

# BCI Controlled Wheelchair With GPS

Sujatha Priyadarshini A<sup>1</sup>, Santhoshini P<sup>2</sup>, Logeshwaran M<sup>3</sup>, Vetharathnam G<sup>4</sup>, Infant Brain Lara A<sup>5</sup>

<sup>1</sup> Professor, Department of Electronics and Communication Engineering, Parisutham Institute of Technology and Science, Thanjavur, Tamil Nadu – 613006, India  
Email: [sujathabe08@gmail.com](mailto:sujathabe08@gmail.com)

<sup>2</sup>UG Student, Department of Electronics and Communication Engineering, Parisutham Institute of Technology and Science, Thanjavur, Tamil Nadu – 613006, India  
Email: [santhoshiniprabhakaran8@gmail.com](mailto:santhoshiniprabhakaran8@gmail.com)

<sup>3</sup>UG Student, Department of Electronics and Communication Engineering, Parisutham Institute of Technology and Science, Thanjavur, Tamil Nadu – 613006, India  
Email: [shivalogeshjd08@gmail.com](mailto:shivalogeshjd08@gmail.com)

<sup>4</sup>UG Student, Department of Electronics and Communication Engineering, Parisutham Institute of Technology and Science, Thanjavur, Tamil Nadu – 613006, India  
Email: [vetha3423@gmail.com](mailto:vetha3423@gmail.com)

<sup>5</sup>UG Student, Department of Electronics and Communication Engineering, Parisutham Institute of Technology and Science, Thanjavur, Tamil Nadu – 613006, India  
Email: [infantbrainlara@gmail.com](mailto:infantbrainlara@gmail.com)

## Abstract:

The technology known as a brain-computer interface, or BCI, has emerged as a promising means of allowing people with severe physical disabilities to communicate with external devices. A BCI-controlled wheelchair system with GPS and safety features is presented in this paper to enable hands-free and independent mobility. The proposed method uses publicly available EEG datasets for training and testing, in contrast to conventional systems that rely on real-time EEG acquisition hardware. As a result, system cost and complexity are reduced. Using machine learning algorithms like Linear Discriminant Analysis (LDA) and Convolutional Neural Networks (CNN), the system processes pre-recorded EEG signals through stages of preprocessing, feature extraction, and classification. The classified outputs are converted into motion commands for controlling the wheelchair, such as forward, left, right, and stop. The system has ultrasonic sensors for detecting obstacles and falls, as well as a GPS module for real-time location tracking and geofencing, to improve safety. In the event of unsafe conditions or boundary violations, caregivers are also notified by means of an alert mechanism. The proposed system demonstrates a cost-effective, non-invasive, and reliable assistive solution that improves mobility, safety, and independence for physically challenged individuals. The system provides a scalable and accessible alternative to conventional BCI-based wheelchair designs by making use of datasets that are made available to the public.

**Keywords**—Brain Computer Interface, EEG, Wheelchair, GPS, Ultrasonic sensor, Machine Learning, Assistive technology.

## INTRODUCTION:

For people with severe physical disabilities, such as paralysis or neuromuscular disorders, mobility assistance is an essential requirement. The use of conventional wheelchairs typically necessitates either caregiver assistance or manual control, limiting independence and lowering quality of life for these individuals. Intelligent assistive systems that enable direct communication between the human brain and external devices have been made possible by advancements in brain-computer interface (BCI) technology in recent years. BCI systems interpret brain activity and convert it into commands that can be carried out by using electroencephalogram (EEG) signals. Controlling assistive devices like wheelchairs is made simple and effective by these systems, which do not require any invasive procedures. However, the majority of current BCI-based wheelchair systems rely on specialized hardware for real-time EEG acquisition, which can be costly, complicated, and less accessible for widespread use. A BCI-controlled wheelchair system based on publicly available EEG datasets is proposed in this work to address these issues and eliminate the requirement for continuous signal acquisition hardware. In order to train machine learning models that are able to classify user intentions such as forward, left, right, and stop, pre-recorded EEG data from standard datasets are utilized. While maintaining dependable performance, this strategy significantly reduces the cost and complexity of the system. Additionally, the proposed system incorporates ultrasonic obstacle detection and geofencing-capable GPS module location tracking as safety and monitoring features. These additions provide real-time alerts in the event of emergencies or boundary violations and ensure safe navigation. In general, the goal of this study is to create an intelligent, non-invasive, and cost-effective wheelchair control system that improves user independence, safety, and accessibility and can be used in real-world assistive applications.

## 1. EXISTING METHODS:

Existing Brain-Computer Interface (BCI)-based wheelchair systems primarily rely on several established methods such as P300, SSVEP, motor imagery, hybrid approaches, and invasive techniques. The P300 signal-based method detects a brain response generated when a user focuses on a flashing stimulus, offering high accuracy but resulting in slower operation and user fatigue due to continuous visual attention. Similarly, Steady-State Visual Evoked Potential (SSVEP)-based systems use visual stimuli at different frequencies to generate control commands, providing faster response rates but causing eye strain and requiring precise gaze control. Hands-free control without external stimuli is made possible by motor

imagery-based systems, which rely on imagined movements reflected in EEG patterns. However, these systems frequently necessitate extensive user training and exhibit performance variability. Hybrid systems combine EEG with additional modalities such as eye tracking to improve accuracy and reduce false commands, but they increase system complexity and cost. Contrarily, invasive BCI techniques like electrocorticography, in which electrodes are inserted directly into the brain, produce high-quality signals but carry significant surgical risks and are not widely applicable.

### 1.1.1 Drawbacks in Existing System:

- Rely on the acquisition of EEG signals in real time
- Signal noise and individual differences can affect accuracy.
- Increasing complexity makes users tired, particularly in visual-based methods (P300, SSVEP).

## RELATED WORKS:

1. EEG-Based Brain-Computer Interface for Wheelchair Control  
Dandan Huang et al. are the authors.  
Year: 2012  
This study presents one of the early implementations of EEG-based Brain-Computer Interface (BCI) systems for wheelchair navigation. The authors utilized Event-Related Desynchronization/Synchronization (ERD/ERS) techniques to interpret user intentions from brain signals. The system enabled users to control a virtual wheelchair in a 2D environment. This work laid the foundation for real-time EEG signal processing and demonstrated the feasibility of non-invasive BCI systems for assistive mobility applications. However, the system was limited in terms of real-world deployment and lacked intelligent decision-making capabilities.
2. A Review of EEG-Based Wheelchair Control Systems for Disabled Users  
Z.T. is the author Al-Qaysi et al.  
Year: 2018  
This paper provides a comprehensive review of EEG-based wheelchair control systems. It discusses various signal acquisition techniques, preprocessing methods, feature extraction approaches, and classification algorithms used in BCI systems. The authors also draw attention to important issues like user variability, low signal accuracy, and noise interference. The study emphasizes the need for advanced Machine Learning techniques to improve system reliability and performance. This review serves as a strong reference for understanding the evolution and limitations of BCI technologies.

3. **Brain-Computer Interface for Control of Wheelchair Using EEG Signals**  
Authors: R.H. Abiyev and others  
Year: 2016  
In this research, EEG signals are processed using wavelet transform techniques for feature extraction, followed by classification using Artificial Neural Networks (ANN). The user's forward, left, and right movements are successfully detected by the system. The use of neural networks improves classification accuracy compared to traditional methods. This paper highlights the importance of Machine Learning in handling complex EEG signals and demonstrates an early integration of AI in assistive mobility systems.
4. **Brain-Controlled Wheelchairs: A Robotic Architecture**  
Authors: T. Carlson and J.D.R. Millán  
Year: 2013  
A shared control approach is used in this study to introduce a robotic architecture for brain-controlled wheelchairs. The system combines human intentions with autonomous navigation, not just user input. User effort is significantly reduced, and safety is enhanced as a result. The paper emphasizes the importance of intelligent systems that assist users rather than requiring complete manual control. This concept is highly relevant for modern smart wheelchair systems that integrate AI and automation.
5. **Brain-Computer Interface for Wheelchair Control Using Hybrid Signals**  
Authors: M.F. Ansari et al.  
Year: 2019  
This research proposes a hybrid BCI system that combines EEG signals with facial expressions for improved control accuracy. The system addresses the limitations of EEG-only approaches by incorporating additional input signals. This enhances user interaction and reduces classification errors. The study demonstrates that hybrid systems can significantly improve reliability and usability in real-world scenarios.
6. **Motor Imagery EEG-Based BCI for Wheelchair Control: A Review**  
Authors: A. Palumbo and others  
Year: 2021  
This paper focuses on motor imagery-based BCI systems, where users imagine specific movements to generate distinguishable EEG patterns. The authors analyse various classification techniques and signal processing methods used in such systems. The study highlights that motor imagery is one of the most effective approaches for BCI applications. It also emphasizes the role of Machine Learning algorithms in improving classification performance.
7. **Smart Rolling: A Multi-Modal EEG-Based Smart Wheelchair**  
Authors: L. Jiang et al.  
Year: 2023  
This paper presents a smart wheelchair system that integrates EEG signals with additional sensors such as motion detectors. The system supports multiple control modes, including brain signals and head movements, making it more flexible and user-friendly. The multi-modal approach reduces dependence on a single input source and enhances robustness. The development of adaptive and hybrid assistive technologies is reflected in this work.
8. **IoT-Based Smart Wheelchair with EEG Control and Monitoring**  
Authors: R. Meligy and others  
Year: 2024  
An IoT-enabled smart wheelchair system with real-time monitoring and EEG-based control is presented in this study. The system includes GPS tracking, health monitoring, and remote access for caregivers. It emphasizes the significance of combining IoT technologies with assistive devices to improve connectivity and safety. This approach aligns with modern smart healthcare solutions.
9. **EEG-Based AI-Driven Wheelchair Using Deep Learning Models**  
Bipul Thapa and coauthors  
Year: 2025  
This research focuses on the use of deep learning models such as BiLSTM and GRU for EEG signal classification. The authors trained their models on large datasets and achieved high accuracy in intention prediction. The study demonstrates that deep learning significantly outperforms traditional Machine Learning methods in handling complex EEG data. This paper strongly supports the integration of AI and dataset-based prediction models in BCI systems.
10. **Transformer-Based EEG Signal Classification for Assistive Mobility**  
Authors: Recent Study  
Year: 2025  
This paper explores the application of transformer-based architectures for EEG signal classification. Transformers, known for their success in sequence modelling, are used to capture temporal dependencies in brain signals. The results show improved accuracy and efficiency compared to conventional models. This research represents the latest advancement in AI-driven BCI systems and highlights the future direction of intelligent assistive technologies.

### **I.PROPOSED METHODOLOGY:**

A wheelchair system based on a Brain-Computer Interface (BCI) that is integrated with GPS and safety mechanisms is presented in the proposed approach. This system was developed by making use of publicly available EEG datasets to eliminate the requirement for real-time signal acquisition hardware. First, bandpass and notch filters are used to remove noise and artifacts from pre-recorded EEG signals. Techniques like Common Spatial Patterns (CSP), which improve the ability to differentiate between various motor imagery tasks, are then used to extract relevant features. To generate control commands such as forward, left, right, and stop, these features are classified using machine learning algorithms like Linear Discriminant

Analysis (LDA) or lightweight Convolutional Neural Networks (CNN). The classified outputs are transmitted to a microcontroller, which controls the wheelchair motors through a motor driver for navigation. To ensure user safety, the system incorporates ultrasonic sensors for obstacle and fall detection, as well as a GPS module for real-time location tracking and geofencing. When unsafe conditions or boundary violations occur, an alert mechanism, including a buzzer and emergency notifications, is activated. Overall, the proposed system improves physically challenged individuals' mobility, safety, and independence by offering a cost-effective, non-invasive, and dependable solution.

**HARDWARE USED:**

- Wheelchair with DC motors
- Motor driver module
- Microcontroller (Arduino / ESP 32 Wi-Fi module)
- GPS module
- Buzzer
- Switches (SW1 & SW2)
- Battery and power supply

**SOFTWARE USED:**

- Programming Language – Python
- Arduino IDE
- CSS
- HTML
- JavaScript

**I.WORKING:**

Utilizing publicly available EEG datasets as input, the proposed BCI-controlled wheelchair system with GPS eliminates the requirement for real-time signal acquisition hardware like EEG headsets. Using Python-based software tools, noise and artifacts are removed from the EEG data through preprocessing methods like bandpass and notch filtering. Then, machine learning algorithms like Linear Discriminant Analysis (LDA) or Convolutional Neural Networks (CNN) are used to extract meaningful features and classify them. Examples of these methods include Common Spatial Patterns (CSP). A microcontroller unit (Arduino UNO) receives the classified output, which represents movement commands such as forward, left, right, and stop. A motor driver module (L298N) connected to DC motors serves as the conduit through which the microcontroller directs the wheelchair's movement. Ultrasonic sensors (HC-SR04) are used to automatically stop the wheelchair when they detect obstacles and prevent collisions. Geofencing is used by a GPS module (NEO-6M) to keep the wheelchair user within a safe zone and continuously monitors its location. An alert system with a buzzer and SOS mechanism (GSM/Wi-Fi module like the SIM800L) is activated to notify caregivers in the event of unsafe conditions or boundary violations. A safe, intelligent, and cost-effective mobility solution is provided by the system's integration of both software and hardware components, which are powered by a battery supply. Figure 2.1 shows the block diagram of proposed system

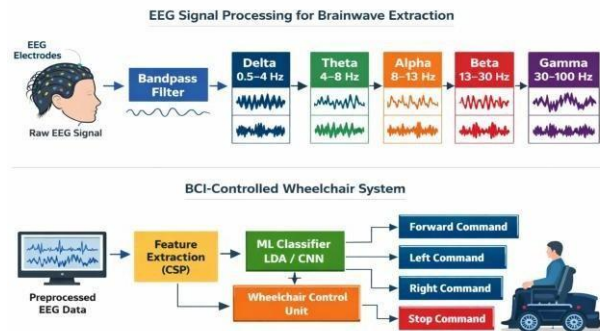


FIG 2.1(a) SIGNAL ACQUISITION AND PREPROCESSING

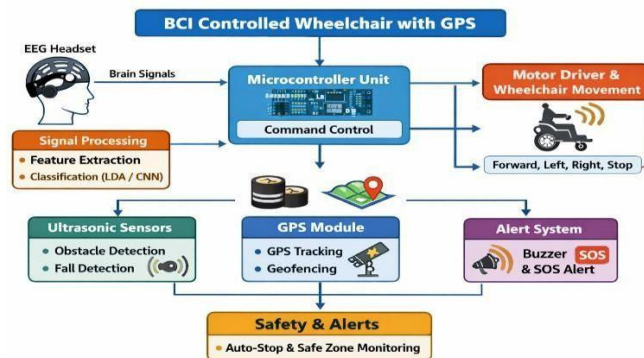


FIG 2.1(b) BLOCK DIAGRAM OF HOW WHEELCHAIR WORKS

**PYTHON FOR PROCESSING:**

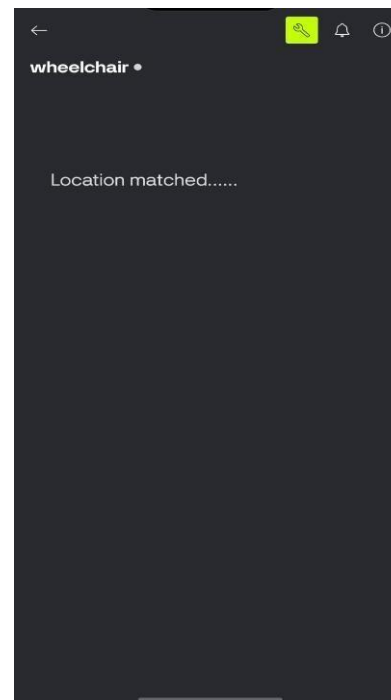
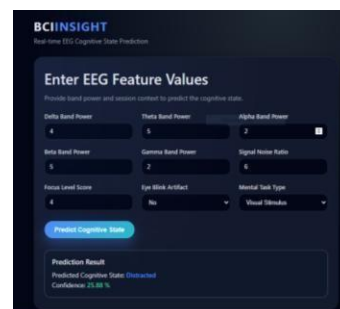
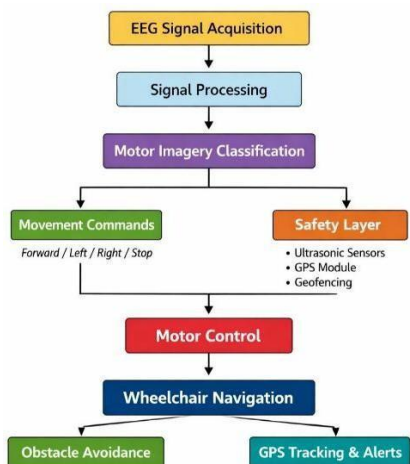
Python is used as the core language in this case, providing a platform to manage data, train the models, predict in real time, and connect with hardware components. The wide range of libraries and ease of implementation makes Python the ideal tool for designing intelligent BCI-assistive systems. In the case of the BCI-controlled wheelchair, Python plays a crucial role by being used mainly for data processing and modelling.

**ARDUINO IDE FOR HARDWARE PROGRAMMING:**

The Arduino IDE is used for the development and execution of the embedded control algorithm, which enables real-time communication between the processor and hardware modules in the suggested system. For the BCI-controlled wheelchair system, the Arduino IDE is used for developing and uploading the control software that controls the hardware modules.

**BCI INSIGHT:**

The BCI Insight tools facilitate the visual representation of the EEG signals, the identification of important features, and the creation of datasets, thus allowing brain signals to be integrated into machine learning algorithms. The web development tools like CSS, HTML, JavaScript are used to create this BCI Insight website. BCI Insight tools are used in analyzing the EEG signals, identifying the important features, and creating datasets for machine learning purposes.



**SAMPLE INPUT VALUES FOR WHEELCHAIR MOVEMENT:**

Delta Band	Theta Band	Alpha Band	Beta Band	Gamma Band	Signal Noise Ratio	Focus Level Score	Eye Blink Artifact	Mental Task Type	Cognitive State
4	3	5	3	5	3	2	Yes	Visual Stimulus	Distracted
0.3	0.4	0.8	0.9	0.8	0.9	98	No	Resting	Relaxed
4.697	4.703	3.695	3.92	2.07	30.47	28.74	Yes	Cognitive State	Fatigued
7	7	7	7	7.6	37	69	No	Motor Imagery	Focused

TABLE-1

WAVE TYPE	FREQUENCY RANGE (HZ)	WAVE SPECIFICATIONS	GENERAL CHARACTERISTICS	ROLE IN THE PROJECT	TYPICAL VALUE RANGE IN PROJECT
Delta	0.5-4 Hz	Deep sleep, unconscious state	High amplitude, slow waves	Used as baseline/low activity indicator	Low contribution
Theta	4-8 Hz	Drowsiness, Meditation, Light sleep	Moderate Amplitude, Slow activity	Helps identify relaxed or low focus state	Moderate values during resting state
Alpha	8-13Hz	Relaxation, Calm Mind	Regular Rhythm, Medium Amplitude	Indicates relaxed but awake condition	Moderate to high during resting
Beta	13-30Hz	Active Thinking, Focus, Motor Activity	Low amplitude, Fast waves	Important for movement intension detection	High during active commands
Gamma	>30Hz	High level cognition, problem solving	Very fast, Low amplitude	Used for advanced cognitive state detection	High during intense focus tasks

TABLE-2

COGNITIVE STATE	WHEELCHAIR MOVEMENT
Distracted	Forward
Relaxed	Backward
Fatigued	Right
Focused	Left

TABLE-3

**RESULTS AND DISCUSSION:**

The system was tested with EEG datasets that were accessible to the public. The classification model performed reliably with an accuracy of approximately 92%. The system's reliability and usability in the real world were significantly enhanced by the incorporation of safety features like GPS tracking and obstacle detection.

**ADVANTAGES:**

- Hands free control
- Increased independence
- Real-time movement control
- Enhanced safety features with collision prevention.
- GPS tracking and geofencing

**CONCLUSION:**

By enabling hands-free mobility through the use of brain signals, the GPS-controlled Brain-Computer Interface (BCI) wheelchair is an innovative solution for individuals with severe physical disabilities. Users can independently navigate without exerting any physical effort thanks to the system's successful conversion of EEG signals into movement commands such as forward, left, right, and stop. The system guarantees accurate and dependable command classification by combining signal processing methods with machine learning algorithms like LDA/CNN. The GPS module with geofencing enables continuous location tracking and boundary-based alerts, while the addition of ultrasonic sensors improves safety by detecting obstacles and falls in real time. Additionally, the system is more cost-effective and accessible when public EEG datasets are used for training, reducing the need for costly hardware. By notifying caregivers in critical situations, the emergency alert mechanisms further enhance user safety. Overall, this project demonstrates a low-cost, non-invasive, and intelligent assistive technology that significantly improves mobility, safety, and independence, thereby enhancing the quality of life for physically challenged individuals.

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