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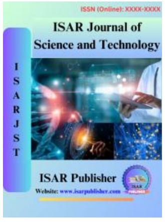

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Design and Implementation of IoT Based Smart Glasses Device for Visually Impaired People

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Abstract: Visually impaired people face tremendous challenges in navigating their environment in a safe and independent way. As a response to these challenges, this project provides the Smart Glasses for Visually Impaired People, an assistive device to enhance mobility, safety, and emergency y communication. The system utilizes ultrasonic sensors, ESP32 Wi-Fi module, GPS module, GSM module, vibration motor and LiPo battery to provide real-time obstacle detection, GPS navigation n, and emergency SMS notificationn. The ultrasonic sensors detect objects at a distance of up to 1 meter, and the system provides haptic (vibration) and audio feedback to alert the user. During an emergency, the GSM module (A6) sends an SMS alert along with GPS coordinates to a pre-registered contact, allowing remote assistance. The ESP32 module sends real-time location and sensor data to Thing Speak, allowing remote tracking of the user's movement. The data from thingspeak retrieved to the web page dashboard. The system is energy-efficient, low-cost, and portable, suitable for the visually impaired. It offers real-time obstacle detection, IoT-based remote tracking, and emergency response, significant ly improving user safety and mobility. The system was successfully tested and demonstrated high accuracy in obstacle detection and seamless GSM-GPS communication.

Keywords: ESP32, Ultrasonic Sensors, GSM (A6), GPS, Thing Speak, web page dashboard, LiPo Battery, IoT and Assistive Technology.

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1. Introduction

Blindness and visual impairment severely impair millions of individuals worldwide, reducing their mobility and independence. The World Health Organization (WHO) reports that not less than 2.2 billion individuals worldwide suffer from near vision or distance vision impairment and that at least 1 billion of these conditions are preventable or remain uncured [1]. The sex- and age-adjusted blindness prevalence in Rwanda is approximately 1.1%, of which 83.9% is preventable and is mostly caused by cataract [2]. For the blind, safe mobility poses a major challenge, particularly outdoors. It is impossible to steer clear of crowded pavements, impediments, and hazards such as stairs, potholes, poles, glass doors, and moving cars. Traditional mobility devices such as white canes and guide dogs do not work, particularly in complex city environments. In the interest of mobility and autonomy, various assistive technologies have been explored. Existing solutions such as wearable cameras and LiDAR-based systems are often expensive or internet-reliant. This necessitates a low-cost, robust, and independent smart navigation system. This project proposes Smart Glasses for Visually Impaired based on ultrasonic sensors, vibration n motors, and voice messages being used to find obstacles and assist the users. The system includes a GSM module for calling emergencies and GPS positioning for further safety.

2. Problem Statement

Blindness is generally misconceived, and blind people are under mobility restrictions that limit their autonomy. Most of them need the help of family members, friends, or regular aids such as white canes, which are limited in scope and perception. One of the biggest issues is the fact that one cannot see obstacles ahead and therefore end up being involved in accidents and injuries. The majority of visually impaired individuals utilize memory- based way-finding, and this becomes dangerous in dynamic environments where objects or barriers are in motion. Also, in an emergency situation, the blind individuals may not be able to request help or inform caregivers of their location. This makes it possible for easy instances of accidents, especially in isolated areas. For their solution, this project proposes the Smart Glasses for Visually Impaired Individuals, a wearable technology that enhances mobility by utilizing ultrasonic sensors for obstacle detection and real-time response through vibration and audio. It also includes an emergency alert through GSM module and GPS location tracking for real-time sharing.

3. Literature Review

The section identifies the basic ideas needed for the understanding of designing Smart Glasses for Visually Impaired People. Obstacle detection is essential in assistive technology for the blind. Ultrasonic sensors operate by emitting high-frequency acoustic waves and determining the time taken for reflection to take place after hitting an object. The time difference is employed to calculate the distance of the obstacle and provide feedback in the form of audio or vibration **[3]**. Ultrasonic-based navigation systems have also been studied extensively due to their affordability and efficiency. A study conducted by demonstrated the feasibility of wearable ultrasonic navigate aid, highlighting their capacity to identify obstacles up to 4 meters away with minimal error rates **[4].** This research project uses two ultrasonic sensors to detect obstacle in front, left and right. ESP32 calculate distance and determines the direction of safety accordingly: If the front is blocked, it looks both left and right. If one side is unobstructed, it tells the user to turn in that direction. If all the sides are interrupted, it alerts the user to quit or to stop moving. Emergence of visually impaired assistive technologies has become a broad research domain with the incorporation of sensor-based wayfinding, AI, and IoT-based technologies **[5].** This review seeks out associated research papers on smart glasses and wearable aid devices to identify existing solutions, their limitations, and contributions of this work **[6].** Smart Glasses for Visually Impaired Person: Others have investigated wearable assistive technology for visually impaired individuals, emphasizing navigation and object recognition using smart glasses. Envision Glasses by bala in 2021 rely on artificial intelligence (AI) to recognize objects and read texts, assisting visually impaired users **[7].** GPS and GSM modules have been studied for location tracking and emergency calls in assistive devices. For example, Chaudhary in 2020 developed a walking stick featuring a GPS and GSM module to allow users to transmit their location via SMS in the event of an emergency. However, as a handheld device, it had to be manually held at all times, which is impractical for the visually impaired [8]. Another research by Patil in 2021 presented an IoT-enabled intelligent navigation belt that alarms caregivers through GPS tracking. The system, although effective, was limited by its battery life and no real-time obstacle detection [9]. Another recent research by Fernandez in 2023, Discussed IoT based GPS tracking for the visually impaired. Their research highlighted data logging to support long-term mobility analysis but did not incorporate obstacle detection system [10]. The main contributions of this research are summarized as follows: *Create wearable smart glasses to enable mobility for the blind using ultrasonic sensors for obstacle detection in real time, Provide real-time vibration and sound alerts based on obstacle distance to guide users safely, Include GSM for emergency text messaging and GPS for live location tracking through SMS or Thing Speak, Test the system in actual environments and include a dashboard to show real-time GPS and obstacle data for analysis and monitoring.*

4. System Analysis and Design

4.1 Smart Glasses Design Architecture

Figure 1: Smart Glasses Design Architecture

The smart glasses, as shown in Fig. 1, is basically an embedded system integrating the following: pair of ultrasonic sensors to detect obstacles in front of the blind from ground level height to head level height in the range of 1m a head. Ultrasonic sensors and infrared sensor collect real time data and send it to microcontroller. After processing this data, the microcontroller actives the motor to vibrate and send SMS to any guidance of this blind human. rechargeable battery to power the circuits [11]. The ESP32 detects sensor input and activates the feedback system in the event of encountering obstacles. The GPS and sensor data are transmitted to Thing Speak, which it can then remotely analyze and access for dashboard output.

4.2. Flowchart Diagram

Flow diagram is a diagram representing a flow or set of dynamic relationships in a system. The term flowchart diagram is also used as a synonym for flowchart, and sometimes as a counterpart of the flowchart [12].

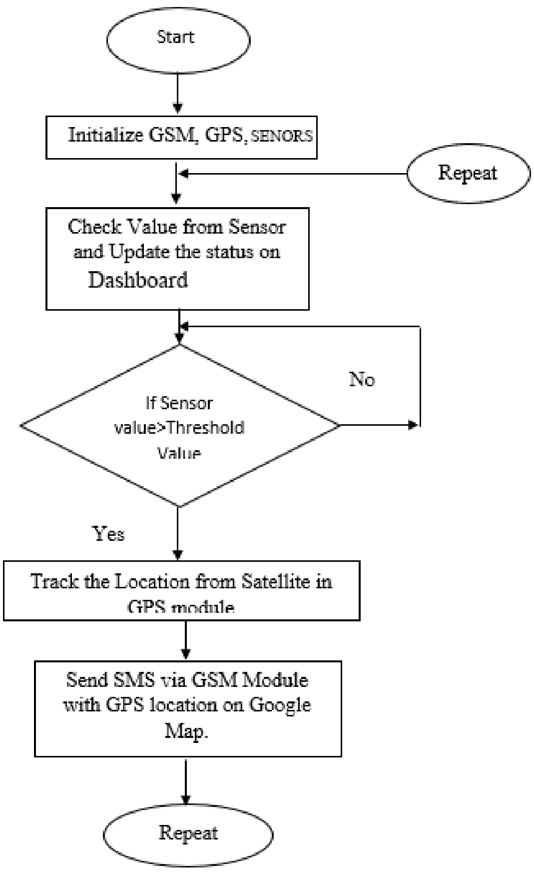

Figure 2: Energy Flow Diagram

As it is shown in fig 2: the flowchart shows the logical flow of how the system works.it described how GPS, sensors and GSM was initialized as inputs parameters and if it provides the output greater than threshold defined, the system will automatically provide the output but if not reaching the threshold, the system will repeat again on the initial steps. As the ESP32 is the heart of the system as all the individual units are interfaced with the Arduino. The ultrasonic sensor and the GPS, GSM unit and the vibration motor unit basically are the outputs from the microcontroller [13]. The motor unit alerts the user regarding the obstacle; the GSM unit provides message and call service to the dear ones of the user in case of emergency or failure. The diagram can be one of the suitable methods for observing the functional decomposition of the product as it demonstrates the presence of each module starting from its arrival till the service is served to the user and it describes how the modules are interlinked with each other and work together to achieve the desired goal.

4.3. System Design

The system provides obstacle data transmission and storage on ThingSpeak through HTTP requests. GPS positions are uploaded intermittently to send real-time location updates, supporting permanent monitoring. The stored data is then retrieved from ThingSpeak and displayed on a web-based dashboard for easy-to-use and user-friendly visualization and exploration of the data in real time.

Figure 3: System Design Overview

As shown in figure 3, this image illustrates a **Smart Glasses system for the visually impaired** using **GPS and GSM** for location tracking and emergency communication, combined with ultrasonic sensors for obstacle detection. Let's break down the key components and their connections. The system continuously sweeps the environment with ultrasonic sensors to detect obstacles, and sensor data is processed by the ESP32 microcontroller. On detecting an obstacle, the feedback mechanism is triggered, and a vibration motor and vibration motor are activated to alert the user in real time. During emergency, the emergency button sends an SMS alert and GPS location via the GSM module. For remote monitoring, the system provides GPS position and obstacle detection information to ThingSpeak in the form of HTTP requests. This information is then fetched and displayed in real- time on a web-based dashboard so that caregivers or monitoring centers can track the user's status and location efficiently.

4.4. Flowchart of Smart Glasses Working Principles

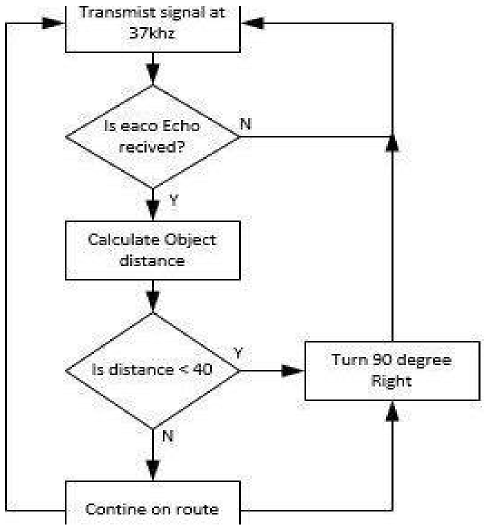

Figure4: Flow chart Smart Glasses Working Principal

The flowchart above in figure 4 , represents an obstacle detection and avoidance system. It starts by transmitting a 37kHz ultrasonic signal and waits for the echo. If an echo is received, it calculates the distance to the object. If the object is closer than 40 units (likely centimeters), the system turns 90 degrees to the right to avoid the obstacle. If the path is clear, it continues moving forward [14].. This process repeats continuously to ensure safe navigation, ideal for applications. The microcontroller then processes this data and calculates if the obstacle is close enough. If the obstacle is not that close the circuit does nothing. If the obstacle is close the microcontroller sends a signal to sound a vibration motor. This system the ultrasonic sensors are used to sense the obstacle (if there is any). The sensors are set a threshold limit if any obstacle is found within that range it gives beep speech through speaker. Generating, Detecting & Processing Ultrasonic Signals: Ultrasonic sensors generate sound waves above the frequency of human hearing and are used in a wide range of applications such as sonic rulers, proximity detectors, motion sensors, and liquid level measurement.

The **HC-SR04 ultrasonic sensor module** offers non-contact measurement from 2 cm to 400 cm, with an accuracy of up to 3 mm. Working Principle: The sensor is triggered using a 10 µs high-level pulse via the IO pin, the module emits eight 40 kHz ultrasonic pulses and waits for an echo, if the echo is received, the sensor outputs a high-level signal [15].The duration of this signal represents the time taken for the sound wave to travel to the obstacle and back. A **transducer** (which converts electrical energy into mechanical energy) is used for this operation. The **vibration motor**, which operates in the lower portion of the audible frequency range (20 Hz to 20 kHz), converts the electrical oscillating signal into mechanical energy in the form of sound waves. In this project, the vibration motor warns the visually impaired user of nearby obstacles by generating sound whose intensity is proportional to the distance from the obstacle [16]. The **microcontroller** processes input from the sensors in real-time to ensure the vibration motor alerts are not delayed, minimizing the risk of collision.

For emergencies, the smart glasses also have a dedicated emergency button that, when pressed, directly triggers the GSM A6 communication module. The module is programmed to send a pre-set text message to the user's guardian or emergency contact, notifying them of the possible danger or situation the user might be facing. In addition to the SMS notification, the system also automatically calls the guardian over the phone, allowing for immediate communication and increasing the likelihood of timely assistance. This dual alert system provides an added security measure and guarantee, particularly for visually impaired users who may be in trouble and cannot communicate verbally [18] [19] ...

5. Implementation Results

5.1. Interface design result:

Figure 5: GSM sends signals

As shown in figure 5, are screenshots demonstrating the GSM alert system in operation: The first image is an incoming call from the GSM module titled "GSM Module Alert", showing emergency calling is working. The second photo shows several SMS alerts from the GSM module, alerting low battery and obstacle detection. In brief, the system effectively sends SMS messages and calls in case of emergency, keeping the user safe.

5.2. Retrieving Data from ThingSpeak to the Web Dashboard

The system not only uploads GPS and obstacle detection data to ThingSpeak, but it also retrieves and visualizes this data on a web-based dashboard for real-time monitoring and analysis.

Implementation Steps:

ThingSpeak API for Data Retrieval

- The ESP32 sends GPS and obstacle data to ThingSpeak.
- The web dashboard retrieves data using the ThingSpeak Read API.

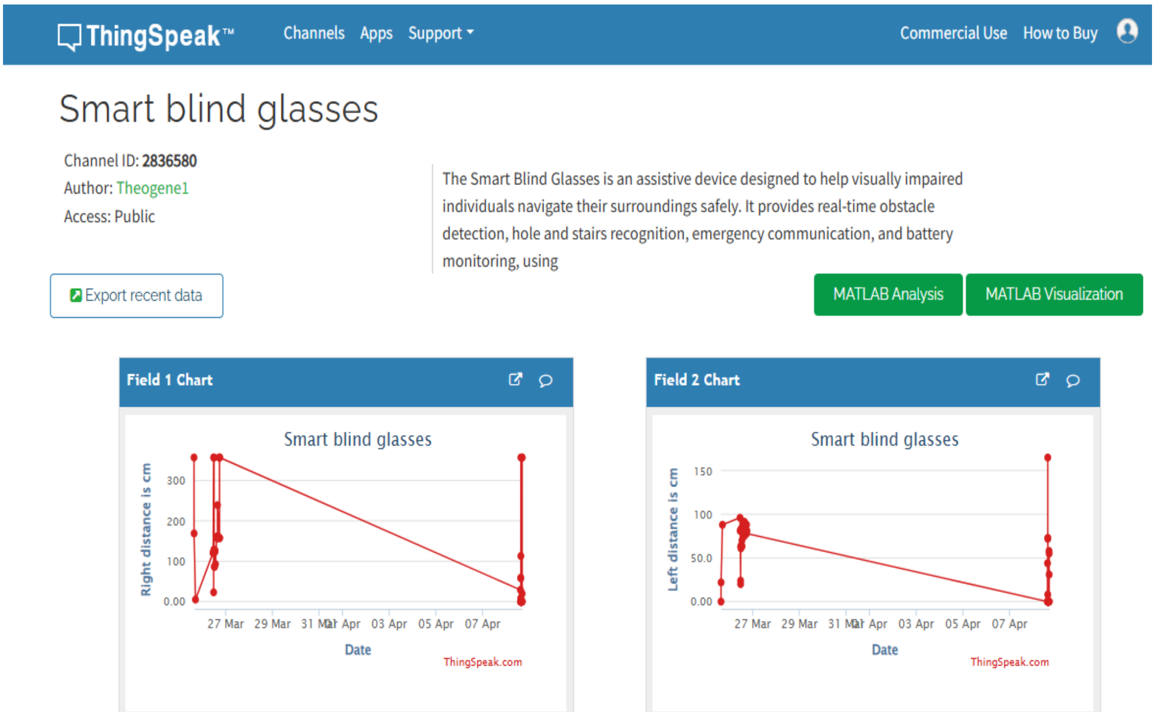

Figure 6: Thingspeak data

As shown in Fig.6 above illustrates the graphs in ThingSpeak are for several sensor readings. Field 1 and Field 2 graphs are for distance readings in centimeters, which were perhaps recorded using ultrasonic sensors placed at an angle on the spectacles. These readings give feedback on the presence and distance of an obstacle in the user's path, with Field 1 reading shorter distances and Field 2 reading longer distances.

Figure 7: Data in thingspeak

As shown in Fig.7 above illustrates the graphs in ThingSpeak are for several sensor readings. Field 5 is battery voltage, which is relevant to maintaining track of the power supply to the device and ensuring continuous operation. Finally, Field 6 logs sensor messages, which are warnings or notifications created by environmental conditions or changes in device status. This system in its entirety enhances the autonomy and safety of visually impaired users by continuously monitoring their environment and system status at all times.

5.3. Developed Dashboard

A web interface is built using HTML, JavaScript, and Chart.js to display: Real-time GPS coordinates, Obstacle detection status, Movement history

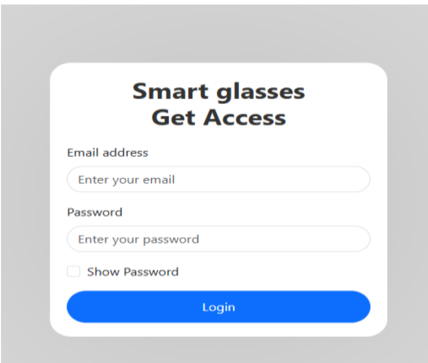

Figure 8: Login form

As shown in Fig.8 above illustrates a simple login screen for "Smart glasses Get Access". It is a simple, modern design, a white rounded square shape against a light gray background. The shape has two input fields: "Email address" and "Password", both with placeholder text to help the user. A "Show Password" check box is provided for convenience to the user, allowing them to verify their password before submission. At the bottom, a big blue "Login" button completes the form. The design as a whole is minimalist in style, focusing on simplicity and ease of use by the user to input their credentials quickly and access the smart glasses system.

5.4. This figure illustrates the glasses detecting obstacles and transmitting real-time GPS data to ThingSpeak and the web dashboard

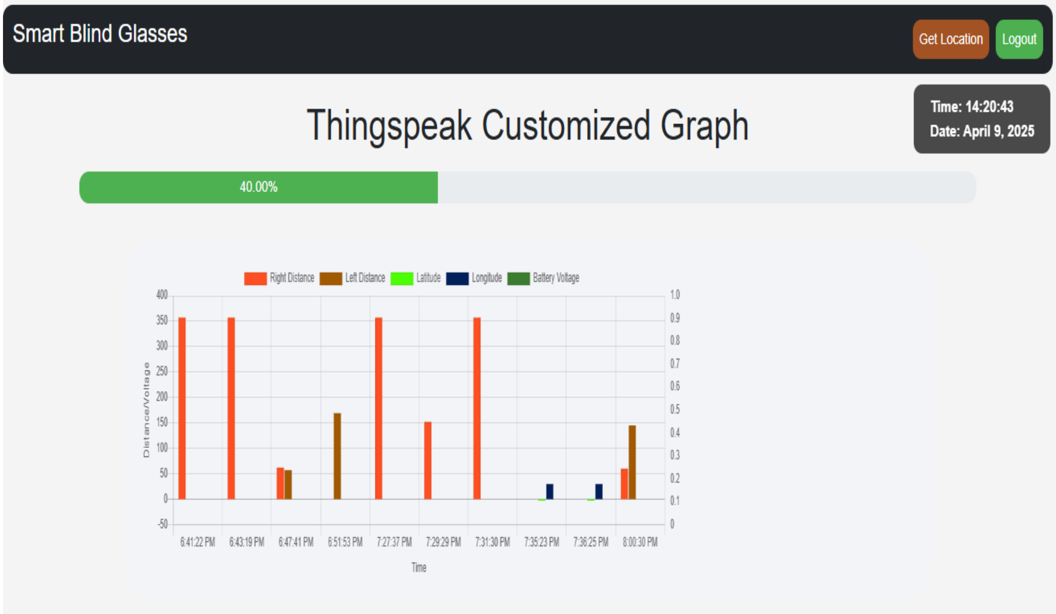

Figure 9: Data in web page

As shown in Fig. 26 above illustrates a caregiver's interface of "Smart Blind Glasses" having a dashboard providing real-time details and functionality. The app name is at the top with "Get Location" and "Logout" buttons placed to its side, indicating location tracking and controlling the user session. A horizontal progress bar displaying the label "40.00%"that show distance level for obstacle closed with user and most likely indicates the battery level or equivalent. Centering the interface is a "Thingspeak Customized Graph" which shows various sensor values over time like "Right Distance", "Left Distance", "Latitude", "Longitude", and "Battery Voltage". The graph is drawn in bar chart form with different colored bars representing each data type.

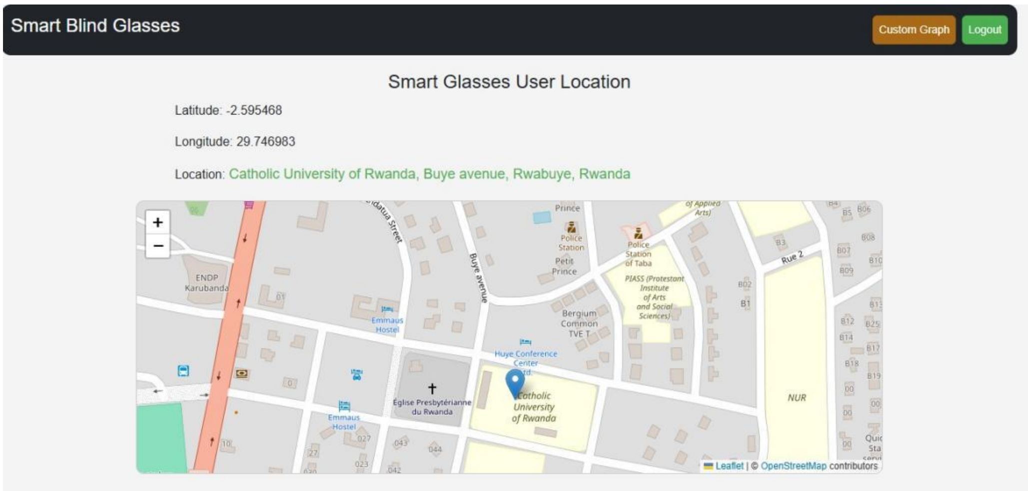

Figure 10: GPS user location

As shown in Fig. 10 above illustrates the interface of "Smart Blind Glasses" with the location information of the user. The header section contains the name of the application and "Custom Graph" and "Logout" buttons, suggesting links to additional functionalities. The body section, labeled "Smart Glasses User Location," contains the latitude (-2.595468) and longitude (29.746983) coordinates of the user. A more readable location description reads: "Catholic University of Rwanda, Buye avenue, Rwabuye, Rwanda." The bottom half of the screen is occupied by a map, centered on the Catholic University of Rwanda, identified by a blue pin marker. The map, powered by Leaflet and OpenStreetMap contributors, gives a graphical representation of the user's location in the area, with streets, buildings, and other points of interest. This interface is designed to provide the user of the intelligent blind glasses with available and comprehensible location information.

Real-Time Monitoring & Alerts

- ✓ Caregivers can track the user's movements remotely.
- ✓ Alerts are generated if abnormal movement patterns are detected.

This functionality improves system usability by offering real-time access to navigation data, enhancing both safety and caregiver support.

5.5. Prototype device

The implementation outcomes provide a thorough analysis of how the suggested system or solution performed after it had been implemented or tested in a real or simulated environment. The outcomes typically include key metrics such as performance efficiency, accuracy, speed, resource utilization, and user feedback, based on the project objectives.

Figure 11: Final Smart Glasses Prototype

The smart glasses, as shown in Fig.11, shows the performance parameters of the Smart Glasses for the Blind system, which emphasizes the accuracy and effectiveness of the obstacle detection mechanism. The values of the ultrasonic sensors are indicated in terms of distance, which depicts how the system detects objects in front of the user. The vibration motor goes up as the distance gets closer to signal an oncoming obstacle. In addition, the Serial MP3 Player Module's audio feedback is initiated at critical levels of proximity so that the user is alerted acoustically.

6. Conclusions

Smart Glasses for the Blind created in this project efficiently solve the most significant mobility issues of the blind, both indoors and outdoors. Equipped with modules like ESP32 microcontroller, ultrasonic sensors, GPS module, GSM module, vibration motor, and IoT-based tracking, the system provides real-time obstacle detection, emergency notification, and location tracking to facilitate the safety and independence of the user. The following goals were attained: Real-Time Obstacle Detection: The ultrasonic sensors precisely scan for obstacles in the 1-meter range. They are coupled with vibration motors to provide real-time haptic feedback, warning the user of any obstacle in their path. Emergency Communication & GPS Tracking: The A6G GSM module allows the system to send alarm SMS messages, along with GPS coordinates, to pre-programmed contacts. The GPS module provides precise location tracking, providing an additional layer of safety for the user. IoT-Based Remote Monitoring (ThingSpeak): The system sends GPS and obstacle data to the ThingSpeak platform using the ESP32. The caregivers can view the data remotely in real time, enabling continuous tracking of the user's location and movement. Visualization and tracking are also enabled by a web-based dashboard. Energy-Efficient & Portable Design: Driven by a rechargeable LiPo battery, the system is efficient in terms of power, lightweight, and compact, providing long use with less charging. This low-cost but effective assistive tool greatly enhances mobility, independence, and safety for the visually disabled. The success of this project shows how IoT, GSM, and sensor technologies along with platforms such as ThingSpeak can give rise to innovative applications that can enhance the lives of visually disabled individuals.

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