Design of Assistive Smart Gloves for Visually Impaired Individuals

A.Sarvani[1], M. Raghu Ram[2], P. Keshav[3], M. Tanmai[4], Khushi Singh[5]

[1,2,3,4,5]Dept of ECM, Vignan's Institute of Information Technology, Visakhapatnam, India

ABSTRACT

Visually impaired individuals face challenges in avoiding obstacles while travelling, monitoring their health and more prone to accidental falls. Existing models are designed with limited sensor arrays, failing to detect critical obstacles like holes, stairs, and uneven terrain, posing safety risks. They also lack essential features such as accidental fall detection, alert management, and health monitoring. This paper introduces an IoT-based Assistive Smart glove that overcomes these limitations. It integrates HC-SR04 ultrasonic sensors for accurate obstacle detection and managing them with haptic feedback through buzzer. Health monitoring system is enabled by monitoring pulse rate and oxygen levels of person which send alerts to close people based on their heartbeat and Spo2 levels. Additionally, Smart Glove facilitates Accidental fall detection using accelerometer and gyroscope sensors which sends alerts during accidental falls. By combining advanced sensor technology and real-time alert management, Smart Glove enhances the independence, safety of life of visually impaired individuals.

Key Words: Alert management, Smart Glove, IoT, Visually Impaired, Haptic Feedback, Object Recognition

1.INTRODUCTION

The main objective of the project is to develop a pair of smart gloves that can make a significant difference in the lives of visually impaired individuals by providing them with real-time navigation assistance, Fall detection and health monitoring. The core technology driving this innovation is a fusion of Internet of Things (IoT) and Machine Learning (ML), which enables the smart gloves to detect obstacles, track vital signs, and provide haptic feedback. When it comes to Navigation assistance , we're using Ultrasonic sensors for instant obstacle detection Our model relies on ESP32 module which is particularly effective in integration of sensors and managing alerts. The Health monitoring feature is enabled by pulse oximeter sensor. Accelerometers and Gyroscope sensor will track user location and give feedback in real time. These innovative features are not only a step above existing assistive technologies but also an entirely new degree of independence and accessibility for the visually impaired. In line with Previous drawbacks, we have developed a model with fresh features and enhanced performance of existing applications.

2.RELATED WORK

Various studies have aimed at creating smart gloves for the visually impaired. Iyer et al. (2019) created a sensor- and GPS-enabled smart glove for blind navigation, which improves mobility assistance for the visually impaired [1]. Kim et al. (2020) investigated a wearable smart glove with sensor fusion for visually impaired users, allowing real-time object detection and identification [2].In addition, IoT and cloud-based smart glove systems have been implemented. Rao et al. (2020) conceived an IoT-supported smart glove for visually impaired individuals, with real-time feedback and guidance [3].Wang et al. (2022) investigated a wearable smart glove with GPS and sensor fusion to enhance environmental consciousness, offering users real-time feedback [4].Liu et al. (2020) created a computer vision- and sensor-fused smart glove for visually impaired persons, enhancing independence and mobility [5].Al-Fuqaha et al. (2020) identified a survey regarding smart gloves for visually impaired users, which brings out the applicability of wearables for assistive technologies [6]. Velicheti et al. (2023) proposed a conformal log periodic dipole array antenna with circular and hexagonal patch top loadings, achieving resonance at multiple frequencies. This design can be applied to smart gloves to enable efficient wireless communication [7]. Similarly, Santosh and Mallikarjuna Rao (2021) enhanced the bandwidth and VSWR of a double notch E-shaped inset-fed patch antenna, making it suitable for various wireless communication systems [8][9]. Prabhakar et al. (2019) developed an antenna array using slots for multiband applications, showcasing its potential for use in assistive technology [10]. Pavada et al. (2019) demonstrated the use of inset-fed patch antennas to enhance bandwidth for high-frequency applications, which can be applied to smart gloves for efficient data transmission [11]. Umamaheswari and her team have designed and fabricated an automated water-jet robot for PV panel cleaning using an Arduino-assisted HC-05 Bluetooth module [12]. Predictive analysis is also being used to improve the performance of assistive devices. Researchers have used random forest regression to predict crop yields and futuristic yields, showing the potential of data analysis in various fields [13]. Mishra and his team have studied the strategic placement of solar power plants and interline power flow controllers for prevention of blackouts [14]. Ramisetty and Chennupati have studied the performance of multi-user MIMO systems with successive hybrid information and energy transfer beamformers [15]. Researchers have used Raspberry Pi for real-time lane detection, showing the potential of this technology [16].Wan-jung chang proposed assistive system featuring obstacle detection and accidental fall detection [17].

3.RESEARCH GAP

Existing models have limitations in finding obstacles such as holes, steps and uneven terrains. Previous assistive technologies primarily focus on standalone navigation devices or computer vision-based solutions, which often require expensive hardware and complex setups. Cost effectiveness of the model is low for most of the introduced models. No Sensors are used to detect pulse rate and oxygen levels of user. No Sensors are used to detect accidental falls. Alert system based on persons movements and health is not discussed. Most available solutions lack seamless integration of real-time data processing, Alert Management System. Moreover, limited research has been conducted on a glove-based assistive device that incorporates IoT for enhanced functionality. This study aims to address these gaps by developing a smart glove that integrates multiple sensor modalities, haptic feedback, and communication system to offer a holistic assistive solution.

4.PROPOSED SYSTEM

The Smart Glove for Visually Impaired Individuals is designed to assist users with obstacle detection, fall detection, health monitoring, and home automation. The system integrates multiple sensors and an ESP32 microcontroller to provide real-time feedback via vibration alerts, Bluetooth messages, and voice outputs on a mobile device.

4.1 Obstacle Detection System

The obstacle detection system utilizes two ultrasonic sensors (HC-SR04/SJ-SR04) to detect Swhile the downward-facing sensor analyzes distance variations to detect steps, holes. Upon detecting an obstacle, the system alerts the user through buzzer.

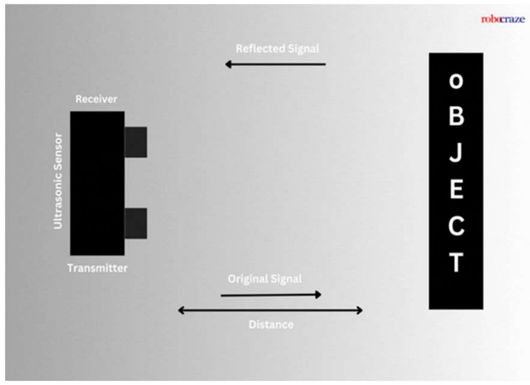

Fig 4.1.1: Obstacle detection using ultrasonic sensor

4.2 Accidental Fall Detection System

The accidental fall detection system employs an MPU9250 accelerometer and gyroscope to detect sudden falls. In the event of a fall, the ESP32 microcontroller sends an alert via Bluetooth to a connected Android device. The Android app then sends an SMS with the user's live location to pre-selected emergency contacts.

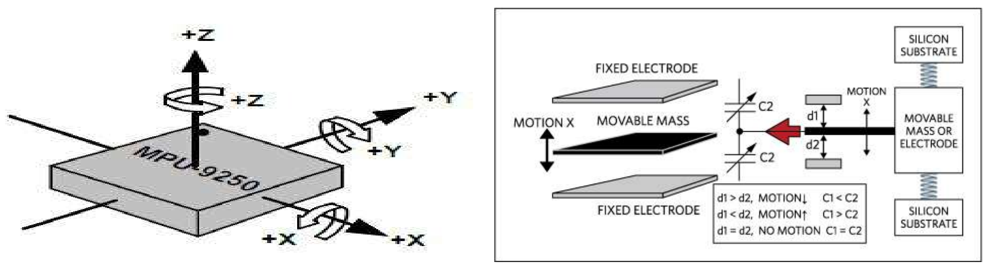

Fig 4.2.1:Accidental Fall detection based on axis and speed of fall

4.3 Health Monitoring System

The health monitoring system utilizes a MAX30100 pulse oximeter to measure the user's heart rate (BPM) and oxygen level(SpO2). If these values exceed threshold limits, the system sends an alert message via Bluetooth to the user's mobile phone. The mobile app provides a voice output announcing the oxygen level and pulse rate.

Age Group	Heart Rate (BPM)	SpO2 (%)
Child (6-12 years)	70-100	95-100
Adolescent (13-19 years)	55-90	95-100
Adult (20-64 years)	60-100	95-100
Older Adult (65+ years)	60-100	90-100

Fig 4.3.1: Average heartbeat and oxygen levels of different age groups

4.4 Mobile Connectivity and Alerts

The system leverages the ESP32's Bluetooth capabilities to communicate with a smartphone. A custom Android app built using Android studio

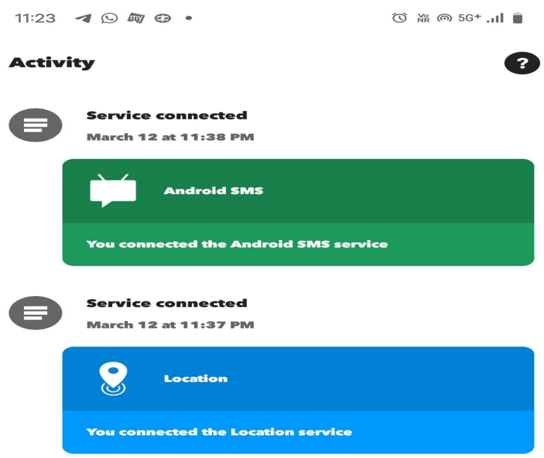

Fig 4.4.1 SMS and Location Services

4.5 Components

Fig. 4.5.1. Ultrasonic Sensor **Fig. 4.5.2. Pulse oximeter**

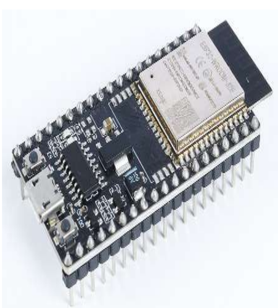

Fig. 4.5.3. ESP32 **Fig. 4.5.4 Accelerometer-Gyroscope module** **Fig. 4.5.5. Buzzer**

The system incorporates several cutting-edge components to enable its advanced functionality. The ultrasonic sensor (Fig. 4.5.1) detects obstacles and measures distance using high-frequency sound waves, providing accurate distance measurements for obstacle detection and navigation. For vital sign monitoring, The pulse oximeter (MAX30100) (Fig. 4.5.2) measures heart rate and oxygen saturation (SpO2) levels using photoplethysmography (PPG). The ESP32 module (Fig. 4.5.3) serves as the brain of the system, handling data processing, communication, and control of other components, while integrating Wi-Fi and Bluetooth connectivity. The accelerometer-gyroscope module (MPU9250) (Fig. 4.5.4) measures acceleration, orientation, and rotation of the device, detecting sudden falls, movements, and changes in orientation. Finally, the buzzer (Fig. 4.5.5) provides haptic feedback to the user through sounds, alerting them of obstacles, falls, or other important events

4.6 Flowchart

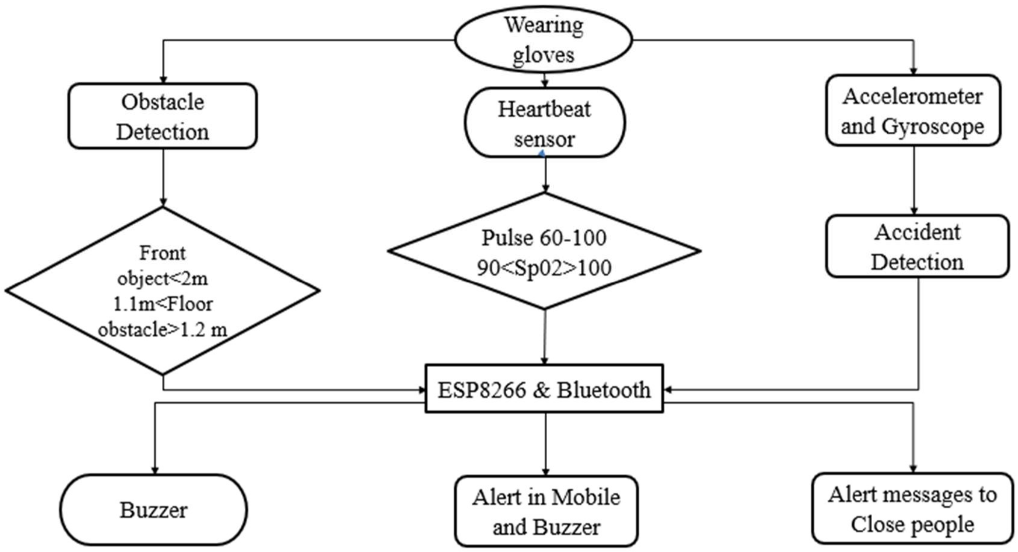

Fig. 4.6.1. The flowchart of the Smart glove assistive system

5.RESULTS AND DISCUSSION

The Assistive Smart Glove prototype was evaluated based on accuracy, latency, and user feedback. Key findings include Accurate Obstacle Detection i.e, The system achieved accuracy in detecting obstacles within a customized ranges and Test participants reported increased confidence and ease of navigation compared to traditional mobility aids. Real-time processing showed an average response time of 2 milliseconds, ensuring minimal delay in feedback. Ensured communication messages feedback between caregivers and blind person. These results indicate that the Assistive Smart Glove is a promising solution for visually impaired individuals, providing accurate and timely assistance in real-world scenarios.

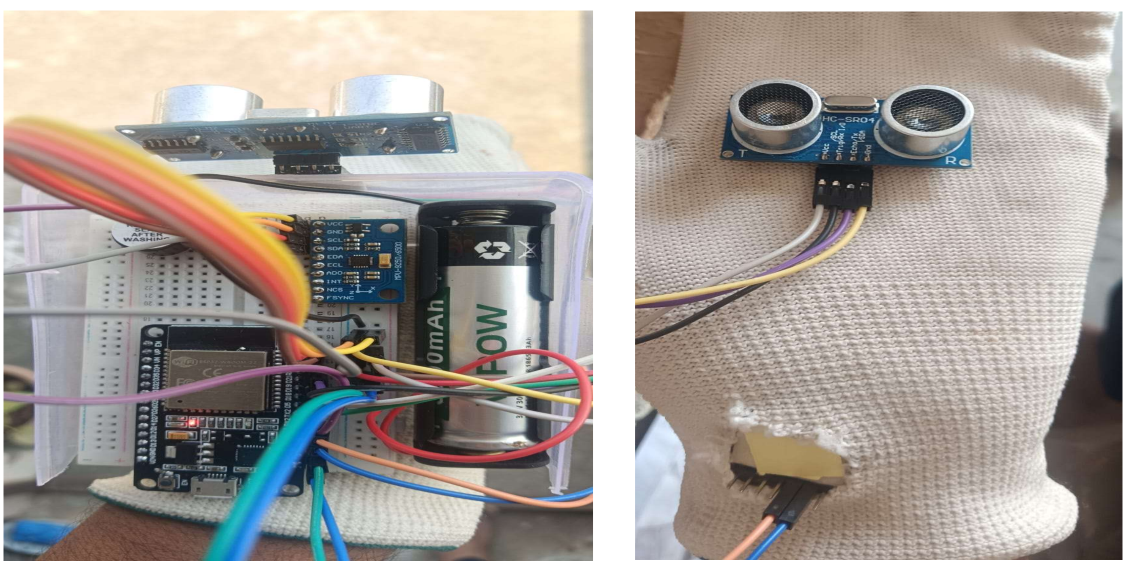

Fig 5.1 Top view and bottom view Images of Smart Glove

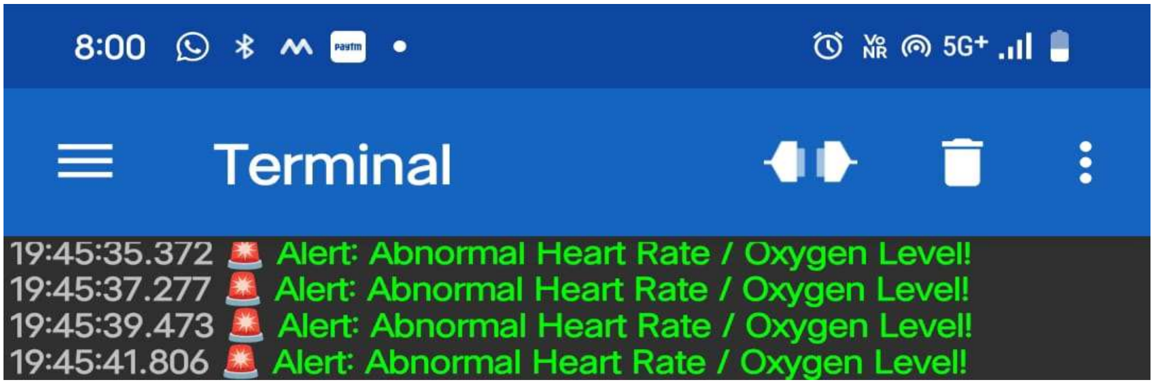

Fig 5.2 Health Monitoring And Alert system

Fig 5.3 Accidental Fall Detection and Alert System

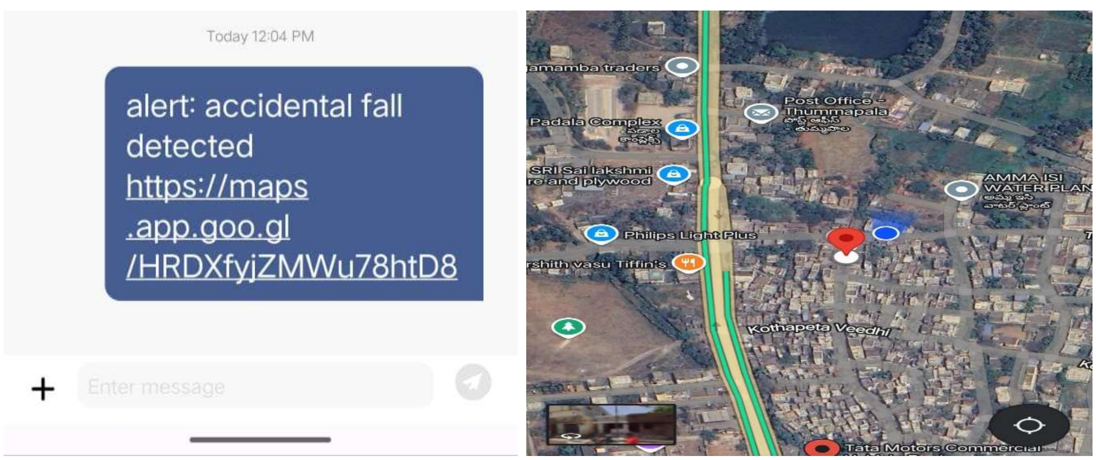

Fig 5.4 Alert messaging System with Location

6.CONCLUSION

The Assistive Smart Glove introduces a new IoT-based approach to assist visually impaired persons, combining numerous assistive features in one wearable device. Building on current gaps in research, the system can enhance mobility, independence, and safety for users. Future activities will involve optimizing hardware components, such as improved health care and broader applicability of the system across various real-world conditions.

7.FUTURE SCOPE

The AI model could be enhanced through deep learning, greatly enhancing the accuracy of object recognition. Also, the design of the glove could be minimized, shrinking it in size and power consumption, and thus become even more convenient, lightweight, and environmentally friendly. Also, the project will look into combining 5G and edge computing to allow quicker processing and real-time feedback. Multi-language functionality can also be included by applying NLP models, which will offer users smooth multilingual voice support. Last but not least, the project will go through lengthy trials with an increased user base, smoothing out the system and making it comfortable with the changing needs of users.

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