

Ultrasonic Glasses for the Blind

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ABSTRACT

Ultrasonic Glasses for the Blind is a real-time wearable assistive system developed to improve the mobility and safety of visually impaired individuals through intelligent obstacle detection and voice-based navigation assistance. The system integrates an HC-SR04 ultrasonic sensor, Arduino Nano microcontroller, and ISD1820 voice module to continuously monitor surrounding obstacles and provide immediate audio alerts. Distance measurement is performed using ultrasonic echo-time calculation and processed using predefined threshold logic for real-time obstacle identification.

The complete prototype is mounted on a lightweight spectacle frame and powered by a rechargeable lithium battery, ensuring portability and continuous operation for daily use. Experimental evaluation demonstrated an obstacle detection accuracy of 97%, an average response time of 150 ms, and an effective detection range of 2 cm to 400 cm, with continuous battery backup of 5 hours. The total implementation cost of approximately ₹1500 makes the proposed system affordable and accessible for practical deployment.

Compared to conventional buzzer-based assistive devices, the proposed voice-alert mechanism offers clearer and more intuitive user guidance, improving usability and response efficiency. The experimental results confirm that the system provides a reliable, low-cost, and efficient embedded assistive technology solution that significantly enhances independent mobility and safety for visually impaired users.

Keywords: Ultrasonic Sensor, Arduino Nano, Assistive Technology, Embedded Systems, Obstacle Detection, Voice Module, Wearable Device, Blind Navigation.

INTRODUCTION

Navigation and environmental awareness are essential aspects of daily life, enabling individuals to move safely and interact effectively with their surroundings. However, for visually impaired individuals, these activities become significantly challenging due to the absence of visual perception. According to the World Health Organization (WHO), more than 2.2 billion people worldwide live with some form of vision impairment, creating a growing need for effective assistive technologies that can improve mobility, safety, and independence.

Traditional mobility aids such as white canes and guide assistance provide limited support, as they are primarily restricted to short-range and ground-level obstacle detection. These methods are often unable to detect obstacles at head level or at greater distances, increasing the risk of collisions and reducing user confidence, particularly in unfamiliar or crowded environments. Such limitations highlight the need for intelligent wearable systems capable of providing real-time environmental awareness.

Recent advancements in embedded systems, wearable electronics, and sensor technologies have enabled the development of smart assistive devices for visually impaired users. Among these technologies, ultrasonic sensing is widely preferred because of its low cost, reliability, ease of implementation, and real-time obstacle detection capability. Although several existing systems use artificial intelligence and advanced processing techniques, many of them suffer from high implementation costs, bulky hardware, increased complexity, and

reduced accessibility for economically weaker users.

To address these challenges, this work proposes the Ultrasonic Glasses for the Blind system, a lightweight and portable wearable assistive device that integrates an HC-SR04 ultrasonic sensor, Arduino Nano microcontroller, ISD1820 voice module, rechargeable battery, and compact spectacle frame. The system continuously monitors the surrounding environment, calculates obstacle distance using ultrasonic echo-time analysis, and provides immediate voice-based alerts whenever an obstacle is detected within a predefined threshold range.

The major contribution of this work lies in its affordability, portability, low power consumption, and intuitive voice-guided feedback mechanism. Unlike conventional buzzer-based systems, the proposed voice-alert approach provides clearer navigation assistance and improves usability. The system is designed to offer an efficient, practical, and cost-effective solution that enhances independent mobility and safety for visually impaired individuals in real-world environments.

LITERATURE REVIEW

Several assistive technologies have been developed to improve mobility and navigation for visually impaired individuals. These systems mainly focus on obstacle detection, environmental awareness, and real-time user guidance using ultrasonic sensing, computer vision, artificial intelligence, and wearable embedded systems.

Bai et al. (2017) proposed smart guiding glasses for visually impaired individuals in indoor environments using ultrasonic sensing and intelligent obstacle avoidance mechanisms. The system demonstrated effective indoor navigation performance and reliable obstacle detection. However, the implementation was primarily optimized for indoor applications, limiting its adaptability to dynamic outdoor environments.

Shashitha and P. A. Babu (2021) developed ultrasonic smart spectacles designed to provide obstacle detection for visually impaired users. The system was simple, low-cost, and easy to implement. Although the design achieved effective obstacle sensing, its alert mechanism relied mainly on basic warning outputs, reducing intuitive communication and practical usability in real-world conditions.

S. Busaeed et al. (2022) introduced LidSonic, a machine learning-based assistive smart glasses system integrating ultrasonic sensing with smartphone-based processing. The system achieved improved object recognition and navigation assistance. However, the dependency on machine learning algorithms and smartphone processing increased computational complexity, hardware cost, and power consumption.

A. A. O. Adegoke et al. (2019) designed obstacle-detecting smart glasses for visually impaired users using embedded ultrasonic sensing technology. The system demonstrated reliable obstacle detection performance with low implementation cost. However, limited portability and basic alert feedback restricted user interaction quality and reduced practical convenience.

Mukhiddinov and J. Cho (2021) proposed a deep learning-based smart glasses system capable of advanced object detection and environmental recognition. Although the system provided highly accurate obstacle classification, it required powerful processing hardware and significantly increased system complexity and overall implementation cost.

A. A. Ferreira et al. (2025) presented modular smart glasses for real-time obstacle detection using advanced sensor integration. Their system improved flexibility and detection performance but involved increased hardware complexity and higher implementation cost, making it less accessible for economically weaker users.

Despite significant advancements in assistive technologies, several limitations remain, including high implementation cost, bulky hardware design, dependency on artificial intelligence-based processing, increased computational complexity, and reduced affordability for practical daily deployment. Many existing systems also lack intuitive real-time voice-based guidance, which limits usability for visually impaired users.

To overcome these limitations, the proposed Ultrasonic Glasses for the Blind system integrates an HC-SR04 ultrasonic sensor, Arduino Nano microcontroller, ISD1820 voice module, rechargeable battery, and lightweight spectacle frame to provide real-time obstacle detection with immediate voice-based feedback. Unlike conventional buzzer-based systems, the proposed voice alert mechanism offers clearer and more intuitive guidance. The system is designed to be affordable, portable, energy-efficient, and practical for daily use, making it an effective assistive solution for enhancing mobility, safety, and independence for visually impaired individuals.

Proposed System

System Overview

The proposed system is a smart wearable assistive device designed to support visually impaired individuals by providing real-time obstacle detection and voice-based navigation assistance. The system utilizes ultrasonic sensing technology to detect nearby obstacles and generate immediate voice alerts, enabling safer and more independent navigation.

The system mainly consists of an HC-SR04 ultrasonic sensor, Arduino Nano microcontroller, ISD1820 voice module, speaker, rechargeable Li-Po battery, TP4056 charging module, and spectacle frame. The ultrasonic sensor continuously measures the distance between the user and surrounding objects by transmitting ultrasonic sound waves and receiving their reflected echoes.

The Arduino Nano processes the sensor data and compares the measured distance with predefined threshold values. Whenever an obstacle is detected within the specified range, the controller activates the ISD1820 voice module to generate a pre-recorded audio warning through the speaker.

The complete system is lightweight, portable, rechargeable, and mounted on a spectacle frame, making it comfortable for daily use. The novelty of the proposed system lies in its affordability, low power consumption, compact wearable design, and intuitive voice-based obstacle alert mechanism.

METHODOLOGY

The proposed system operates through the following sequence of steps for real-time obstacle detection and user assistance:

1. The HC-SR04 ultrasonic sensor continuously emits ultrasonic sound waves toward the surrounding environment.
2. These ultrasonic waves strike nearby obstacles and are reflected back toward the sensor receiver.
3. The sensor measures the echo return time and calculates the obstacle distance using the following formula:

$$\text{Distance} = (\text{Time} \times \text{Speed of Sound}) / 2$$

Where the division by two accounts for forward and reflected signal travel.

4. The Arduino Nano receives and processes the measured distance information.
5. The measured distance is compared with a predefined threshold value.
6. If the obstacle distance is less than the threshold value, the Arduino Nano activates the ISD1820 voice module.
7. The voice module generates a pre-recorded audio warning through the speaker to alert the user.
8. The user receives the warning and takes corrective action to avoid collision.

9. The process repeats continuously for real-time environmental monitoring and obstacle detection.

Hardware Components

HC-SR04 Ultrasonic Sensor

The HC-SR04 ultrasonic sensor is used for obstacle detection by measuring the distance between the user and surrounding objects using ultrasonic sound waves. It consists of a transmitter and receiver that work together to calculate the distance by measuring the echo return time. The sensor continuously scans the environment and sends distance information to the microcontroller for processing.

Specifications:

Operating Voltage: 5V DC Measuring Range: 2 cm to 400 cm Operating Frequency: 40 kHz
Accuracy: ± 3 mm

Measuring Angle: $<15^\circ$

Arduino Nano

The Arduino Nano acts as the main controller of the system. It receives data from the ultrasonic sensor, processes the measured distance, and controls the voice alert mechanism accordingly. It is based on the ATmega328P microcontroller and is widely used in embedded applications due to its compact size, low power consumption, and ease of programming.

Specifications:

Microcontroller: ATmega328P Operating Voltage: 5V

Digital I/O Pins: 14 Analog Input Pins: 8 Clock Speed: 16 MHz Flash Memory: 32
KB

ISD1820 Voice Module

The ISD1820 voice module is used for recording and playing pre-recorded voice messages. In this project, it generates voice alerts such as "Obstacle Ahead" whenever the system detects an obstacle within the predefined range. This provides clear and effective audio guidance for the user. Features:

Recording Time: Up to 10 seconds Operating Voltage: 3V–5V

Built-in Microphone Speaker Support

Low Power Consumption

TP4056 Charging Module

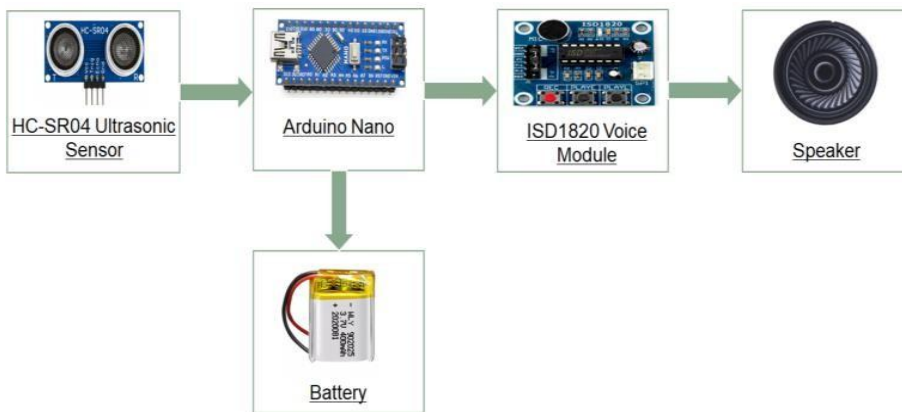
The TP4056 charging module is used to safely charge the

V lithium-polymer battery. It provides protection against overcharging, over-discharging, and short circuits, ensuring safe battery operation and increasing the overall reliability of the system.

Features:

Input Voltage: 5V Battery Protection Circuit Overcharge Protection Short Circuit
Protection Compact Design

Fig. 3.1 System Block Diagram



Li-Po Battery

The 3.7V lithium-polymer (Li-Po) battery supplies power to the entire system. It is lightweight, rechargeable, and suitable for wearable devices, ensuring portability and uninterrupted system operation.

Features:

Rechargeable Lightweight and Portable High Energy Density Long Backup Time

Speaker

The speaker is used to deliver voice alerts generated by the ISD1820 module. It provides clear audio output to inform the user about nearby obstacles and helps improve navigation safety.

Features:

Clear Audio Output

Low Power Consumption Compact Size

Easy Integration with Voice Module

Spectacle Frame

The spectacle frame serves as the physical structure for mounting all hardware components. It is lightweight, comfortable to wear, and ensures proper placement of the ultrasonic sensor for accurate obstacle detection.

Features:

Lightweight Design Comfortable for Daily Use Durable Structure

Supports Wearable Integration

System Block Diagram

The block diagram below presents the complete signal and data flow of Ultrasonic Glasses for the Blind system from obstacle detection to voice output, organized across its processing stages.

System Workflow Analysis

The system workflow analysis explains the complete step-by-step operation of the Ultrasonic Glasses for the Blind system, from obstacle detection to voice alert generation. The workflow ensures continuous environmental

monitoring and provides real-time audio assistance to visually impaired users for safe navigation.

Step 1: Ultrasonic Signal Transmission

In the initial stage, the HC-SR04 ultrasonic sensor generates high-frequency sound waves (approximately 40 kHz) and transmits them into the surrounding environment. These ultrasonic waves travel forward until they encounter an object or obstacle. This process enables the system to continuously scan the user's path for potential obstructions in real time.

Step 2: Echo Reception

When the transmitted ultrasonic waves strike an obstacle, they are reflected back toward the sensor as echoes. The receiving unit of the sensor captures these reflected waves and records the time interval between transmission and reception. This echo return time is essential for determining the exact distance of the obstacle from the user.

Step 3: Distance Calculation

The Arduino Nano microcontroller processes the measured echo return time to calculate the distance of the obstacle. This calculation is based on the principle of sound wave propagation, where the total travel time of the wave is divided by two to account for both forward and return travel. The calculated distance provides accurate real-time information about nearby obstacles.

Step 4: Data Processing and Threshold Comparison

The calculated distance value is compared with a predefined safety threshold stored in the Arduino Nano. If the detected obstacle lies outside the threshold range, the system continues monitoring without generating an alert. If the obstacle is detected within the critical range, the system initiates the warning process.

Step 5: Voice Alert Activation

When an obstacle is detected within the predefined distance, the Arduino Nano sends a control signal to the ISD1820 voice module. The module activates and plays a pre-recorded warning message such as "Obstacle Ahead" through the connected speaker.

Step 6: User Notification

The speaker delivers a clear audio alert to notify the user about the detected obstacle. This immediate feedback allows the user to react quickly and change direction or stop, thereby preventing collisions and ensuring safer movement.

Step 7: Continuous Monitoring

After the alert is delivered, the system automatically resumes scanning the environment. This process repeats continuously to provide uninterrupted obstacle detection and navigation assistance during movement.

Circuit Diagram and Connections

The circuit diagram illustrates the interconnection of all hardware components used in the Ultrasonic Glasses for the Blind system. The HC-SR04 ultrasonic sensor is interfaced with the Arduino Nano through digital trigger and echo pins for distance measurement. The ISD1820 voice module is connected to digital pin D8 of the Arduino Nano for playback activation and voice alert generation. The TP4056 charging module is used to safely charge and regulate the Li-Po battery supply, while the speaker provides real-time audio alerts to the user.

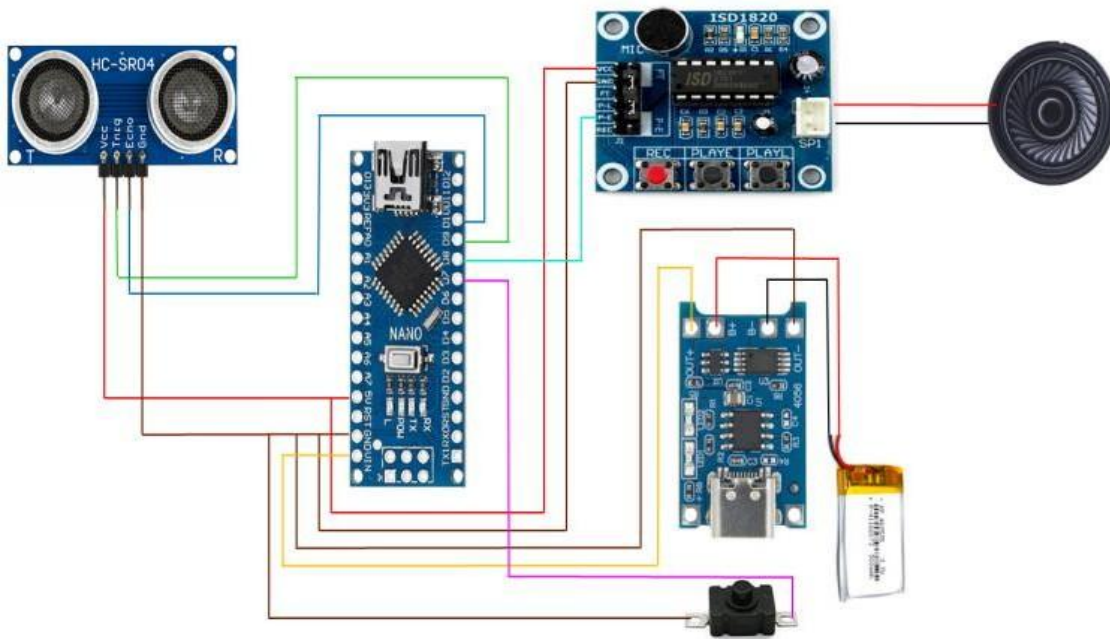


Fig. 4.1 Circuit Diagram of Ultrasonic Glasses **Sensor Connections (HC-SR04 to Arduino Nano)** HC-SR04 Pin Arduino Nano

VCC	5V
GND	GND
TRIG	D9
ECHO	D10

Voice Module Connections (ISD1820 to Arduino Nano)

ISD1820 Pin	Arduino Nano	VCC	5V
GND	GND		
PLAYE	D8		

Battery and Charging Connections

TP4056 Module	Arduino Nano	OUT+	VIN
OUT-	GND		

Battery Terminals:

Li-Po Positive → B+ Li-Po Negative → B-

The Arduino Nano continuously receives obstacle distance data from the ultrasonic sensor and processes it in real time. When an obstacle is detected within the predefined threshold distance, the controller activates the ISD1820 voice module, which generates a pre-recorded audio warning through the speaker. The TP4056 charging module ensures safe battery charging and stable power supply, making the system portable, efficient, and suitable for wearable assistive applications.

IMPLEMENTATION AND RESULTS

Sensor Testing

The HC-SR04 ultrasonic sensor was tested for obstacle detection and distance measurement performance. Experimental testing confirmed accurate obstacle detection within the sensing range of 2 cm to 400 cm. The measured distance values were consistent and reliable, and the sensor response time was sufficiently fast for real-time operation. The results verified that the sensor is suitable for continuous environmental monitoring in wearable assistive applications.

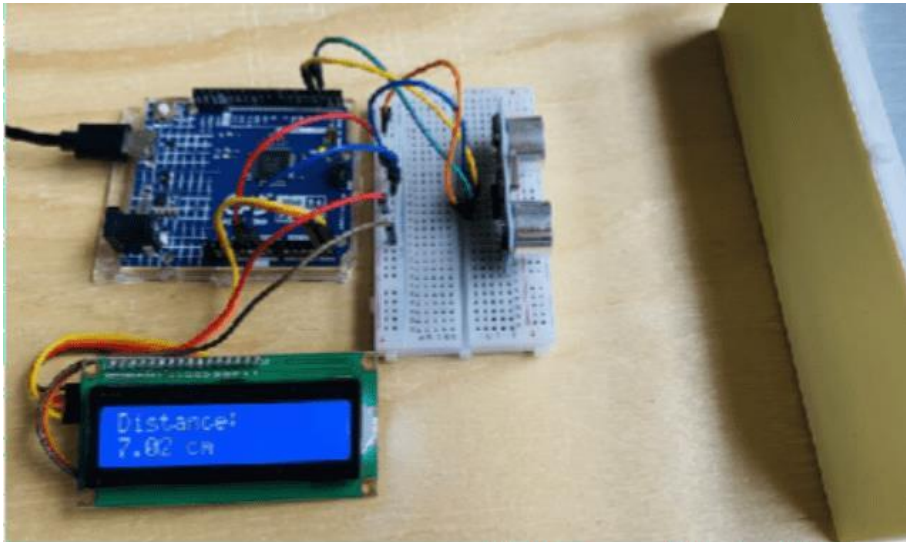


Fig. 5.1 Testing of HC-SR04 Ultrasonic Sensor

Voice Module Testing

The ISD1820 voice module was tested with a speaker to generate obstacle warning alerts. The module successfully played the pre-recorded voice message whenever an obstacle was detected within the predefined threshold distance. The audio output was clear, understandable, and sufficiently loud for practical real-time user notification.



Fig. 5.2 Testing of Voice Module (ISD1820) with Speaker

Power Module Testing

The system was powered using a 3.7V rechargeable Li-Po battery integrated with a TP4056 charging module. The charging circuit ensured safe battery charging and stable voltage regulation during operation. Power consumption was low, allowing extended portable usage and making the system practical for wearable daily assistance.



Fig. 5.3 Testing of 3.7V Li-Po battery

Complete System Testing

All hardware components were successfully integrated onto the spectacle frame and tested as a complete wearable assistive system. During testing, the ultrasonic sensor accurately detected obstacles positioned in front of the user, while the Arduino Nano processed sensor data and activated the ISD1820 voice module in real time. The system demonstrated stable operation, reliable obstacle detection, and immediate voice feedback, confirming its effectiveness as a smart navigation aid for visually impaired individuals.



Front View (Sensors)



Side View (Modules)

Fig. 5.4 Testing of Complete Ultrasonic Glasses System (a & b)

Advantages and Applications

Advantages

Low Cost

The proposed system uses simple and affordable electronic components, making it a cost-effective solution compared to existing assistive devices.

Easy to Use

The system is user-friendly and does not require any special training for operation.

Low Power Consumption

The device consumes very low power and operates efficiently using a rechargeable battery.

Real-Time Obstacle Detection

The system provides instant voice alerts for immediate obstacle detection and quick user response.

Portable and Lightweight Design

Mounted on a spectacle frame, the device is compact, lightweight, and comfortable for daily use.

Applications

Mobility Assistance for Visually Impaired Individuals The system helps blind and visually impaired users detect obstacles and move safely.

Indoor Navigation

It assists users in avoiding obstacles such as walls, furniture, and household objects.

Outdoor Navigation

The device enables safer movement on roads, footpaths, and public places.

Educational and Research Applications

The system is useful for learning embedded systems, sensor interfacing, and assistive technology development.

Affordable Assistive Technology Solution

It serves as a low-cost alternative to expensive navigation assistance systems.

Future Scope

The proposed system can be further enhanced by integrating advanced technologies and additional features to improve performance and usability.

1. GPS-Based Navigation System

A GPS module can be integrated to provide real-time location tracking and route guidance.

2. AI-Based Object Recognition

Artificial intelligence can be used for object identification and obstacle classification.

3. Wireless Connectivity

Bluetooth or Wi-Fi integration can enable smartphone connectivity and remote monitoring.

CONCLUSION

The proposed Ultrasonic Glasses for Blind Assistance provide an effective and reliable solution for visually impaired individuals. The system uses ultrasonic sensing technology to detect nearby obstacles and generates real-time voice alerts through a speaker, helping users move safely and independently.

The Arduino Nano efficiently controls the system and ensures fast obstacle detection with quick response time. The device is compact, lightweight, portable, low-cost, and easy to use in both indoor and outdoor environments.

Experimental testing confirmed that the system successfully detects obstacles and improves user safety and mobility. This project demonstrates the practical use of embedded systems and assistive technology for solving real-life challenges faced by visually impaired people.

Future improvements such as GPS integration, artificial intelligence, and additional sensors can further enhance system performance and usability.

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