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DEVELOPMENT OF MULTIFUNCTIONAL GLOVE FOR OBSTACLE DETECTION AND HEALTH MONITORING USING ESP32

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Article Info

Abstract

Advances in wearable technology coupled with Internet of Things (IoT) innovations allow developers to make mobility and healthcare assistive equipment. Current assistive devices do not effectively address the needs of the visually impaired or people with mobility impairments, especially in detecting obstacles or providing real-time fall detection. In this research, the development process of an Obstacle Detection and Health Monitoring Glove using the ESP32 microcontroller is demonstrated. The glove integrates an ultrasonic sensor for real-time obstacle detection and a MAX30100 sensor for heart rate and blood oxygen level (SpO2) monitoring. Haptic feedback via a vibration motor warns the user of nearby obstacles, benefiting visually impaired individuals and those with mobility limitations. The Blynk and ThingSpeak IoT platforms support remote health monitoring and instant notifications for caregivers. Hardware testing confirmed that the glove has an obstacle detection range of up to 30 cm, provides accurate health measurements, and maintains a reliable network connection. User testing validated its usability, real-time feedback, and user-friendly web interface. However, challenges such as network delays and lower accuracy of the MAX30100 sensor compared to professional devices were identified. Future improvements will focus on enhancing sensor precision, optimizing data transfer, and incorporating AI-based medical analytics for predictive healthcare. This research highlights the potential of IoT-based assistive technology to enhance autonomous mobility and health monitoring for individuals with disabilities.

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INTRODUCTION

Vision is one of the most crucial senses for humans to navigate and interact with their surroundings. Visually impaired individuals face significant challenges in mobility, making everyday tasks more difficult. Assistive technologies such as canes and guide dogs provide support, but these solutions have limitations in terms of usability, cost, and effectiveness in certain environments. Similarly, stroke patients and individuals with physical disabilities struggle with movement and require assistive devices to enhance their mobility and health monitoring.

Recent advancements in IoT and wearable technology have enabled the development of innovative solutions that integrate sensors, microcontrollers, and cloud-based monitoring systems. This study focuses on designing an Obstacle Detection and Health Monitoring Glove using the ESP32 microcontroller. The glove incorporates an ultrasonic sensor for detecting obstacles, a MAX30100 sensor for health monitoring, and a vibration motor for haptic feedback. The data collected is transmitted to caregivers via IoT platforms, allowing remote monitoring and emergency alerts.

The primary goal of this research is to develop a cost-effective, portable, and user-friendly assistive device for individuals with disabilities. This study explores the design, implementation, and evaluation of the glove, highlighting its benefits and limitations.

LITERATURE REVIEW

Wearable Technology for Assistive Devices

Wearable technology has emerged as a transformative field, providing innovative solutions for healthcare and assistive applications. Modern wearable devices integrate sensors within IoT networks to enable real-time monitoring and enhance user mobility. Existing solutions such as smart glasses and ultrasonic canes provide navigation assistance but have limitations related to cost, complexity, and usability (Lord et al., 2018).

Obstacle Detection System

Obstacle detection for visually impaired individuals is commonly implemented using ultrasonic sensors, infrared sensors, or LIDAR technology. Ultrasonic sensors are widely used due to their reliability and affordability. They work by emitting sound waves and measuring the time taken for the echo to return, allowing distance measurement. However, challenges such as detecting soft objects and performance in noisy environments need to be addressed (Smith et al., 2020).

Health Monitoring System

Wearable health monitoring devices commonly use sensors like the MAX30100 to measure heart rate and blood oxygen levels. These devices provide real-time health data to users and caregivers. However, existing wearable health devices often lack integration with emergency response systems, limiting their effectiveness in critical situations (Kim et al., 2023).

Challenges in Assistive Technology

The integration of multiple sensors, microcontrollers, and wireless communication modules in wearable devices presents hardware and software challenges. Ensuring low power consumption, real-time data transmission, and user-friendly interfaces are key considerations in designing effective assistive technology (Lord et al., 2018).

METHODOLOGY

Project methodology is structured around the Waterfall Model, a sequential software development process with distinct phases. The methodology outlines a structured approach for system development, defining specific steps in creating a system. It provides a framework for organizing work activities during each development phase. This chapter describes the phases and workflows based on the chosen methodology, listing the activities to facilitate the development process.

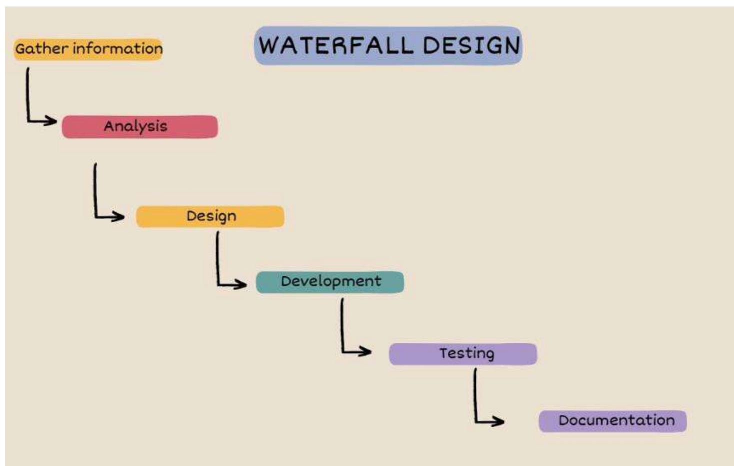

Figure 1 Methodology Framework

Under the Waterfall Design model software developers need to finish each development stage before moving forward to the subsequent stage. User requirements along with expectations get collected during the Gather Information stage at the beginning of the process. The Analysis phase follows immediately after the first stage to evaluate feasibility alongside risk identification and system specifications definition. System blueprints and architectural plans get created during the Design phase following requirement clarification.

For the Design and Development phase, the system architecture is designed, and the web-application and connectivity between the microcontroller ESP32 and the web-application are developed. Techniques such as flow charts, use cases, Logical Diagram are used. The outcomes include Logical Diagram, System Circuit, flow chart system, and the system source code. Testing phase involves conducting functionality testing and network performance testing. Functionality testing ensures that each functionality of the web-application works with the microcontroller ESP32. Network performance testing measures the system's latency at various distances and locations. Figure 2 Flowchart of Obstacle Detection and Health Monitoring glove using ESP32

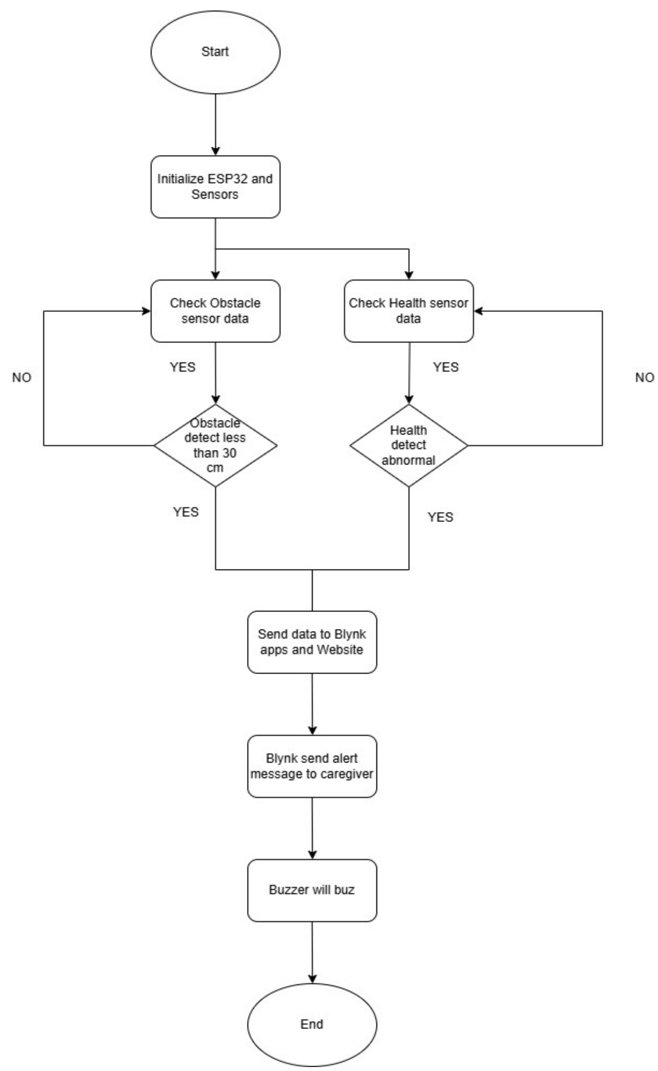

Figure 2 Flowchart of Obstacle Detection and Health Monitoring Glove using ESP32

Referring to Figure 2 above shows that the flowchart of the glove system functioned by using an ESP32 microcontroller along with Ultrasonic sensor and Max30100 sensor. The process began when the system was powered on, initializing the ESP32 and all connected sensors. The system continuously monitored two main aspects: obstacles in the user's path and health status. The ultrasonic sensor was responsible for detecting nearby objects, checking if any obstacle was within 30 cm. Meanwhile, the health sensor, which is MAX30100 sensor, measured parameters such as heart rate and blood oxygen levels. If no obstacles were found and the health readings remained normal, the system kept looping, checking the conditions repeatedly to ensure continuous monitoring.

Despite this, if an obstacle was less than 30 cm or if the health sensor reported any abnormal readings, the system reacted immediately. This would send the gathered data to Blynk, a cloud-based platform used for IoT applications. This information was processed by Blynk and the alert message was automatically sent to a caregiver to notify of possible danger or health concern. Furthermore, a buzzer would be triggered, making the issue audible for the user. This smart glove system was meant to improve safety with obstacle detection and health monitoring being available in real time to both the user and caregivers. This process was constantly looped by the system to continuously monitor and respond.

Circuit of the System

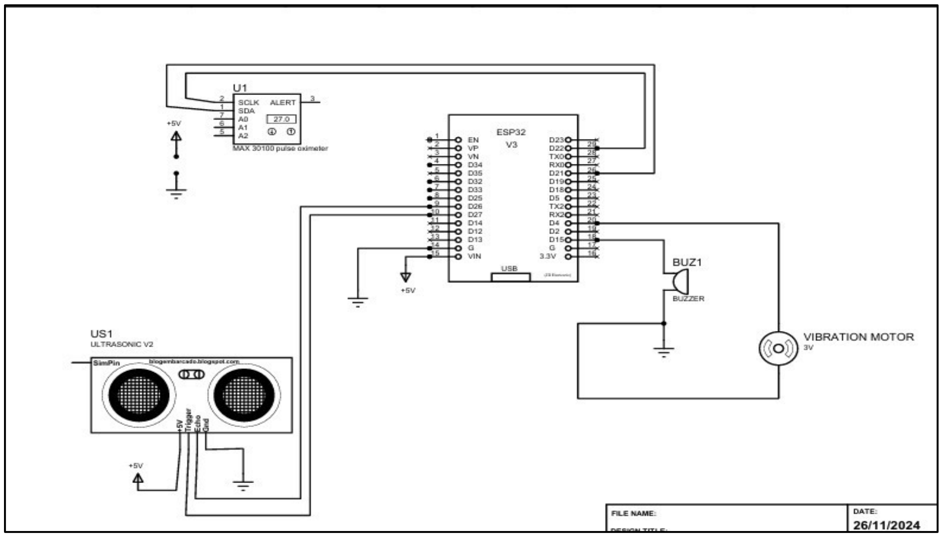

Figure 3 ESP32 circuit connection

The circuit diagram of the project is given in figure 3 shows that, an ESP32 microcontroller, an ultrasonic sensor (US1), a MAX30100 pulse oximeter and heart rate sensor (U1), a buzzer (BUZ1) and a vibration motor are used to design the system with a health monitoring and obstacle detection system. The data collection, processing and output signals are handled by the core processing unit, which is the ESP32. The ESP32 is connected to the MAX30100 sensor via its data pins (SCL, SDA) so that the microcontroller can collect vital health data such as heart rate and blood oxygen levels. Trigger and echo pins of the ultrasonic sensor (US1) are interfaced with the ESP32 to detect the obstacles by measuring the time taken for the ultrasonic waves to bounce back from the objects. Both sensors are powered by a +5V supply and have common ground with the ESP32 to provide stable operation.

There is a buzzer and a vibration motor connected to GPIO pins of the ESP32 in the circuit as well. These components act as alert mechanisms. When abnormal health parameters or obstacles are detected, the ESP32 activates the buzzer to produce an audible alarm and the vibration motor to provide haptic feedback. This dual alert system ensures that the user is notified in multiple ways, enhancing reliability and accessibility.

Physical Diagram

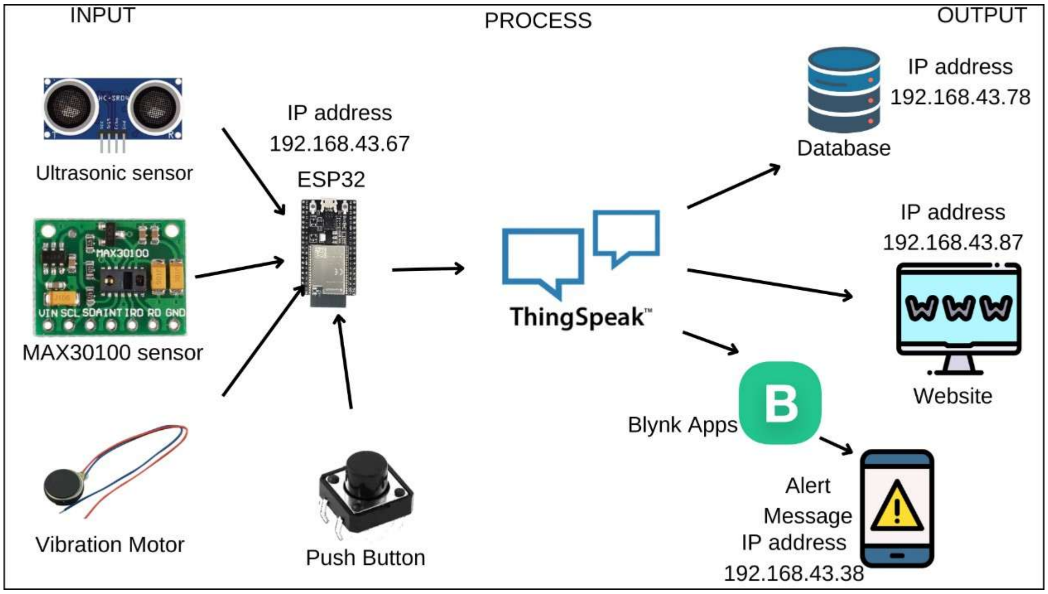

Figure 4 Logical Diagram for the project

The Physical Diagram of the project is given in figure 4 shows that the input stage of the system, illustrated in Figure 4, comprises three key components: an ultrasonic sensor, a MAX30100 sensor, and a push button switch. The ultrasonic sensor detects obstacles by emitting sound waves and measuring the time taken for the echo to return, enabling users to navigate safely. The MAX30100 sensor monitors heart rate and blood oxygen levels, making it ideal for continuous health tracking, particularly for patients, the elderly, or individuals with specific medical conditions. The push button switch serves as a manual control for users to operate, reset, or activate system features. At the core of the system, the ESP32 microcontroller processes data from these inputs, executing programmed logic to determine outputs. With its capability to handle multiple inputs and wireless connectivity, the ESP32 ensures efficient and reliable system performance. The output stage provides feedback through a buzzer and vibration motor, delivering tactile and auditory alerts when obstacles are detected, or health anomalies occur. Additionally, the system integrates the Blynk mobile application for real-time remote monitoring, offering an intuitive interface for users to track health metrics and obstacle alerts. Complementing this, a website output presents data in a more detailed and analytical format, supporting long-term tracking, reporting, and sharing information with caregivers or healthcare professionals.

RESULT AND DISCUSSION

Testing functionality is a necessary process to ensure that each device in the system operates according to the specified requirements. It aims to identify and address any errors present. The table below displays the tested results.

Table 1 Functional Testing for the project

TEST ID	TEST CASE	EXPECTED OUTCOME	PASS/FAIL
TEST1	Power ON/OFF Button	Device powers ON/OFF successfully when the button is pressed.	PASS
TEST 2	Ultrasonic Sensor	Detects obstacles within a 30 cm range and triggers vibration feedback.	PASS
TEST 3	MAX30100 Sensor	Accurately measures heart rate and SpO2 levels and displays data on the app/website.	PASS
TEST 4	Vibration Motor	Vibrates in response to detected obstacles and health warnings.	PASS

TEST 5	Blynk Notifications	Sends real-time notifications to the Blynk app upon detecting health irregularities or obstacles.	PASS
TEST 6	Battery Charging	Charges smoothly via Type-C charger device operates at full capacity after full charge.	PASS
TEST 7	System Integration	All components work seamlessly together Slightly delays or malfunctions.	PASS

Obstacle Detection Testing

Table 2 Obstacle Detection Testing

Detection Distance (CM)	Ultrasonic Detection and Buzzer status	PASS/ FAIL
< 30 cm	Detect and buzzer will buzz	PASS
> 30 cm	Detect and buzzer will not buzz	PASS

The table describes the relationship between detection distance and the status of an ultrasonic sensor and a buzzer. When the detection distance is less than 30 cm, the ultrasonic sensor detects the object, and the buzzer activates to provide an alert. However, when the detection distance exceeds 30 cm, the ultrasonic sensor continues to detect the object, but the buzzer remains inactive.

Network Testing

Latency and Packet Loss Testing

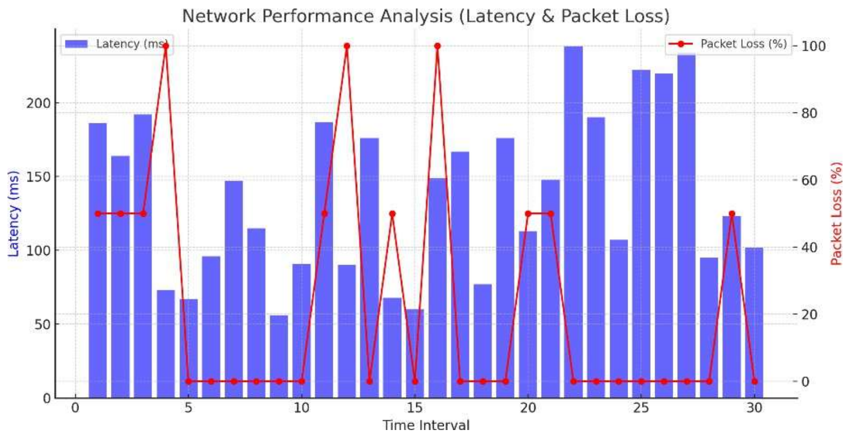

Figure 5 Network Performance Analysis (latency and Packet Loss)

The graph above shows the Network Performance Analysis (Latency & Packet Loss) for the system. It could have caused delays in sending data to the thingspeak and blynk apps. High latency could have slowed down the response time, making real-time alerts for obstacles or health monitoring less effective. When the packet loss reached 100%, important data might have been completely lost, affecting the accuracy of the system. Such issues could have been caused by network congestion, weak signal strength, or interference.

CONCLUSION

With the ESP32 microcontroller, the Glove was designed and developed successfully for indoor applications. This project's main goals were implemented by using the MAX30100 sensor for health monitoring, an ultrasonic sensor for avoiding obstacles and a vibration motor for haptic feedback to give real time feedback and alert.

Furthermore, the glove was also reliable under different scenarios of testing, showing its practicality for use in the real world. Usability was further enhanced by its compact design and user-friendly interface that makes it very easy to use by people who need safety and health monitoring. The project points out the possibility of using IoT and wearable technology to aid personal safety and health management, and to guide the further development of smart and connected devices specifically designed to serve relevant applications.

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