FEDERAL UNIVERSITY OF TECHNOLOGY, AKURE
JOURNAL OF ENGINEERING AND ENGINEERING TECHNOLOGY

# DEVELOPMENT OF A MICROCONTROLLER-DRIVEN OBSTACLE DETECTION AND NAVIGATION SMART EYEGLASSES FOR THE VISUALLY IMPAIRED

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Olubunmi O. A., Awe O. F., Ayeni T. R., and Ogundipe O. J. (2026): Development of a Microcontroller-Driven Obstacle Detection and Navigation Smart Eyeglasses for the Visually Impaired. FUTA Journal of Engineering and Engineering Technology, 20 (special) 166-173

**Received Date: 15.01.2026** **Accepted Date: 10.03.2026**

***Abstract***

For persons with visual impairment, taking part in day-to-day activities can be especially challenging, because their physical limitations also put them at a greater risk of falling. In some cases, it can be life-threatening. We present an innovative assistive device that intends to help blind people in wayfinding and determining the presence of objects, especially at face-level, as well as for alerting them about dangerous situations. This obstacle avoidance and navigation system, based on an ATmega328 Arduino microcontroller, is intended for blind pedestrians. This device uses ultrasonic sensors, which detect obstacles nearby, allowing safe and easy manoeuvrability in risky places. Attached is a buzzer that produces auditory alerts for impending danger. The main component is the Arduino Uno board, which holds the ATmega328 microcontroller essential for control and coordination of the system. The whole system in the form of smart eyeglasses weighs merely 73 grams, runs on a 3.7-volt battery and, has an obstacle detection range of 59.97 cm. The ultrasonic sensor sends a signal to the microcontroller when it detects an obstacle within the 59.97 cm range. The microcontroller processes this input and activates the buzzer output components. The buzzer will give audio alerts, providing an auditory alert to the user regarding the obstacle through these alerts. The main objective of the system that is being proposed is to improve the user awareness regarding their path, along with detecting and informing any obstacles that may come their way.

***Keywords:*** *Visual Impairment, Assistive Device, Obstacle Avoidance and Navigation System, Smart Eyeglasses, Arduino Uno, ATmega328 Microcontroller.*

## Introduction

According to the International Agency for the Prevention of Blindness (IAPB), over 1.1 billion people worldwide live with varying degrees of visual impairment, including 24.27 million people in Nigeria (Bourne et al., 2020). Having a visual impairment increases the risk of injury and death. Due to systemic, structural and health problems, the incidence of injuries with low vision is prevalent in the developing countries. Other than trauma, it appears that vision impairment also has a dose-response effect on all-cause mortality. Severe vision impairment has been found to have a hazard ratio of 1.89 for death when compared with having normal vision. This increased risk also applies to death due to cardiovascular problems and injury, showing the independent links between visual impairments and systemic health deterioration. The public health burden from being blind stems from the intersection of the pathways of chronic disease and the pathways from biomechanical hazards, which calls for integrated interventions forinjuries and mortality outcomes (Ekemiri et al., 2024; Han et al., 2021).

With all the improvements being made in society for the greater good, the plight of persons suffering deep hardships owing to blindness is something that is getting neglected. This underprivileged group continues to face systemic issues like accessibility and inclusivity, demonstrating the pressing need for equitable tech and social solutions. In performing daily activities, people with visual disabilities encounter a lot of challenges, leading to more dependence on others. The simultaneous presence of functional limitations and social exclusion exacerbates their susceptibility in mainstream society (Rhamati et al., 2025; Remillard et al., 2023).

Moreover, those with visual impairments frequently require external support for safe and independent mobility. Current assistive methodologies, as documented in the literature, encompass a spectrum of technological and human-centred solutions designed to facilitate navigation. These methodologies range from conventional mobility aids to advanced electronic systems, each trying to address the multifaceted environmental challenges encountered by this population. Efforts must continue in this regard to research and implement innovative solutions that promote both independence and enhanced quality of life for individuals with visual impairments.

A common method to help blind people relies on specially trained service animals, such as guide dogs and possibly guide cats. Though these animals can help quite considerably, this method has its own number of considerable limitations, which are financial costs and a long period of adjustment (Hwang et al., 2022; Lloyd et al., 2021). The latest developments in assistive technology are a great step forward in mobility for the blind. A range of new technologies has been developed to combat the problems faced by this group. Unfortunately, a lot of solutions have significant drawbacks, which mainly consist of user experience issues and cost issues, so they are not used in practice or widely accepted in the community (Masal et al., 2023).

The goal of this project is to come up with an assistive smart device for navigation that helps visually impaired individuals. The technology has the potential to achieve autonomous mobility and reduce the necessity for human help and white cane use by the vision-impaired. The obstacle detection smart eyeglasses will help visually impaired individuals by enhancing their mobility and safety during their daily activities. This creative wearable device uses ultrasonic wave technology built into glasses. The system produces environmental feedback in real-time through sound alerts to move without fear by detecting nearby obstacles.

Thus, this research seeks to develop cost-efficient and simpler smart eyeglasses with ultrasonic technology for detecting obstacles to make the disabled more aware of hazards and respond to them. Another goal was to determine whether the developed prototype functions correctly and operates reliably.

**Related Works**

During the past decade, a range of assistive technology systems has been proposed for the visually impaired. These systems utilise various mechanisms and technologies to enhance adaptability and independence. The use of smart sticks by the visually impaired to aid navigation and obstacle detection has been researched by several researchers (Wani et al., 2025; Khan et al., 2024; Solanki et al., 2023). The system's objective is to improve the identification of potholes and obstacles on the paths of visually impaired persons for the safe travelling of users. The systems designed include a unit for an ultrasonic sensor interfacing with a microcontroller unit, which controls the working of a smart stick through a feedback system. The information is implanted within the system to warn users of any hazards or challenges.

According to Akula et al. (2023), researchers designed a device for the visually impaired that can incorporate multiple cameras, enabling a wider area coverage. There is a Raspberry Pi used for object detection and giving voice feedback. An Arduino which has ultrasonic sensors is used to detect obstacles and alert them accordingly. These sensors use infrared waves that get reflected from stationary or moving objects to avoid collisions. The Arduino Uno-based microcontroller processes the data and indicates the surroundings and obstacles of users in real time.

Another research proposes an inexpensive navigation system aimed at enhancing the lives of most people with visual impairment. An ultrasonic smart walking stick for blind people that detects various obstacles through vibration and audio alerts is considered in this work (De Alwis and Samarawickrama, 2017).

Donkrajang et al. (2012) designed a complementary system equipped with a GSM-GPS module that accurately determines the location of a blind person and enables two-way wireless communication. This system uses ultrasonic sensors to detect obstacles. The GPS-GSM unit gives directions and location coordinates to help navigate safely. Extra features in the alarm system include audio output through a buzzer, tactile output through a vibrator, and motion detection through an accelerometer sensor. Built to be compact and lightweight in size, it will work hand in glove with a normal mobility cane. The barrier recognition system first recognises an obstacle and then delivers information about it to the user in various ways. This could be its distance from the user, orientation and could be in an audible mode or tactile feedback.

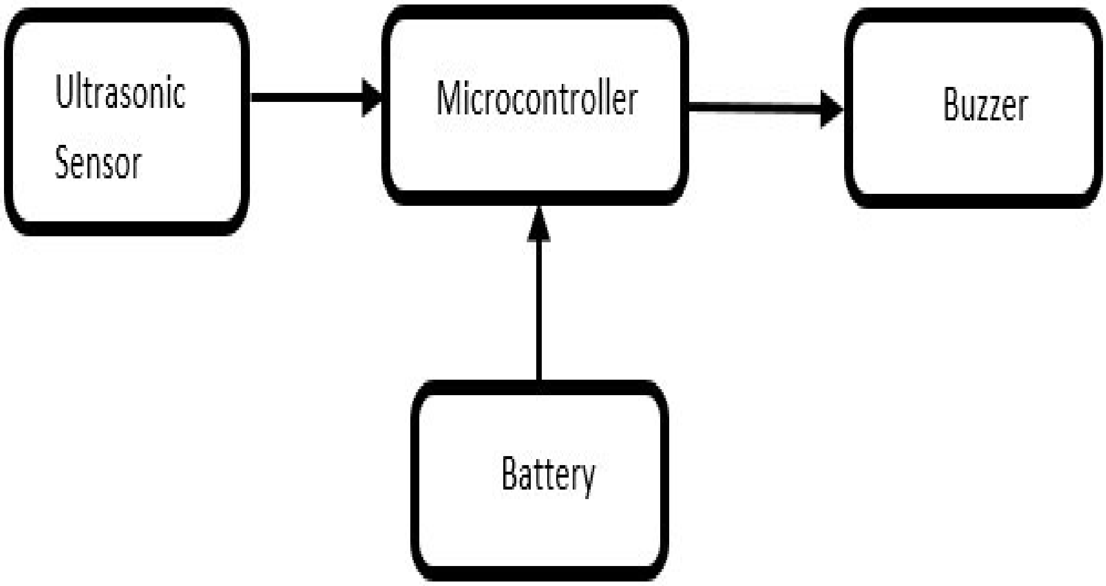


Figure 1: Block Diagram of the Proposed System

**Methodology**

Figure 1 illustrates a simplified methodology and hardware architecture for smart eyeglasses intended to assist the visually impaired with obstacle detection and navigation. The methodological approach is based on functional modularisation, facilitating the isolated examination of individual system elements to reduce analytical burden during fault diagnosis, as described below.

- **Ultrasonic Sensor:** This sensor emits high frequency, inaudible sound waves and detects their echoes after bouncing off nearby obstacles. This allows the system to measure the distance between the user and objects in their path, and mounted on the eyeglasses' frame, the sensor continuously scans the environment within a 59.97cm range.
- **Arduino Uno-based ATmega328 Microcontroller**: This microcontroller acts as the central processing unit. It receives distance data from the ultrasonic sensor and calculates the proximity, direction, and size of detected obstacles. The algorithms within the microcontroller interpret the sensor data to determine threat levels like imminent collision against a distant object. Based on this analysis, it triggers appropriate alerts via the buzzer.
- **Buzzer:** It indicates with beeps or tones the presence of obstacles, which can harm the user. The sound of the buzzer changes in pitch, frequency, or pattern with the direction. For instance, a series of quick beeping sounds means the user is near an object or person. On the other hand, slow beeps are an indication of a faraway obstacle.
- **Rechargeable Battery:** It supplies the required power to all the components in the system like the ultrasonic sensor, the Arduino Uno board microcontroller, and the buzzer. A compact, 3.7v rechargeable battery ensures portability and uninterrupted operation, enabling users to rely on the device during daily activities.
- **Eyeglasses:** The prototype assembly is constructed by securely attaching all other components to the frame of the eyeglasses, resulting in a consolidated, operational, and wearable unit.

**Proposed System Flowchart**

Figure 2 represents the system algorithm consisting of three primary steps as listed below;

Step 1: initiates the startup of the system.
Step 2: obstacle scan is executed; the operation proceeds to step 3 if an obstacle is detected.
Step 3: buzzer beep or tone is activated; if no obstacle is detected, the system goes back to Step 2 to continue scanning.

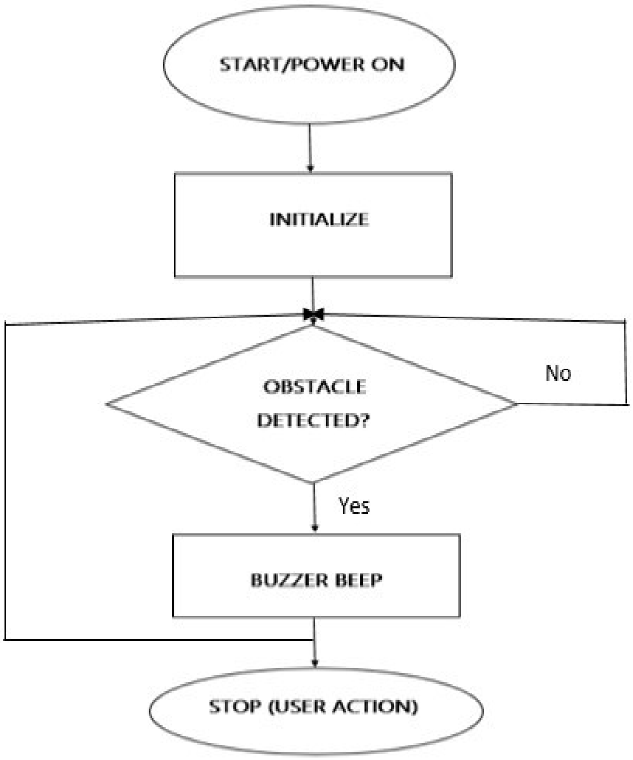


Figure 2: The System Flowchart

- **Proposed System Operation and Circuit**

When the visually impaired person begins to move, the obstacle detection and navigation aid, worn as a pair of eyeglasses, aligns with their intended pathway. This device has an ultrasonic sensor built into its body, which constantly checks its nearby surroundings for obstacles so that the user can move freely and safely.

- The ultrasonic sensor produces an electric signal which goes to an ATmega328 microcontroller to detect any obstacle. The microcontroller then processes this input and activates the buzzer mechanism to generate some sounds. It warns the user to take quick action to avoid collision through these audible alerts. The user switches off the sound alarm, and the system continues monitoring continuously and guiding the user. The circuit diagram of smart eyeglasses that consists of a sensor, microcontroller and buzzer is shown in Figure 3.

**Tests and Results**

The testing was conducted in two distinct phases:

- **Pre-testing:** Initial validation procedures were conducted on individual components or parts to verify compliance with operational specifications regarding the quality, reliability, and safety of such device or component. Specialised diagnostic instruments, such as a digital multimeter, were systematically employed during this preliminary evaluation phase.

- **Post-testing**: The obstacle detection and navigation assistance mechanism was algorithmically configured via the Arduino Uno microcontroller using the Arduino Integrated Development Environment (IDE), enabling detection of obstructions across calibrated distance thresholds. During validation, the system underwent empirical testing with standardised test objects positioned at preprogrammed benchmark distances. Measured detection distances were systematically recorded and analysed against the algorithmically defined parameters. As evidenced by the comparative data in Table 1, the intelligent eyewear demonstrated operational efficacy, with observed detection metrics exhibiting congruence between empirical measurements and predefined thresholds. This outcome confirms the system's adherence to its intended design specifications during the validation protocol.

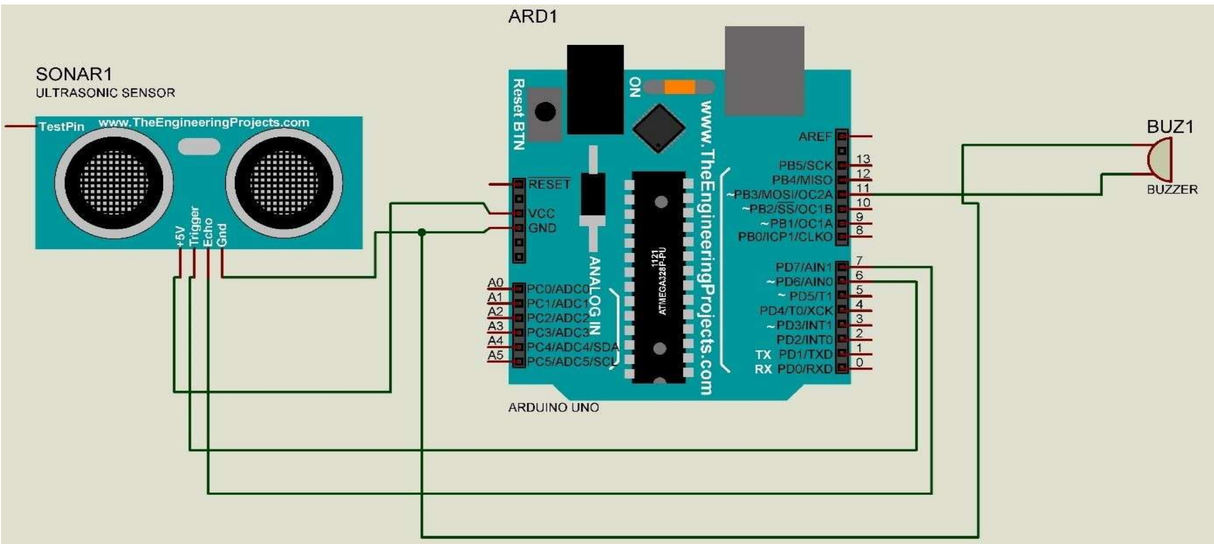


Figure 3: Proteus Circuit Design of the Proposed System

Table 1: Smart Eyeglasses Test Results

| S/N | Distance [cm] | Beep |
|---|---|---|
| 1. | 40.55 | On |
| 2. | 59.97 | On |
| 3. | 85.06 | Off |
| 4. | 110.63 | Off |
| 5. | 133.81 | Off |
| 6. | 162.08 | Off |

**Hardware Implementation of the System**

The implementation of the system involved the construction of the system using the jumper wires, which are used in connecting to an Arduino Uno microcontroller. Before being tested as a part of the final circuit, modules were tested alone. In the first phase of the development, the ultrasonic sensor subsystem was fixed onto the arm of the wearable eyeglasses. The circuit was then incorporated with the sound-producing element or buzzer, and the portable power supply was adjusted to ensure proper working. The completed prototype is shown in Figure 4a and 4b, as a pair of smart eyeglasses provided to help the visually impaired to detect obstacles and improve navigation.

**Conclusion**

The obstacle detection and navigation system developed for persons with visual impairments is cheap, portable, and durable. It reduces the stress on caregivers while improving safety and comfort for users during movement. Several tests conducted demonstrate encouraging outcomes, justifying the practical execution of the system. The device operates on predefined specifications, presenting a satisfactory outcome.

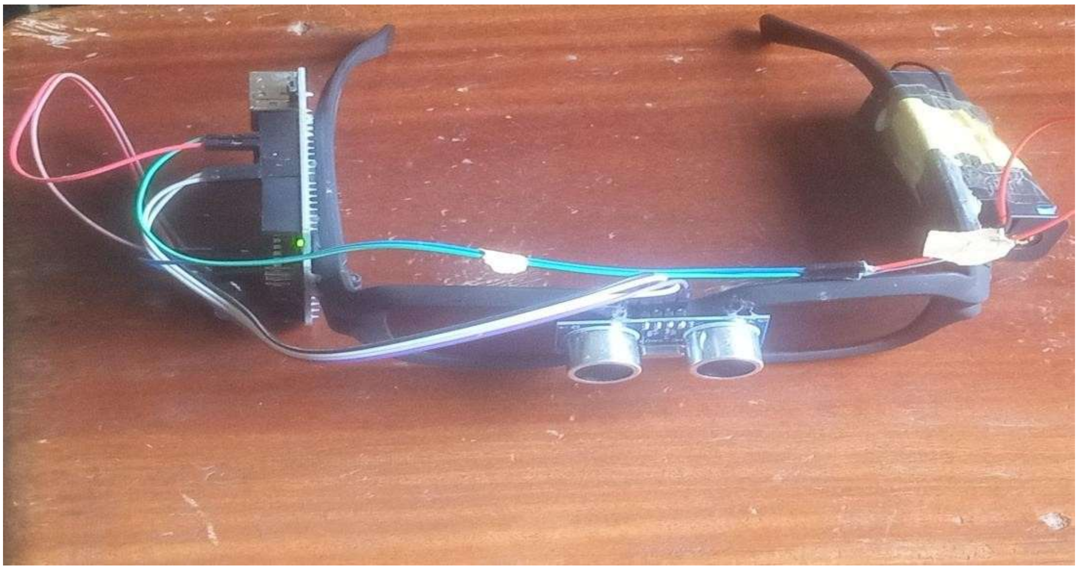

Figure 4a: Frontal view of the system

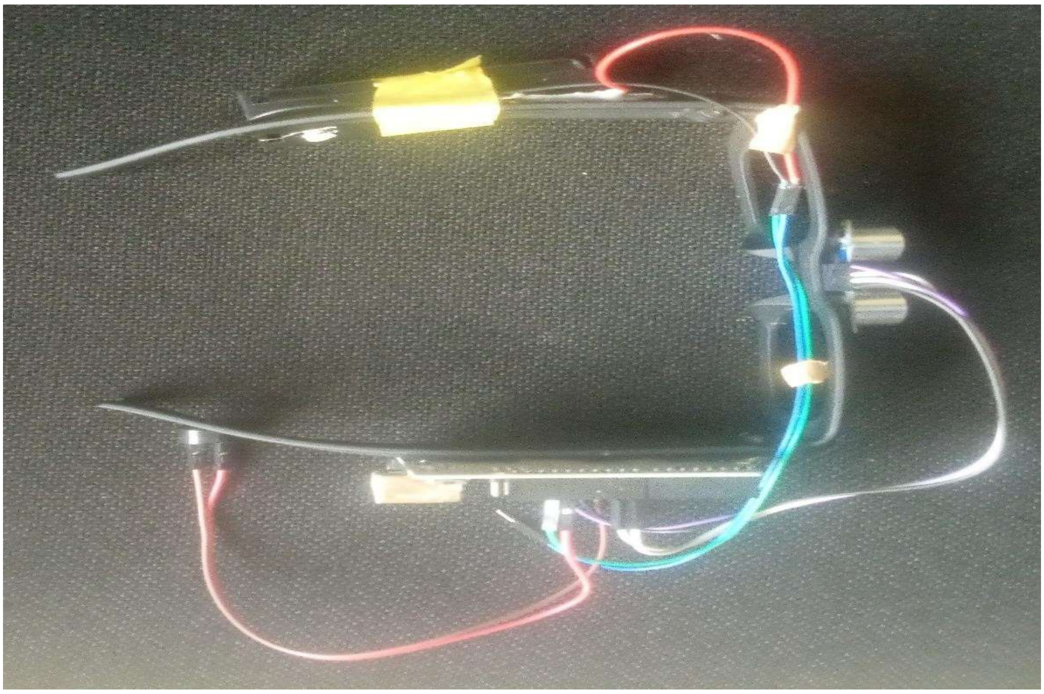

Figure 4b: Top view of the system

Functionally, it gathers real-time environmental data through integrated sensors, processes and synthesises this information, and transforms it into sounds as feedback, enabling users to understand and respond to environmental cues. Unique auditory patterns are employed to differentiate the extent of proximity to any obstruction on the user's path, ensuring intuitive user interpretation.

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