory alerts in real time. The device was validated through experimental tests in a controlled indoor environment using four simulated users. The results showed a reliable detection range of up to 1.90 meters, consistent performance for opaque obstacles, and a response latency below 50 milliseconds. Signal stabilization techniques and ergonomic improvements were implemented to enhance usability. This research demonstrates the feasibility of building low-cost wearable assistive devices using open-source hardware and offers a promising foundation for future development and user-centered testing in real-world conditions.**

***Index Terms*—Arduino, assistive technology, auditory feedback, smart glasses, ultrasonic sensors, visual disability, visual impairment.**

I. Introduction

Visual impairment is a condition that significantly impacts the quality of life of millions of individuals worldwide, limiting their ability to perform daily tasks independently and safely. Characterized by a reduction in visual acuity that cannot be fully corrected through conventional lenses, surgery, or medical treatment, this condition presents unique challenges for both patients and ophthalmic healthcare providers [1].

Amidst the ongoing digital transformation and technological advancements in the healthcare sector, there is a growing need for innovative solutions that complement traditional treatments and enhance the patient experience [2]. Assistive technologies have emerged as fundamental tools to empower people with visual disabilities, providing them with greater autonomy and facilitating their integration into diverse environments. [3].

In response to the increasing demand for personalized and inclusive healthcare services, this project introduces the development of a smart guidance system based on auditory feedback for individuals with low vision. The system is designed to enhance mobility and spatial awareness by detecting obstacles in real time through the use of ultrasonic sensors. Based on accessible and low-cost technology principles, the proposed solution represents a step toward inclusive medicine by leveraging microcontroller-based electronics to assist visually impaired individuals.

The main objective of this research is to develop an initial prototype of smart glasses equipped with ultrasonic sensors, using the Arduino platform, aimed at improving navigation and independence for people with low vision. The system incorporates real-time object detection and feedback mechanisms through auditory or vibratory alerts to notify users of nearby obstacles. The study also seeks to evaluate the accuracy and reliability of the device in controlled indoor environments through structured testing protocols.

This work focuses on the design and implementation of the electronic system, signal processing algorithms, and documentation of the prototype. Validation tests will be conducted exclusively by the development team, in closed and controlled settings, without involving individuals with visual impairments, as this constitutes a preliminary technical validation phase. The experiments will assess the system's effectiveness at various distances to determine its ability to detect obstacles across multiple ranges. As such, this study does not include clinical trials or patient-related evaluations.

A. Related Work

1) Low Vision: Low vision refers to a permanent reduction in visual function that cannot be corrected by conventional methods such as glasses, contact lenses, surgery, or medical treatment. It prevents individuals from carrying out daily tasks independently and safely, such as reading, walking unaided, or recognizing faces. As mentioned in [4], addressing this condition requires not only clinical intervention but also technological solutions that enable users to compensate for their sensory limitations. In recent years, the use of wearable electronic aids has gained attention as a viable approach to support navigation and interaction with the environment.

2) Visual Impairment: Visual impairment encompasses a wide range of conditions, from partial vision loss to complete blindness. These conditions may be congenital, acquired, or progressive in nature, and their impact is particularly critical in pediatric populations. As discussed in [5], early-onset visual impairment can significantly affect a child's psychological, educational, and social development. In response to this, technological interventions aimed at improving environmental perception and mobility are becoming increasingly important. According to [6], such devices should be adaptable, intuitive, and capable of functioning in real-world scenarios.

3) Mobility Challenges: Navigating environments designed primarily for sighted individuals presents persistent challenges for people with visual impairments. These include inconsistent pavement conditions, lack of tactile signage, unexpected obstacles, and changing light conditions. As pointed out in [7], emotional factors such as anxiety and fatigue also influence the effectiveness of orientation and mobility techniques. Assistive systems must therefore account for both environmental and user-centered variables to ensure reliability and ease of use.

4) Assistive Technology: Assistive technologies play a key role in improving quality of life for individuals with disabilities. They enable access, independence, and active participation in society. As highlighted in [8], for users with visual impairments, these technologies often include devices that provide haptic, auditory, or spoken feedback to compensate for lack of visual input. The integration of real-time sensing and feedback mechanisms is particularly relevant in this context.

5) Smart Glasses: Smart glasses represent a growing field within assistive technology. These systems combine sensors, microcontrollers, and output interfaces (such as audio) to provide spatial awareness to the user. As shown in [**?**], [10], low-cost prototypes developed using platforms like Arduino and ultrasonic sensors are capable of detecting frontal obstacles and delivering real-time alerts. These solutions are particularly valuable in educational settings and low-resource environments due to their affordability and simplicity.

6) Obstacle Detection: The core function of many assistive navigation systems is reliable obstacle detection. Various sensing technologies have been employed to this end, including ultrasonic, infrared, and computer vision-based approaches. As demonstrated in [**?**], [10], ultrasonic sensors provide a practical trade-off between range, precision, and cost, making them suitable for wearable applications. The combination of obstacle detection and audio alerts has proven effective in enhancing user awareness and avoiding collisions in indoor environments.

7) Ultrasonic Sensors: Ultrasonic sensors are widely used in assistive devices due to their robustness in different lighting conditions, low power consumption, and straightforward signal processing. These sensors operate by emitting a burst of sound waves and measuring the echo return time to calculate distance. According to [11], such sensors offer consistent performance for near-field detection and are particularly well suited to portable applications with limited processing power.

8) Personal Autonomy: One of the main objectives of assistive technologies is to increase personal autonomy, allowing users to navigate and perform tasks without continuous external support. Studies like [12] indicate that devices which enhance spatial awareness and reduce dependency on others can have a significant psychological and functional impact. The design of these tools must balance technical effectiveness with user comfort and confidence.

9) Applied Electronics: The development of wearable assistive devices requires the integration of embedded electronics capable of real-time environmental interaction. As shown in [13], platforms based on microcontrollers such as Arduino allow for flexible sensor integration and custom signal processing algorithms. These systems are ideal for rapid prototyping and iterative design in both academic and clinical settings.

10) Social Inclusion: Beyond functionality, assistive technologies must also promote social inclusion by supporting the participation of individuals with disabilities in various aspects of life. As emphasized in [14], inclusive design principles require that these technologies be accessible, affordable, and culturally adaptable. This approach ensures that assistive systems address not only physiological needs but also the social and emotional context of the user.

11) Arduino Applications: The Arduino platform has become a cornerstone in the development of educational and assistive technology projects. Its open-source architecture, ease of use, and extensive documentation make it an ideal choice for implementing wearable electronic systems. As demonstrated in [15], Arduino-based prototypes can successfully integrate distance sensors, feedback mechanisms, and power management in a compact, portable format. These systems are valuable both as proof-of-concept tools and as deployable solutions in low-resource environments.

II. Methodology

A. Design Approach

This research follows an experimental design focused on developing a prototype of smart glasses to assist people with low vision. The primary goal is to create a wearable electronic system capable of detecting obstacles in real time using ultrasonic sensors and providing feedback through auditory alerts. The prototype aims to support user mobility in both indoor and outdoor environments.

The initial phase involved a comprehensive review of scientific literature and prior assistive device projects. This investigation guided the technical decisions regarding component selection, system architecture, and programming strategies. The solution prioritizes low-cost components with reliable performance and ease of integration.

B. Component Selection and System Architecture

Based on performance, cost-efficiency, and ease of use, the HC-SR04 ultrasonic sensor was selected for obstacle detection. [16] The Arduino Nano board was chosen as the microcontroller platform due to its compact size and compatibility with various modules. For auditory feedback, the DFPlayer Mini MP3 module was integrated into the design to play prerecorded alert sounds when obstacles are detected.

The electronic components were initially assembled on a breadboard for testing purposes. The system was later migrated to a more permanent protoboard. The physical support for the system was based on modified commercial safety glasses, to which all electronic components were securely mounted, ensuring comfort and stability during use. [17]

C. Prototype Assembly and Signal Processing

The prototype's firmware was developed using the Arduino IDE, incorporating libraries for the HC-SR04 and DFPlayer modules. The microcontroller triggers the ultrasonic sensor through a 10 µs pulse sent via the TRIG pin. The echo response is captured and processed with `pulseIn()`, and the measured time is converted into distance using a calibrated factor.

A threshold value with a hysteresis margin of 5 cm was implemented in the software to avoid output oscillations. If the measured distance is below the threshold, a command is sent through a serial connection to the DFPlayer Mini to trigger an audio alert. The system monitors the BUSY pin to ensure that audio clips do not overlap during playback.

D. Validation Testing

Validation tests were conducted in a controlled indoor environment, specifically a classroom, where a predefined circuit was set up using common obstacles such as walls, desks, chairs, and a lectern. The testing involved four members of the development team acting as test subjects. Each participant simulated visual impairment by covering their eyes completely to eliminate visual input.

Each subject followed a structured procedure individually:

1) The participant was equipped with the smart glasses and placed himself at the designated starting point.
2) With their vision blocked, they proceeded to walk along the circuit path.
3) The system continuously scanned the environment using the ultrasonic sensor while the subject moved.
4) Upon detection of an obstacle, the device emitted an audio warning.
5) The participant was instructed to stop or change direction in response to the alert.
6) The test continued until the subject completed the entire course.

The ultrasonic sensor demonstrated consistent obstacle detection within a maximum range of 1.90 meters. However, detection was limited to objects located from the waist level upward, with optimal response occurring between the chest and head height. Vertical coverage was influenced by head orientation, and performance remained reliable only within a ±10 cm vertical movement window relative to the horizontal axis of the sensor. Outside of this range, the accuracy of obstacle detection diminished significantly. .

E. Component Selection and System Architecture

The system integrates the HC-SR04 ultrasonic sensor for distance measurement and the DFPlayer Mini module for audio playback. The Arduino Nano was selected as the central microcontroller due to its compact size, pin compatibility, and sufficient processing power.

A physical prototype was built using modified cycling glasses as the base structure. Electronic components were mounted on a breadboard during early testing and later migrated to a perforated PCB (baquelite) for stability. Power was supplied via a 5V regulated source, with shared ground (GND) in all modules.

F. Development Steps

The system was developed through the following sequence:

1) Component Testing:: The HC-SR04 was tested for range and stability. The DFPlayer Mini was programmed to play predefined audio tracks via serial commands.

2) Circuit Assembly:: The ultrasonic sensor was connected to digital pins D5 (TRIG) and D6 (ECHO). The DFPlayer was connected to D10 (TX) and D11 (RX), with the BUSY pin linked to D13 to monitor playback status.

3) Firmware Implementation:: Custom Arduino code was written to handle real-time detection, decision logic, and communication with the audio module.

4) Threshold Calibration:: The system was tuned with detection thresholds and hysteresis buffers to avoid flickering alerts.

5) Physical Integration:: Components were mounted on glasses, optimizing both weight distribution and frontal coverage of the ultrasonic beam. The complete wiring layout of the system components, including the Arduino Nano, ultrasonic sensor, DFPlayer Mini, and speaker, is illustrated in Fig. 1.

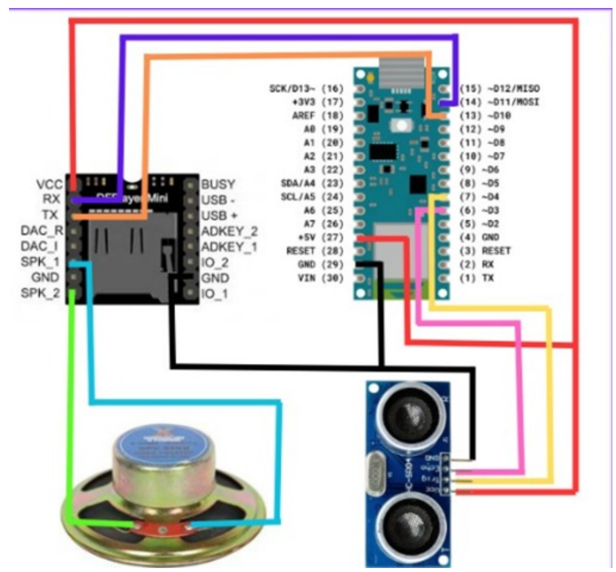

Fig. 1. Connection Diagram.

G. Signal Processing

The ultrasonic sensing process starts with a 10 µs digital pulse sent from the Arduino to the TRIG pin of the HC-SR04 sensor. [18],The echo is captured via the ECHO pin and processed using the `pulseIn()` function, which calculates pulse duration with 1 µs resolution. The signal is then converted into centimeters using the formula:

$$d = \frac{t \cdot 0.0343}{2} \tag{1}$$

To improve consistency, multiple samples are averaged, and a hysteresis margin of 5 cm is applied to the threshold logic to prevent unstable switching [18].

If an object is detected within the threshold range, the Arduino transmits a command over SoftwareSerial to the DFPlayer Mini to play a warning sound. The BUSY line is polled to avoid overlapping playback. The signal processing workflow of the system, from pulse generation to audio playback based on obstacle detection, is detailed in Fig. 2.

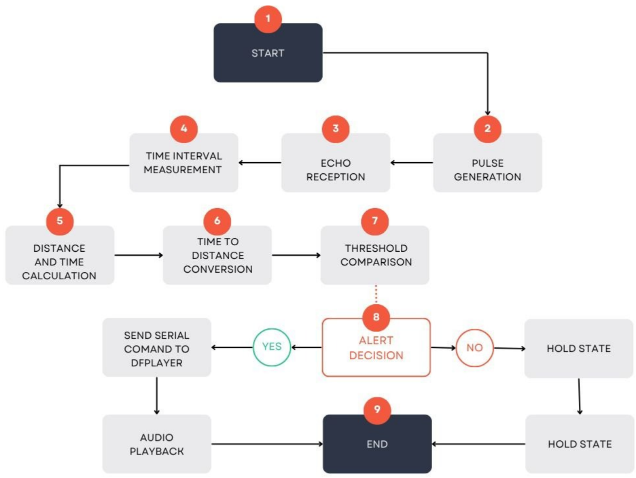

Fig. 2. Signal Processing Diagram.

H. Microcontroller Code Logic

The Arduino code includes two main functions: (1) real-time distance measurement and (2) conditional audio triggering. It uses the libraries `SoftwareSerial` and `DFRobotDFPlayerMini`. The DFPlayer is initialized over pins D10 and D11, while the ultrasonic measurements occur over D5 and D6 [19].

27

After initializing all components, the code continuously monitors the environment. When the average measured distance falls below the set threshold (e.g., 200 cm), and the audio player is idle, it issues the `play(1)` command to emit an alert. If no object is detected, the audio is stopped using `stop()` [20].

The logic flow guarantees non-redundant playback and maintains system responsiveness under dynamic conditions.

I. Challenges During Implementation

Several issues were encountered during development. The initial use of an Arduino Uno proved impractical due to its size; it was replaced by the more compact Nano. Additionally, the first DFPlayer Mini module was damaged during power testing and required replacement.

Mechanical integration required multiple adjustments to secure components on the glasses without affecting comfort. An initial power adapter failed to provide stable 5V output, necessitating a new power design using regulated batteries.

Finally, to avoid ghost echoes in successive measurements, a cleaning pulse was implemented. Before each valid measurement, a blank pulse was sent to dissipate residual waves, followed by a 2–5 μs delay to ensure acoustic silence. This technique improved the sensor's reliability and measurement stability.

III. Results and Discussion

A series of experimental tests were conducted to evaluate the performance of the smart glasses prototype. The validation process involved obstacle detection scenarios in a controlled indoor circuit using four team members as test subjects, each simulating visual impairment by covering their eyes.

A. Detection Accuracy and Range

The ultrasonic system successfully detected frontal obstacles located within a vertical range extending from the thoracic area to the head, provided the head position remained within ±5 cm of the sensor's emission plane. The effective horizontal detection range reached a maximum of approximately 1.90 meters. Within this range, the HC-SR04 sensor demonstrated consistent and reliable responses to typical indoor obstacles such as tables, chairs, and walls.

Detection reliability across all test runs was above 90% for opaque obstacles within range. Alert sounds were triggered promptly when the measured distance dropped below the software-configured threshold, and no false positives were observed due to background reflections or environmental clutter.

1) Cost-Effective Design: The system was intentionally developed as a low-cost prototype to maximize accessibility and replicability in academic, clinical, and community-based settings. From the design perspective of the development team, "low-cost" refers not only to the price of individual components but also to the overall feasibility of assembly using widely available materials and minimal infrastructure. For instance, while infrared sensors commonly used in commercial navigation aids can cost up to L 2,900, the HC-SR04 ultrasonic sensor used in this design is priced at approximately L 250. This substitution alone represents a cost reduction of over **91%**.The choice of these elements reflects an intentional strategy to ensure that the technology can be reproduced by students, researchers, without requiring advanced tools, expensive modules, or proprietary systems. Therefore, the term "low-cost" encompasses both the affordability of implementing the system in resource-constrained environments.

B. Head Positioning and Spatial Sensitivity

Maintaining a stable head orientation was essential to preserving detection performance. Tilting the head too far upwards or downwards caused the ultrasonic beam to deviate vertically, reducing the probability of detecting mid-level obstacles. This reinforces the importance of aligning the sensor's emission cone with the user's natural line of movement to ensure accurate obstacle identification. As shown in Fig. 3, maintaining proper head alignment was critical to keeping the ultrasonic beam directed within the optimal vertical detection range.

C. Latency and Real-Time Response

System responsiveness was assessed by measuring the latency between detection and alert playback. The total delay from obstacle detection to audio output remained consistently below 50 milliseconds. This low latency was achieved through real-time signal processing on the Arduino Nano and non-blocking serial communication with the DFPlayer Mini module.

The system included logic to monitor the DFPlayer's BUSY pin, ensuring that no overlapping audio messages were played.

Fig. 3. Testing Head Positioning and Spatial Sensitivity.

This maintained clear, uninterrupted communication of obstacle proximity to the user.

D. Experimental Testing with Simulated Users

Four subjects were involved in the validation testing. Each followed a predefined route within a furnished interior environment. The circuit included obstacles at different heights and materials. All participants successfully completed the course relying only on the auditory alerts provided by the glasses.

In all cases, the system provided timely warnings, enabling participants to pause or adjust their direction before impact. These qualitative observations confirmed the system's usability and intuitiveness, even during first-time use.

E. Limitations with Transparent Obstacles

One of the primary limitations observed was the system's inability to reliably detect transparent surfaces such as glass panels. In multiple trials, the sensor failed to generate a strong echo when facing smooth glass, due to low acoustic impedance and shallow angle of incidence. This led to undetected collisions in approximately 30% of glass-related encounters.

This limitation is inherent to ultrasonic sensing technology and represents an area for improvement in future iterations. Alternative sensors such as LiDAR or infrared could complement the system to improve detection of transparent or reflective surfaces. Fig. 4, illustrates one of the main challenges faced by the system: its inability to detect transparent surfaces such as glass, due to weak echo reflection and low acoustic impedance.

Fig. 4. Testing with Transparent Obstacles.

F. Measurement Stabilization Techniques

To minimize noise and increase reading reliability, a "reset pulse" protocol was implemented. Before each distance reading, a brief 10 µs pulse was emitted into open space to dissipate any residual echoes. After a 2–5 µs delay, a valid measurement was taken. This technique helped eliminate erroneous readings caused by echo overlap or environmental resonance and ensured consistent sensor behavior throughout testing.

G. Recommendations

To improve the prototype in future iterations, several recommendations are proposed:

- **Sensor Upgrade:** Replace or supplement the ultrasonic sensor with LiDAR or Time-of-Flight (ToF) modules to improve detection of transparent materials like glass, which the current sensor struggled to recognize.
- **Power System Optimization:** Use lightweight, high-density lithium polymer (Li-Po) batteries to reduce the device's overall weight and increase user comfort. Proper voltage regulation should be ensured to avoid hardware damage.
- **Ergonomic Redesign:** Implement a 3D-modeled frame tailored to the user's facial dimensions, using CAD software such as SolidWorks, to enhance mechanical integration and long-term comfort. A redesign of the frame, tailored for improved ergonomics and user comfort, is shown in Fig. 5.

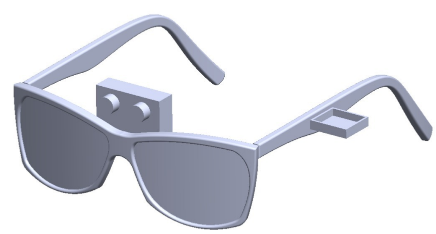

Fig. 5. Recommended 3D-modeled frame

- **Field Testing with Users:** Conduct pilot tests with individuals with actual visual impairments in real-world environments to validate usability, threshold tuning, and responsiveness under diverse conditions.
- **Educational Documentation:** Systematize the project into a practical guide or instruction manual, including schematics, code comments, troubleshooting tips, and deployment procedures. This would facilitate replication by other students and developers in assistive technology.

IV. Conclusion

The development and testing of the prototype of smart glasses demonstrated the technical feasibility of creating an accessible and low-cost assistive device for individuals with low vision. By integrating an ultrasonic distance sensor (HC-SR04) with a compact microcontroller (Arduino Nano) and a dedicated audio module (DFPlayer Mini), the system achieved real-time obstacle detection with auditory feedback.

Validation tests conducted in controlled environments showed that the device could consistently detect opaque obstacles located within 1.90 meters, as long as the user's head remained properly aligned with the sensor's axis. Auditory alerts were timely and clear, with total system latency remaining under 50 milliseconds. These performance indicators support the potential of the device to serve as a foundational assistive tool to improve personal mobility and autonomy.

The investigation also validated the use of open source hardware for inclusive design. The modular architecture, ease of programming, and simplicity of component integration make the system replicable and scalable. The implementation of signal stabilization methods, such as hysteresis and echo-reset pulses, enhanced sensor reliability, and reduced false readings.

Despite the overall success, some limitations were identified. The system must be improved to consistently detect transparent obstacles such as glass, and certain mechanical and power-supply challenges require design iterations. However, the prototype provided a initial and intuitive interface for simulated users, indicating its potential for real-world application after further refinement.

References

[1] E. K. Fenwick, E. L. Lamoureux, and J. C. Crowston, "The impact of visual impairment on quality of life," *BMJ Open*, vol. 7, no. 3, e013658, Mar. 2017, doi: 10.1136/bmjopen-2016-013658.

[2] World Health Organization, "Digital Health," WHO, Geneva, Switzerland. [Online]. Available: https://www.who.int/health-topics/digital-health#tab=tab_1. [Accessed: Jun. 28, 2025].

[3] Facultad de Ingeniería, "La importancia y aplicaciones de los microcontroladores en la electrónica," Universidad La Salle México. [Online]. Available: https://ingenieria.lasalle.mx/temas-de-interes/la-importancia-y-aplicaciones-de-los-microcontroladores-en-la-electr

[4] J. C. S. Escudero, "Discapacidad visual y ceguera en el adulto: Revisión de tema," *MEDICINA U.P.B.*, 2011.

[5] A. Yekta *et al.*, "Global Prevalence and Causes of Visual Impairment and Blindness in Children: A Systematic Review and Meta-Analysis," *J Curr Ophthalmol*, vol. 34, no. 1, pp. 1–15, Apr. 2022, doi: 10.4103/joco.joco_135_21.

[6] M. H. Abidi, A. N. Siddiquee, H. Alkhalefah, and V. Srivastava, "A comprehensive review of navigation systems for visually impaired individuals," *Heliyon*, vol. 10, no. 11, p. e31825, Jun. 2024, doi: 10.1016/j.heliyon.2024.e31825.

[7] "Assistive Technology Science and Engineering Projects — Science Buddies Blog," Science Buddies. [Online]. Available: https://www.sciencebuddies.org/blog/assistive-technology-science-projects. [Accessed: May 25, 2025].

[8] "Aplicaciones de las gafas inteligentes en las ciencias aplicadas: una revisión sistemática." [Online]. Available: https://www.mdpi.com/2076-3417/11/11/4956. [Accessed: May 25, 2025].

[9] X. Leong and R. K. Ramasamy, "Obstacle Detection and Distance Estimation for Visually Impaired People," *IEEE Access*, vol. 11, pp. 136609–136629, 2023, doi: 10.1109/ACCESS.2023.3338154.

[10] "Arduino Obstacle-Detecting Glasses with Ultrasonic Sensor — Science Project," Science Buddies. [Online]. Available: https://www.sciencebuddies.org/science-fair-projects/project-ideas/Elec_p108/electricity-electronics/obstacle-detecting-glasses. [Accessed: May 24, 2025].

[11] U. Masud, T. Saeed, H. M. Malaikah, F. U. Islam, and G. Abbas, "Smart Assistive System for Visually Impaired People Obstruction Avoidance Through Object Detection and Classification," *IEEE Access*, vol. 10, pp. 13428–13441, 2022, doi: 10.1109/ACCESS.2022.3146320.

[12] A. Roselló Leyva, S. Rodríguez Masó, I. Rojas Rondón, M. Linares Guerra, E. A. Ramos Gómez, and Y. Vázquez Adan, "Defectos refractivos más frecuentes que causan baja visión," *Revista Cubana de Oftalmología*, vol. 24, no. 2, pp. 271–278, Dec. 2011.

[13] M. Glatz *et al.*, "Blindness and visual impairment in Central Europe," *PLoS One*, vol. 17, no. 1, p. e0261897, Jan. 2022, doi: 10.1371/journal.pone.0261897.

[14] "Tecnología inclusiva: Soluciones tecnológicas para impulsar la inclusión social y laboral de las personas con discapacidad." [Online]. Available: https://www.bilib.es/actualidad/articulos-tecnologicos/post/noticia/tecnologia-inclusiva-soluciones-tecnologicas-para-impulsar-la-inclusion-social-y-laboral-de-las-personas-con-discapacidad. [Accessed: May 25, 2025].

[15] S. Rivera Menjura, "Estudio del diseño de un sistema de dispositivos de asistencia para personas con baja visión o ceguera," Bachelor thesis, Universitat Politècnica de Catalunya, 2023. [Online]. Available: https://upcommons.upc.edu/handle/2117/393926. [Accessed: May 25, 2025].

[16] R. E. Vargas Flores, "Diseño e implementación de un dispositivo electrónico para asistencia de lectura de textos impresos mediante visión computacional para personas con discapacidad visual," Bachelor thesis, Univ. Tecnológica de México, 2024. [Online]. Available: https://www.researchgate.net/publication/392608283. [Accessed: Jun. 22, 2025].

[17] SparkFun Electronics, "Ultrasonic Sensor HC-SR04 Technical Data Sheet." [Online]. Available: https://learn.sparkfun.com/tutorials/hc-sr04-ultrasonic-sensor. [Accessed: May 25, 2025].

[18] M. Margolis, *Arduino Cookbook*, 3rd ed. Sebastopol, CA: O'Reilly Media, 2020. [Online]. Available: https://www.oreilly.com/library/view/arduino-cookbook-3rd/9781491903513/. [Accessed: May 25, 2025].

[19] "How to Use the DFPlayer Mini MP3 Module with Arduino," Maker Pro. [Online]. Available: https://maker.pro/arduino/projects/how-to-use-the-dfmini-player-mp3-module-with-arduino. [Accessed: May 25, 2025].

[20] "Ultrasonic Sensor HC-SR04 with Arduino Tutorial," How To Mechatronics. [Online]. Available: https://howtomechatronics.com/tutorials/arduino/ultrasonic-sensor-hc-sr04/. [Accessed: May 25, 2025].