ChAIr: Brain-Computer Interface for Wheelchair Mobility

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Contents

1 Abstract

Quadriplegic individuals face significant challenges in mobility due to limited control options for wheelchairs. Existing solutions, such as hand, head, and sip-and-puff controls, fail to provide universal accessibility. This paper presents **ChAIr**, a novel Brain-Computer Interface (BCI)-enabled wheelchair control system that leverages EEG signal processing and AI to create a customizable and adaptive mobility solution. We discuss current state-of-the-art control methods, the technological advancements in BCI, and our proposed system's potential to revolutionize wheelchair mobility.

2 Problem Statement

The global wheelchair user base exceeds 65 million, with 5 million individuals suffering from quadriplegia. Traditional control mechanisms rely on residual motor function, making them unsuitable for users with severe neuromuscular disorders.

2.1 Existing Control Mechanisms

- Hand control (joysticks)
- Head control (tilt sensors)
- Sip-and-puff systems (breath-based control)
- Chin control (limited effectiveness for advanced neuromuscular diseases)

These approaches are often cumbersome, require extensive training, and do not account for degenerative conditions where motor function continues to decline.

3 State of the Art

Recent advancements in assistive technology have introduced alternative wheelchair control methods:

3.1 Advanced Joystick and Voice Control

Voice commands and AI-assisted joystick input offer improvements in accessibility but still depend on the user's residual mobility or speech capabilities.

3.2 Brain-Computer Interfaces (BCI)

BCI technology interprets neural activity to control external devices, offering a promising avenue for hands-free and muscle-independent wheelchair navigation.

3.3 EEG-Based Signal Processing

BCI systems rely on Electroencephalography (EEG) to capture brain signals. The processing pipeline consists of:

- Signal Acquisition: Raw EEG data collection.
- Preprocessing: Noise removal and normalization.
- Feature Extraction: Techniques such as Common Spatial Patterns (CSP) and Fast Fourier Transform (FFT).
- Classification: Machine learning models (SVM, LDA, CNN) to map EEG patterns to wheelchair commands.

3.4 Challenges in BCI Implementation

- High variability in EEG signals between users.
- Noise and artifacts from muscle movements.
- Lengthy calibration times.

4 Proposed Solution

ChAIr integrates cutting-edge BCI technologies with machine learning-based classifiers for real-time wheelchair control. Our approach focuses on:

Device	Features
OpenBCI	Open-source, full raw data access
Muse	User-friendly, beginner-friendly
Unicorn Hybrid Black	Research-grade, professional use
Emotiv	Consumer-friendly, wireless design
Neurosity	Developer-focused, cloud integration
NeuroSky MindWave	Affordable, entry-level

Table 1: Comparison of EEG hardware options

4.1 BCI Hardware Selection

We evaluate multiple EEG headsets based on usability and affordability:

4.2 Customizable AI Training

Users can train their AI classifier in under an hour, allowing for personalized movement control with no predefined presets. The intuitive setup ensures ease of use, even for non-technical users.

5 Organization

The development and deployment of **ChAIr** follow a structured timeline:

- February: AI backend development, hardware procurement.
- March: Virtual testing environment setup.
- April: AI training interface implementation.
- May: Beta testing phase.
- Summer 2025: Global launch.

Our interdisciplinary team combines expertise in computer science, aerospace engineering, and mathematics to bring **ChAIr** to life.

6 Conclusion

ChAIr represents a significant leap forward in mobility solutions for quadriplegic individuals. By harnessing BCI technology, we enable seamless and intuitive wheelchair control, reducing dependency on physical movement. Future work includes optimizing classification models, reducing calibration time, and expanding accessibility to lower-cost EEG solutions.

References

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Here's a **ChAIr** for you