EOG - Controlled Smart Wheelchair with Health Monitoring and Emergency Alert System

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Abstract - This project presents the design and development of an EOG-controlled smart wheelchair with health monitoring and emergency alert system, aimed at assisting physically disabled individuals in achieving independent mobility. Traditional wheelchairs often rely on manual or joystick-based control, which can be difficult or impossible for users with severe motor impairments. To address this challenge, the proposed system uses eye movement signals (Electrooculography – EOG) as an intuitive and hands-free method of control.

In this system, eye movements are detected using electrodes and processed through a Bio Amp EXG module. These signals are then interpreted by the ESP32 microcontroller to control the movement of the wheelchair in different directions such as forward, backward, left, right, and stop. Along with mobility control, the system also includes health monitoring features, where parameters like heart rate and temperature are continuously observed using sensors.

To enhance user safety, an emergency alert mechanism is integrated, which activates a buzzer and sends alerts when abnormal conditions are detected or triggered by the user. Additionally, the system uses Bluetooth communication to connect with a mobile application, allowing real-time monitoring and manual control when required.

Keywords: - EOG (Electrooculography), Smart Wheelchair, ESP32, Bio Amp EXG Pill, Health Monitoring, Pulse Sensor, DHT11 Sensor, Bluetooth Communication, Emergency Alert System, Assistive Technology

1. INTRODUCTION

Mobility is essential for daily life, but for physically disabled or paralyzed individuals, it becomes difficult due to limitations of traditional wheelchairs that require manual or joystick control. These systems are not suitable for users with severe motor impairments, reducing their independence. To solve this, intelligent assistive technologies are being developed. One effective solution is using Electrooculography (EOG), which detects eye movements and uses them as control signals. Since eye movement is often still possible for such individuals, EOG provides a simple, safe, and reliable way to control devices like wheelchairs independently.

1.2 Problem Statement

Physically disabled and paralyzed individuals often face serious challenges in achieving independent mobility, as most conventional wheelchairs require manual effort or joystick-based control, which may not be possible for users with severe motor impairments. This limitation forces them to depend heavily on caregivers for basic movement, reducing their independence and quality of life. In addition to mobility issues, there is a lack of integrated systems that combine mobility assistance with real-time health monitoring and emergency alert mechanism

1.3 Objectives of the Proposed System

The main objective of the proposed system is to design and develop an EOG-controlled smart wheelchair that enables physically disabled individuals to achieve independent mobility using eye movement signals. The system aims to provide a hands-free and user-friendly control mechanism, making it suitable for users with severe motor impairments.

Another key objective is to integrate a real-time health monitoring system that continuously tracks vital parameters such as heart rate and temperature to ensure the safety of the user. The project also focuses on implementing a Bluetooth-based communication system to allow wireless control and monitoring through a mobile application.

In addition, the system aims to incorporate an emergency alert mechanism that can notify caregivers in critical situations, enhancing overall safety. The proposed system also supports both manual and automatic modes of operation, providing flexibility and ease of use.

2. LITERATURE REVIEW

Several studies have been carried out in the field of assistive technologies to improve mobility for physically disabled individuals. Traditional wheelchairs mainly use manual or joystick-based control, which is not suitable for users with severe motor disabilities. To overcome this limitation, researchers have explored alternative control methods such as voice control, gesture control, and brain-computer interfaces (BCI).

Among these methods, Electrooculography (EOG) has gained attention as it allows control using eye movements, which are easier to perform even for highly disabled patients. Various systems have been developed using EOG signals for controlling wheelchairs and other assistive devices. However, many of these systems focus only on movement control and do not include additional features like health monitoring or emergency alert systems

Recent advancements in embedded systems and wireless communication have enabled the integration of real-time monitoring and remote control features. Despite these improvements, there is still a need for a simple, cost-effective, and reliable system that combines mobility control, health monitoring, and safety features in a single platform.

The proposed system addresses these limitations by integrating EOG-based control, health monitoring, and Bluetooth communication, providing a more efficient and user-friendly solution for physically disabled individuals.

In addition, various studies have focused on improving the accuracy and reliability of bio-signal-based control systems by using advanced signal processing and filtering techniques. The use of embedded platforms such as microcontrollers has made these systems more compact and efficient. Wireless technologies like Bluetooth have also been widely used to enable real-time communication between the system and the user. However, many existing solutions are either complex to use or lack proper integration of multiple features in a single system. Therefore, there is a need for a well-integrated solution that combines accurate signal processing, efficient control, real-time monitoring, and user-friendly communication, which is addressed in the proposed system.

3. SYSTEM ARCHITECTURE

The system architecture of the proposed EOG-controlled smart wheelchair is designed as an integrated embedded system that combines signal acquisition, processing, control, health monitoring, and communication modules. The system mainly consists of EOG electrodes, BioAmp EXG Pill module, ESP32 microcontroller, motor driver (L298N), DC motors, health monitoring sensors, buzzer, and Bluetooth communication interface.
The working begins with the EOG electrodes, which detect eye movement signals and send them to the BioAmp EXG module for amplification and filtering. The processed signals are then given to the ESP32 microcontroller, which acts as the central unit and converts these signals into control commands. Based on these commands, the motor driver controls the DC motors, enabling the wheelchair to move in different directions.

At the same time, the system monitors the user's health using sensors such as pulse sensor and DHT11, and the data is processed by the ESP32. The system also includes a buzzer for emergency alerts, which gets activated during abnormal conditions. Additionally, the ESP32 uses its inbuilt Bluetooth module to communicate with a mobile application, allowing real-time monitoring and manual control.

3.1 Overall Block Diagram

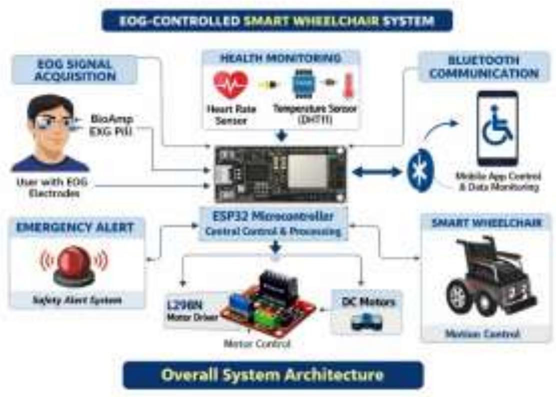

Figure 3.1: Overall System Architecture of EOG-Controlled Smart Wheelchair

The system starts with the EOG signal acquisition unit, where electrodes are placed near the user's eyes to detect eye movement signals. These signals are very weak, so they are passed to the Bio Amp EXG Pill module, which amplifies and filters them to produce a clean signal.

The processed signal is then sent to the ESP32 microcontroller, which acts as the central unit of the system. It analyses the signal, identifies the eye movement pattern, and converts it into corresponding control commands such as forward, backward, left, right, or stop.

The generated commands are given to the L298N motor driver, which controls the operation of the DC motors. Based on these signals, the motors move the wheelchair in the required direction.

Along with movement control, the system includes a health monitoring unit consisting of a pulse sensor and a DHT11 sensor. These sensors continuously measure the user's heart rate, temperature, and humidity, and the data is processed by the ESP32.

The ESP32 also uses its inbuilt Bluetooth module to communicate with a mobile application. Through this, real-time data such as health parameters and system status is transmitted, and the user can also control the wheelchair manually if required.

For safety, an emergency alert system is included. If an abnormal condition is detected or an emergency command is triggered, the buzzer is activated and an alert message is sent through Bluetooth.

Thus, the system works by integrating signal detection, processing, motor control, health monitoring, and wireless communication to provide a complete and efficient smart wheelchair solution.

3.2 Data Flow Sequence

1. Eye Movement Input:
   The process starts when the user moves their eyes. These movements generate small electrical signals (EOG signals).

2. Signal Detection:
   EOG electrodes placed near the eyes detect these signals.

3. Signal Amplification:
   The detected signals are very weak, so they are sent to the Bio Amp EXG module, where they are amplified and filtered.

4. Signal Processing:
   The clean signal is sent to the ESP32 microcontroller. It reads and analyses the signal to identify eye movement patterns.

5. Command Generation:
   Based on the detected pattern (blink or movement), the ESP32 generates commands like forward, backward, left, right, stop or emergency.

6. Motor Control:
   These commands are sent to the motor driver, which controls the DC motors.

7. Wheelchair Movement:
   The motors move the wheelchair in the desired direction.

8. Health Monitoring:
   At the same time, sensors collect health data such as heart rate and temperature.

9. Data Transmission:
   The ESP32 sends movement status and health data to the mobile application using Bluetooth.

10. Emergency Alert:
    If an abnormal condition is detected or triggered, the system activates the buzzer and sends an alert.

3.3 Methodology

The methodology of the proposed EOG-controlled smart wheelchair system is based on a systematic approach that includes signal acquisition, processing, control, and monitoring.

Initially, EOG electrodes are placed near the user's eyes to capture the electrical signals generated by eye movements. These signals are very weak and are therefore passed through the Bio Amp EXG Pill module, where amplification and filtering are performed to obtain a clean and stable signal.

The conditioned signal is then provided to the ESP32 microcontroller, which continuously reads and processes the input. The system calculates a baseline value and uses threshold-based detection to identify eye movement patterns such as blinks. Based on the number and timing of these signals, the ESP32 determines the corresponding movement command.

Once the command is generated, it is sent to the L298N motor driver, which controls the DC motors of the wheelchair. This enables the wheelchair to move in different directions such as forward, backward, left, right, or stop.

In parallel, the system performs health monitoring using sensors like the pulse sensor and DHT11. These sensors collect real-time data related to heart rate, temperature, and humidity, which is processed by the ESP32.

The system also includes a Bluetooth communication module (inbuilt in ESP32), which connects to a mobile application. This allows the user to monitor system data and control the wheelchair manually when required.

For safety, an emergency alert mechanism is implemented. If abnormal conditions are detected or an emergency command is triggered, the system activates a buzzer and sends an alert via Bluetooth.

Overall, the methodology ensures a continuous flow of operations including signal detection, processing, movement control, health monitoring, and communication, making the system efficient and reliable.

4. HARDWARE DESIGN

4.1 Components used in Hardware setup

Figure 4.1.1: BIOAMP EXG Pill (EOG sensor)

Figure 4.1.2: ESP32 Microcontroller

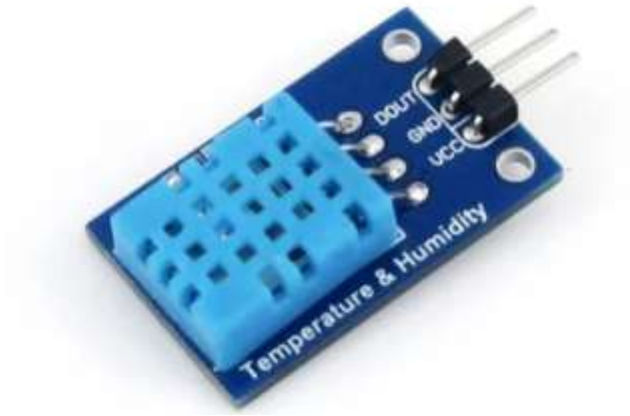

Figure 4.1.3: DHT11 Temperature and humidity sensor

Figure 4.1.4: Pulse sensor

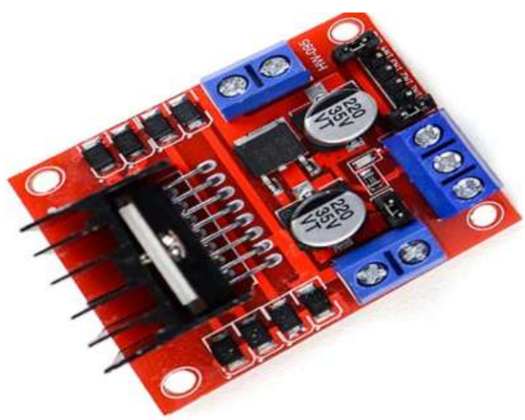

Figure 4.1.5: Motor driver

Figure 4.1.6: DC motor

Figure 4.1.7: EOG Electrodes

4.2 Data Transmission and Workflow

The system operates based on a continuous data flow between input, processing, control, and communication modules. The workflow begins with the acquisition of EOG signals, where eye movements generate electrical signals that are captured by electrodes. These signals are then amplified and filtered using the Bio Amp EXG module to obtain a clean signal.

The processed signal is transmitted to the ESP32 microcontroller, where it is analysed to identify specific patterns. Based on this analysis, the system generates control commands such as forward, backward, left, right, or stop. These commands are then transmitted to the motor driver, which controls the DC motors and enables the movement of the wheelchair.

At the same time, the system collects health-related data from sensors such as the pulse sensor and DHT11. This data is processed by the ESP32 and prepared for transmission.

For communication, the ESP32 uses its Bluetooth interface to transmit real-time data, including movement status and health parameters, to a mobile application. The system also receives control commands from the mobile application in manual mode, enabling bidirectional communication.

In case of emergency or abnormal conditions, alert signals are generated and transmitted through Bluetooth, and the buzzer is activated locally. The entire workflow operates in a continuous loop, ensuring real-time control, monitoring, and response.

5. SOFTWARE IMPLEMENTATION

The software implementation of the proposed system is carried out using the Arduino IDE, where the program is written in embedded C/C++ and uploaded to the ESP32 microcontroller. The software is responsible for handling signal processing, decision-making, motor control, sensor data acquisition, and communication.

Initially, the system is programmed to initialize all input and output components, including EOG input pins, motor driver pins, sensors, buzzer, and Bluetooth module. The ESP32 establishes a Bluetooth connection with the mobile application for data transmission and command reception.

The software continuously reads the EOG signals through the analog input pin. A baseline value is calculated during initialization, and the incoming signals are compared with predefined threshold values. Based on this comparison, the system identifies eye movement patterns such as blinks and converts them into movement commands.

The program also includes logic for dual-mode operation. In manual mode, commands received via Bluetooth are directly executed to control the wheelchair. In automatic mode, the system relies on EOG signal processing for movement control.

For motor control, the ESP32 sends digital signals to the motor driver based on the generated commands. The software also reads data from the pulse sensor and DHT11 sensor to monitor health parameters.

Additionally, the software includes an emergency alert routine, which activates the buzzer and sends alert messages via Bluetooth when abnormal conditions are detected or when triggered by the user.

The entire system operates in a continuous loop, ensuring real-time processing, control, and communication, making the software efficient and responsive.

6. RESULTS AND PERFORMANCE ANALYSIS

6.1 Results

The proposed EOG-controlled smart wheelchair system was successfully designed, developed, and tested under various conditions. The system demonstrated the ability to accurately detect eye movement signals (EOG signals) and convert them into corresponding control commands. The wheelchair was able to perform movements such as forward, backward, left, right, and stop based on the detected eye movement patterns.

During testing, the automatic mode (EOG-based control) functioned effectively when proper electrode placement and calibration were maintained. The system was able to identify blink patterns and convert them into predefined commands with satisfactory accuracy. In addition, the manual mode using Bluetooth communication was successfully implemented, allowing users to control the wheelchair directly through a mobile application. The switching between automatic and manual modes was smooth and responsive.

The health monitoring system was also successfully integrated and tested. The pulse sensor provided continuous heart signal readings, while the DHT11 sensor measured temperature and humidity values. These parameters were displayed in real time and transmitted to the mobile application via Bluetooth.

The Bluetooth communication system worked effectively for both data transmission and command reception. Real-time data such as movement status, sensor readings, and alerts were successfully displayed on the mobile application. The system also responded correctly to commands sent from the application.

Furthermore, the emergency alert system performed as expected. When an emergency command was triggered or abnormal conditions were detected, the buzzer was activated and alert messages were transmitted through Bluetooth. Overall, the system achieved its intended functionality and demonstrated successful integration of all modules.

6.2 Performance Analysis

The performance of the developed system was evaluated based on parameters such as accuracy, response time, reliability, and overall system efficiency. The system showed good accuracy in detecting and interpreting EOG signals, especially when electrodes were properly placed and the baseline was correctly calibrated. The use of the BioAmp EXG module helped in improving signal quality by reducing noise and enhancing signal strength.

The response time of the system was found to be low, as the ESP32 microcontroller processed the input signals and generated output commands with minimal delay. This resulted in smooth and real-time wheelchair movement, ensuring better user experience. The motor driver and DC motors provided stable and consistent performance during operation.

The Bluetooth communication demonstrated reliable performance within its operational range, allowing seamless data transmission and command exchange between the ESP32 and the mobile application. The system was able to maintain continuous communication without significant data loss.

The health monitoring system also performed reliably by continuously measuring and updating parameters such as heart rate and temperature. The data was transmitted in real time, ensuring effective monitoring of the user’s condition.

In terms of safety, the system responded promptly during emergency situations. The buzzer activation and alert transmission ensured immediate notification, which is crucial for assistive devices.

However, certain limitations were observed during testing. The performance of the system can be affected by noise in EOG signals, improper electrode placement, and external environmental interference. These factors may lead to slight variations in accuracy and system response.

7. ADVANTAGES AND LIMITATIONS

7.1 Advantages of the system

1. Provides hands-free control using EOG signals, suitable for users with severe physical disabilities

2. Enhances user independence and mobility, reducing dependency on caregivers

3. Integrates health monitoring features such as heart rate and temperature tracking

4. Includes an emergency alert system for improved safety and quick response

5. Supports dual-mode operation (automatic and manual), offering flexibility in control

6. Enables wireless communication via Bluetooth for real-time monitoring and control

7.2 Limitations

1. Performance depends on proper electrode placement for accurate EOG signal detection

2. EOG signals are prone to noise and interference, which may affect accuracy

3. Limited Bluetooth range, restricting long-distance communication

4. Accuracy may vary based on user's eye movement consistency

8. CONCLUSION

The proposed EOG-controlled smart wheelchair with health monitoring and emergency alert system has been successfully designed and implemented to address the challenges faced by physically disabled individuals in achieving independent mobility. The system effectively utilizes Electrooculography (EOG) signals to provide a hands-free control mechanism, allowing users to operate the wheelchair using simple eye movements. This makes the system highly suitable for individuals with severe motor impairments who are unable to use conventional control methods.

The integration of the ESP32 microcontroller ensures efficient processing of input signals and smooth execution of control commands. The system demonstrates reliable performance in converting eye movement signals into accurate wheelchair movements such as forward, backward, left, right, and stop. The inclusion of dual-mode operation further enhances usability by allowing both automatic (EOG-based) and manual (Bluetooth-based) control.

9. REFERENCES

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