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EMG Sensor based Wheelchair

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ABSTRACT: This project presents the development of a EMG sensor based wheelchair system utilizing Arduino microcontrollers, EMG sensors, and additional physiological sensors. The wheelchair system is designed to provide mobility assistance to users with limited physical capabilities. The core functionality of the system revolves around interpreting signals from EMG sensors attached to the user's eyebrow muscles to detect intentional movements. Additionally, the system integrates sensors for monitoring heart rate, blood oxygen saturation (SpO2), and body temperature to ensure the user's well-being during operation. Through a combination of signal processing algorithms, sensor integration, and user interface design, the wheelchair system aims to offer a reliable and intuitive mobility solution for individuals with motor impairments.

KEYWORDS: Brain-Computer Interface (BCI), Assistive Technology, Wheelchair Control Arduino, Microcontroller, Physiological Monitoring, EMG Signal Processing, Mobility Assistance, Human-Machine Interface

I. INTRODUCTION

In recent years, advancements in technology have opened up new possibilities for improving the quality of life for individuals with disabilities. One significant area of innovation is the development of assistive technologies aimed at enhancing mobility and independence. Among these technologies, brain-controlled wheelchairs represent a groundbreaking approach that enables individuals with severe motor impairments to navigate their surroundings using signals from their brain or muscles. In this context, the present project endeavors to contribute to this field by introducing a brain-controlled wheelchair system built using Arduino microcontrollers and a suite of physiological sensors.

The motivation behind this project stems from the pressing need to address the mobility challenges faced by individuals with disabilities, particularly those with limited or no control over their limbs. Conventional wheelchair designs, while effective for many users, may not suffice for individuals with severe motor impairments, such as those resulting from spinal cord injuries, neuromuscular disorders, or strokes. For such individuals, alternative solutions that leverage advancements in electronics, signal processing, and human-machine interaction are essential.

The core concept of the brain-controlled wheelchair system revolves around the utilization of electromyography (EMG) sensors to detect subtle muscle movements, particularly those associated with facial expressions. By attaching EMG sensors to the eyebrow muscles, the system can interpret intentional movements, such as lifting the eyebrows, as commands for controlling the wheelchair's motion. This approach capitalizes on the fact that even individuals with limited motor control often retain some level of voluntary muscle activity, which can be detected and translated into meaningful actions.

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In addition to EMG sensors, the wheelchair system integrates other physiological sensors to monitor the user's vital signs and ensure their safety and well-being during operation. These include sensors for measuring heart rate, blood oxygen saturation (SpO2), and body temperature. By continuously monitoring these parameters, the system can detect any signs of distress or discomfort experienced by the user and respond accordingly, such as by pausing or adjusting the wheelchair's movement.

Overall, the development of a brain-controlled wheelchair system represents a significant step forward in the quest to empower individuals with disabilities and improve their quality of life. By harnessing the potential of emerging technologies and human-centered design principles, this project aims to provide a practical and effective mobility solution that enhances independence, autonomy, and dignity for users with motor impairments.

II. LITERATURE SURVEY

Brain-computer interface (BCI) technology has shown considerable promise in enabling wheelchair control for individuals with severe physical disabilities. Naveen and Julian [1] proposed a motor imagery-based BCI system to navigate a wheelchair in four directions—left, right, forward, and backward—allowing paralyzed patients to control both simulated and real wheelchairs via brain signals, ultimately to be implemented as a standalone hardware solution. Samy, Rahman, and Khan [2] explored a cost-efficient BCI model using non-invasive EEG signals to control wheelchairs. Their system successfully distinguished commands such as "right turn," "move forward," and "stop," demonstrating practical feasibility despite signal noise and circuit limitations, using microcontrollers for signal processing.

Kumar et al. [3] presented a BCI design based on EEG signals processed using the GDTAB wave classification, with Zigbee modules enabling wireless wheelchair control, thus enhancing mobility for physically challenged users. Gondal et al. [4] developed an EMG-based wheelchair control system integrating classical signal processing and machine learning models such as LDA, SVM, and decision trees, with a maximum classification accuracy of 81.5%, showcasing the use of muscle activity in supplementing BCI for improved reliability.

Cho, Winod, and Cheng [5] introduced a next-generation electric wheelchair using EEG-based skid steering, eliminating conventional mechanical steering and enabling dynamic differential speed control. This approach emphasizes cost-efficiency and compact design, particularly for stroke and disabled patients. Park and Chung [6] focused on performance optimization through selective EEG channel utilization. They applied a covariance matrix and cross-combining region strategy for optimal channel selection, improving classification using LS-SVM and demonstrating superior performance on BCI competition datasets.

Seo et al. [7] addressed the issue of cognitive fatigue during prolonged BCI use. Their five-hour experimental study involving 54 participants revealed increased alpha-band power and reduced attention in MI and SSVEP paradigms, suggesting that fatigue management is crucial for the long-term usability of BCI systems in real-life applications.

III. METHODOLOGY

The methodology for developing a brain-controlled wheelchair system involves a structured, multi-phase approach to ensure the system's functionality, reliability, and user-friendliness. The process begins with system design, where the overall architecture is defined, and the essential components—including the Arduino microcontroller, EMG and physiological sensors, user interface, and motorized wheelchair platform—is selected. Specifications such as sensor accuracy, communication protocols, and power efficiency are also established during this phase. Following this, sensor integration is performed by physically connecting the sensors to the microcontroller and calibrating them for accurate data acquisition. EMG sensors, typically placed on the user's eyebrow muscles, and physiological sensors for monitoring heart rate, SpO₂, and body temperature, are tested to ensure consistent performance.

Next, algorithm development focuses on interpreting the sensor data to control wheelchair movement. Signal processing algorithms detect specific muscle movements, such as eyebrow raises, and convert them into directional commands like forward, backward, left, and right. Simultaneously, the system monitors vital signs to maintain user safety. These algorithms are then incorporated during hardware implementation, where code is written for the Arduino microcontroller to manage data processing, command execution, and interaction with components such as





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motor drivers and actuators. Software programming complements this step by creating a mobile application that enables users to control the wheelchair remotely and monitor real-time system data through an intuitive and accessible interface.

Following implementation, testing is conducted in both controlled and real-world environments to evaluate the system's performance across parameters like sensor accuracy, responsiveness, usability, and safety. Diverse test cases help identify potential issues and guide enhancements. Lastly, iterative refinement plays a vital role in optimizing the system. Feedback from testing and user evaluations is used to revise earlier stages—improving algorithms, modifying hardware or software, and refining the user interface—ensuring the final product meets the specific needs of individuals with motor impairments. This comprehensive and iterative methodology enables the development of a robust and effective brain-controlled wheelchair, aimed at enhancing mobility and independence for users with severe physical disabilities.

IV. EXPERIMENTAL RESULTS

The experimental evaluation of the EMG sensor-based wheelchair system demonstrates its capacity to effectively translate user muscle signals into directional control. The system utilizes EMG sensors to detect muscle activity, typically from the user's eyebrows, and interprets these signals to control the wheelchair's movement. The core of the system comprises an Arduino microcontroller, which processes the signals from the EMG sensors, along with a motor driver to actuate the wheelchair's motors. The hardware setup includes the Arduino, EMG sensors, and motor driver.



Fig. 1 Wheelchair Directional Responses (a) LCD display showing "RIGHT," indicating the wheelchair's response to the user's input for rightward movement. (b) LCD display showing "FORWARD," confirming the wheelchair's forward movement. (c) LCD display showing "BACKWARD," demonstrating the wheelchair's backward movement. (d) LCD display showing "LEFT," indicating the wheelchair's leftward movement.

The results are evident in the wheelchair's ability to respond to specific muscle inputs with corresponding directional outputs. The system accurately displays these outputs on an LCD screen, providing immediate feedback. As seen in Figure 1 (a), the display shows "RIGHT," indicating the wheelchair's response to the user's muscle input for rightward movement. Similarly, as seen in Figure 1 (b), the display shows "FORWARD," confirming the wheelchair's ability to move in the forward direction. The system also accurately responds to the backward movement command, as shown in Figure 1 (c), with the "BACKWARD" display. Furthermore, the system recognizes and executes the left turn command, displaying "LEFT" on the screen, as shown in Figure 1 (d).

These experimental findings confirm the wheelchair's successful operation in interpreting EMG signals and executing fundamental directional controls.





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V. CONCLUSION

In conclusion, the development of a brain-controlled wheelchair system presents a promising solution for enhancing mobility and independence for individuals with severe motor impairments. By leveraging Arduino microcontrollers, EMG sensors, physiological sensors, and a user-friendly interface, the proposed system offers intuitive control mechanisms and real-time feedback to facilitate effortless navigation of the wheelchair.

Through a structured methodology encompassing system design, sensor integration, algorithm development, hardware implementation, software programming, testing, and iterative refinement, the system aims to address the diverse needs and challenges faced by users with disabilities. By prioritizing accessibility, safety, usability, and affordability, the system strives to deliver a comprehensive and effective mobility assistance solution that empowers users to navigate their surroundings with confidence and dignity.

Moving forward, further research and development efforts are warranted to enhance the robustness, reliability, and functionality of the brain-controlled wheelchair system. Continuous iteration and improvement based on user feedback and technological advancements will be crucial for ensuring the system's relevance and efficacy in meeting the evolving needs of individuals with disabilities. Ultimately, the successful deployment and adoption of the system have the potential to significantly improve the quality of life for users, promoting independence, autonomy, and inclusion in society.

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