WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Brain-Link Mobility: A Wheelchair Control System Utilizing EEG, EMG, and EOG Signals for Enhanced Mobility - A Review

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A B S T R A C T

Brainlink Mobility is a groundbreaking assistive technology designed to improve the mobility of individuals with quadriplegia. This innovative system harnesses EEG, EMG, and EOG signals from the prefrontal cortex, allowing users to control their wheelchairs using eye movements and concentration levels. An operational amplifier captures these neural signals, which are then processed by an Arduino Nano. This processed data is wirelessly transmitted to the wheelchair's ESP32 module via the TCP/IP protocol. The ESP32 interprets the data and communicates with the motor controller, enabling precise and responsive wheelchair movement in three directions. With affordability as a key focus, Brainlink Mobility aims to provide a cost-effective solution that empowers individuals with limited mobility to navigate their environment with greater ease. Additional safety features like fall detection and messaging further enhance the system's value proposition.

Keywords: Brainlink Mobility, assistive technology, quadriplegia, neural control, EEG (electroencephalography), EMG (electromyography), EOG (electrooculography), wheelchair control, Arduino Nano, ESP32 module, TCP/IP protocol, motor controller, affordability

Introduction

Quadriplegia presents significant challenges in terms of mobility and independence. While traditional assistive technologies have offered some solutions, they often fall short in addressing the unique needs of users with limited motor control. Brainlink Mobility emerges as a beacon of hope, offering a paradigm shift in wheelchair control. By leveraging the power of brain-computer interface (BCI) technology, the project empowers individuals with quadriplegia to navigate their environment with intuitive eye movements and concentration levels. This shift away from joystick-based control signifies a revolution in user experience, fostering a sense of agency and freedom for individuals who may have previously felt restricted.

The core objective of Brainlink Mobility revolves around empowering individuals with quadriplegia through an innovative and affordable BCI-based wheelchair control system. Traditional solutions can be expensive and impractical, hindering their wider adoption. This project tackles this challenge by prioritizing affordability, ensuring that the transformative potential of BCI technology reaches a broader audience. The system harnesses EEG, EMG, and EOG signals from the prefrontal cortex, offering an intuitive and responsive control mechanism tailored to the user's individual needs. This paper delves deeper into the technical architecture of Brainlink Mobility, exploring the components, their functions, and how they orchestrate seamless wheelchair control.

2. Methodology

The Brainlink Mobility system architecture is an innovative and distributed solution tailored to address the mobility challenges faced by individuals with quadriplegia. This intricate system comprises two main components: the headset and the wheelchair, each playing a vital role in the seamless integration of brain-computer interface (BCI) technology with wheelchair control. The headset, equipped with EEG, EMG, and EOG sensors, serves as the neural signal acquisition hub. These sensors capture the user's brain activity, muscle activity, and eye movements, respectively, facilitating a comprehensive understanding of the user's intent.

The acquired signals undergo processing using an operational amplifier, which amplifies and filters the neural signals to extract relevant data. The Arduino Nano, functioning as the processing unit, takes this refined data and generates control commands that dictate the desired movements of the wheelchair. The wireless communication is facilitated by the ESP32 microcontroller, which transmits the control commands to the wheelchair component using the TCP/IP protocol. This wireless communication is crucial for providing users with real-time and reliable control over the wheelchair's actions.

On the wheelchair side, the ESP32 receives the transmitted control commands, and an Arduino Nano interprets these commands, translating them into motor control signals. The 24V motor controller is then responsible for driving the wheelchair's gear motors, which enable forward and backward movement, as well as turning capabilities. To enhance safety, additional sensors such as the MPU6050, ultrasonic sensors, and a pulse rate monitor are integrated. These sensors contribute to features like fall detection, ensuring the well-being of the user during operation.

The system's versatility is further amplified by the inclusion of servo motors, which assist in specific maneuvers and obstacle avoidance. This comprehensive architecture, combining advanced sensor technologies with efficient microcontrollers and wireless communication protocols, positions the Brainlink Mobility system as a promising assistive technology for individuals with quadriplegia.

3. Literature Review

Brain-Computer Interfaces (BCIs) have emerged as a promising technology to restore mobility and independence for individuals with motor impairments. BCI-based wheelchair control systems offer a hands-free and natural means for users to navigate their surroundings. This literature survey provides an overview of ten research papers exploring various BCI-based wheelchair control approaches.

EEG-Assisted EMG-Controlled Wheelchair for Improved Mobility of Paresis Patients [1] proposes a system that utilizes both EEG and EMG signals to enhance mobility. EEG signals detect focus, while EMG signals control wheelchair movement, aiming to improve accuracy and reduce fatigue for users with paresis. Advanced Eye Blink Sensor-Based Wheelchair [2] presents a system using eye blinks as control commands. An IR sensor detects blinks, processed into control signals for the wheelchair’s motors. Car Control by Using Brain Waves and Arduino-Based Mind Wave Mobile [3] demonstrates hands-free control of a model car using NeuroSky MindWave mobile headset signals. EEG signals related to concentration and eye blinks are processed for motor control. Eye-Controlled Wheelchair Using Image Processing Techniques [4] proposes an eye-controlled system using image processing to track eye movements. Image algorithms determine gaze direction for control commands. Electroencephalogram-Based Wheelchair Controlling System for People with Motor Disability Using Advanced Brainwear [5] presents an EEG-based system using Emotiv INSIGHT EEG headset signals, processed by an Arduino microcontroller for wheelchair control. A microwave radar sensor aids in obstacle avoidance. Designing a Cost-Effective Prototype of an Automated Wheelchair Based on EOG (Electrooculography) [6] proposes a cost-effective EOG-based system utilizing EOG electrodes to detect eye movements, processed by an Arduino microcontroller for wheelchair control. A threshold-based algorithm classifies eye movements into commands. Brain-Controlled Car for Disabled Using EEG [7] demonstrates hands-free control of a model car using an EEG headset with three electrodes. EEG signals transmitted to an Arduino microcontroller control car movement. Design and Development of an EOG-Based System to Control Electric Wheelchairs for People Suffering from Quadriplegia or Quadriparesis [8] presents an EOG-based system utilizing intentional eye blinks and eye movements for wheelchair control. An Arduino platform processes EOG signals to generate commands for the wheelchair’s motors. Design of Wheelchair Based on Electrooculography [9] proposes an EOG-based system utilizing EOG signals to detect eye movements. Electrodes around the eyes measure EOG signals, processed and classified into commands for wheelchair control. Development of a Control System for Electric Wheelchairs Based on Head Movements [10] investigates IMU data from head movements to control electric wheelchairs. IMU data processed using an Arduino Uno classifies head movements into commands, controlling wheelchair movement in a simulated environment.

Based on the reviewed papers, we propose a hybrid BCI-based wheelchair control system that combines EEG and EMG technology for forward movement control and EOG technology for precise left, right, and on/off commands. This combination aims to provide users with both coarse and fine control over their wheelchair, enabling them to navigate their environment with greater ease and control. BCI-based wheelchair control systems offer a promising solution for restoring mobility and independence to individuals with motor impairments. The reviewed papers provide a comprehensive overview of various BCI approaches and their potential applications in wheelchair control. Further research is needed to improve the accuracy, robustness, and usability of these systems to make them more widely available and beneficial for users.

4. Conclusion

In conclusion, the development of an EEG, EMG, and EOG-based wheelchair control system stands as a beacon of hope for individuals grappling with severe motor disabilities, illuminating a path towards enhanced mobility and independence. The seamless integration of cutting-edge technologies and the utilization of an Arduino-based control system within this project signify immense promise for transforming the lives of those who have encountered the challenges of motor impairments. The capability to harness brain signals and eye movements for wheelchair control opens up a world of possibilities, granting individuals the ability to navigate their environment with newfound freedom and ease. This innovative system not only enhances mobility but also instills a sense of self-reliance and dignity, fostering a greater feeling of inclusion and participation in society.

As we envision the future, the potential of this technology extends beyond wheelchair control. Through ongoing research and development, we can foresee a world where individuals with disabilities seamlessly interact with their surroundings, utilizing neural and ocular signals to control a diverse array of assistive devices and communication tools. The pursuit of this vision transcends mere technological advancement; it is a testament to the unwavering resilience of the human spirit in the face of adversity. It serves as a reminder of our collective responsibility to empower individuals with disabilities, ensuring access to the tools and technologies that can unlock their full potential.

With unwavering dedication and a shared commitment to innovation, the transformation of this groundbreaking technology into reality becomes possible. This endeavor has the potential to empower individuals with severe motor disabilities, enabling them to reclaim their mobility and embrace a life filled with endless possibilities.

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