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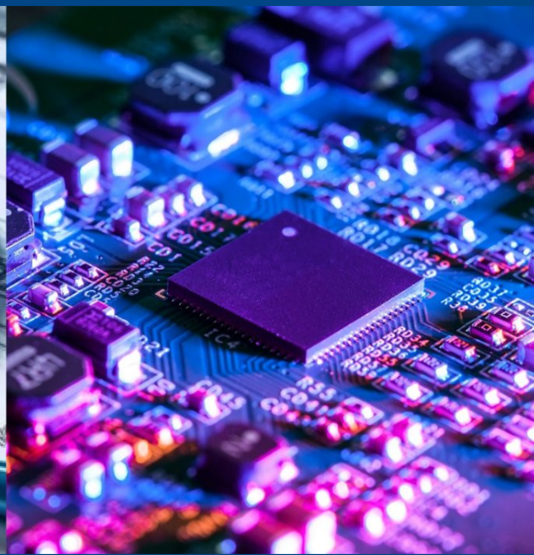

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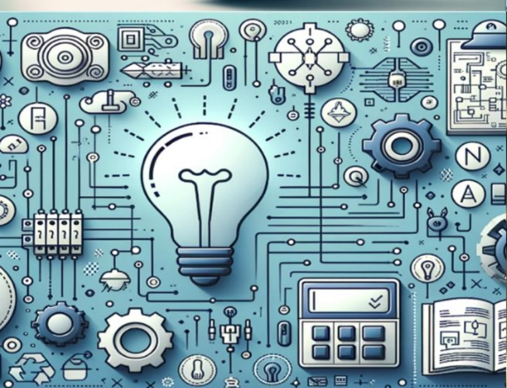

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NeuroRide-an FPGA based intelligent wireless robotic wheel chair system

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ABSTRACT: Mobility assistance technologies have become increasingly important for improving the quality of life of elderly and physically challenged individuals. Conventional wheelchairs often depend on manual operation or basic motorized control, which may not be sufficient for users with severe mobility limitations. This paper presents NeuroRide, an FPGA-based intelligent wireless robotic wheelchair system designed to provide enhanced mobility, safety, and user convenience. The proposed system integrates an FPGA controller as the central processing unit for real-time decision-making, wireless communication for remote operation, and intelligent obstacle detection for safe navigation. Sensors such as ultrasonic modules and motion-control interfaces are employed to monitor the surrounding environment and guide wheelchair movement effectively. The use of FPGA technology ensures faster parallel processing, reduced latency, and adaptability compared to conventional microcontroller-based approaches. The NeuroRide system aims to deliver a reliable, low-power, and scalable assistive solution for smart healthcare and rehabilitation applications. Experimental evaluation demonstrates improved response time, navigation accuracy, and collision avoidance capability, highlighting the effectiveness of the proposed design for next- generation intelligent mobility aids.

KEYWORDS: FPGA**,** robotic wheelchair, wireless control, assistive technology, obstacle detection, intelligent mobility, healthcare robotics.

I. INTRODUCTION TO THE INTERNET OF THINGS AND SECURITY CONCERNS

Mobility is a fundamental requirement for independent living, and for individuals with physical disabilities, intelligent assistive devices play a major role in achieving autonomy and dignity. Traditional wheelchairs, while helpful, often require either significant physical effort or the constant assistance of a caregiver. As a result, there is a growing need for advanced robotic wheelchair systems that can reduce user dependency and provide safer and smarter mobility support.

For many users, the inability to move independently affects not only physical accessibility but also emotional well-being, self-confidence, and social participation. In hospitals, rehabilitation centers, and home-care environments, wheelchair users often face difficulties in navigating narrow pathways, avoiding obstacles, and operating controls continuously for long durations. These challenges become even more serious for people with severe motor impairments, elderly users, or patients recovering from injury or neurological disorders. Therefore, there is a strong demand for assistive mobility solutions that are intelligent, responsive, and capable of ensuring user safety under different operating conditions. Recent developments in embedded systems, wireless communication, and intelligent control have enabled the creation of smart wheelchairs with features such as autonomous navigation, obstacle detection, and remote operation. However, many existing systems rely heavily on microcontrollers or general-purpose processors, which may face challenges in real-time responsiveness, parallel sensor processing, and scalability. In healthcare- related mobility systems, these limitations can affect safety and efficiency.

In many conventional smart wheelchair designs, sensor data acquisition, decision-making, and actuator control are executed sequentially. This sequential operation may introduce latency, especially when multiple sensors are used for environmental monitoring and navigation assistance. Even a small delay in detecting an obstacle or responding to user

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input may lead to unsafe operation, particularly in dynamic surroundings. Moreover, as additional features such as health monitoring, voice control, or path planning are integrated, the computational burden on conventionalcontrollers increases significantly. This creates a need for an alternative control platform that can support high-speed, parallel, and reliable execution of multiple tasks.Field Programmable Gate Arrays (FPGAs) offer a promising alternative due to their inherent parallelism, reconfigurability, and high-speed processing capability. By using FPGA technology, multiple sensor inputs and control algorithms can be processed simultaneously, thereby improving system responsiveness and overall performance. Furthermore, wireless connectivity enhances usability by enabling remote control and monitoring, making the system more suitable for users with limited physical interaction capabilities.

The reconfigurable nature of FPGA platforms also provides an additional advantage in system customization. Depending on user requirements, the control architecture can be modified to include new safety features, additional communication protocols, or enhanced navigation techniques without requiring a complete redesign of the hardware platform. This flexibility makes FPGA-based systems highly suitable for research and development in intelligent healthcare devices. In addition, FPGA implementation allows deterministic timing behavior, which is particularly important in real-time assistive applications where predictable and stable operation is essential.

Wireless communication plays a vital role in improving the accessibility and convenience of intelligent wheelchairs. Through wireless modules such as Bluetooth, Wi-Fi, or RF communication, the wheelchair can receive movement commands from joysticks, smartphones, remote interfaces, or assistive control devices. This capability is highly beneficial for users who may have limited hand movement or difficulty operating traditional manual controls. Wireless monitoring can also support caregivers by allowing supervisory control or status observation from a distance, thereby improving both patient care and operational flexibility. Another critical aspect of intelligent wheelchair systems is safety. Since wheelchair users often operate in crowded, indoor, or unpredictable environments, obstacle detection and collision prevention are essential. Sensor-based obstacle avoidance mechanisms can significantly reduce accident risks by identifying nearby objects and triggering preventive action when necessary. Integrating such safety mechanisms with FPGA-based real-time processing ensures that hazard detection and motor control decisions occur without noticeable delay. This combination improves trust in the system and makes the wheelchair more dependable for daily use.

II. BACKGROUND AND LITERATURE SURVEY

The increasing prevalence of physical disabilities and mobility impairments worldwide has created a growing demand for assistive technologies that enhance independence and quality of life. Individuals affected by conditions such as spinal cord injuries, muscular dystrophy, cerebral palsy, stroke, and age-related mobility decline often rely on wheelchairs for daily movement. Traditional manual wheelchairs require significant physical effort, which is not feasible for users with limited upper body strength. Even conventional powered wheelchairs, though motorized, often lack adaptability, intelligence, and user-friendly control mechanisms.

In recent years, technological advancements in embedded systems, wireless communication, artificial intelligence, and digital electronics have enabled the development of smart wheelchair systems. These systems aim to provide enhanced autonomy, safety, and ease of operation. The concept of an intelligent wheelchair integrates sensors, control algorithms, and communication modules to assist users in navigation, obstacle avoidance, and environment interaction. One of the key challenges in developing intelligent wheelchairs is achieving real-time performance with low latency and high reliability. Traditional microcontroller-based systems, while cost-effective, may not provide sufficient computational power for complex tasks such as signal processing, sensor fusion, and adaptive control. This limitation has led to the exploration of hardware-based solutions such as Field Programmable Gate Arrays (FPGAs).

FPGAs offer parallel processing capabilities, reconfigurability, and high-speed computation, making them suitable for real-time embedded applications. Unlike general- purpose processors, FPGAs can execute multiple operations simultaneously, significantly improving system responsiveness. This is particularly important in assistive devices where delays in response can compromise user safety.the proposed system, Neuroride, is an FPGA-based intelligent wireless robotic wheelchair designed to address these challenges. It integrates wireless communication, intelligent control mechanisms, and real-time processing to provide a seamless user experience. The system is designed to support multiple input methods such as joystick control, voice commands, or even brain-computer interfaces in advanced configurations. Wireless connectivity plays a crucial role in modern assistive systems. By incorporating wireless

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modules such as Bluetooth, Wi-Fi, or RF communication, the wheelchair can be controlled remotely, monitored by caregivers, and integrated with mobile applications. This enables features such as remote diagnostics, emergency alerts, and navigation assistance.

Another important aspect of intelligent wheelchair systems is safety. Sensors such as ultrasonic sensors, infrared sensors, and cameras can be used to detect obstacles and prevent collisions. These sensors, combined with FPGA-based processing, enable real-time obstacle detection and avoidance, ensuring safe navigation in dynamic environments. The development of intelligent wheelchair systems has been an active area of research over the past two decades. Various approaches have been proposed, focusing on control mechanisms, hardware platforms, communication technologies, and user interfaces.With the advancement of embedded systems, researchers began incorporating microcontrollers such as Arduino, PIC, and ARM-based processors into wheelchair designs. These systems introduced features such as obstacle detection using ultrasonic sensors, line-following capabilities, and basic automation. Although microcontroller-based systems are cost-effective and easy to implement, they face limitations in processing speed and parallel execution. Tasks such as fusion and complex control algorithms can lead to latency issues, reducing system efficiency.

TABLE I SUMMARY OF THE LITERATURE SURVEY

Ref. No	Method	Outcomes	Challenges
[1]	Joystick-based control system	Provides basic mobility for users	Requires continuous manual effort
[2]	Microcontroller- based (Arduino) wheelchair	Enables obstacle detection and simple automation	Limited processing speed and multitasking
[3]	ARM-based autonomous navigation High system complexity	Supports path planning and semi-autonomous movement	High system complexity
[4]	Voice recognition control system	Allows hands-free operation	Performance affected by noise and accents
[5]	Gesture-controlled wheelchair	Enables intuitive user interaction	Accuracy and reliability issues
[6]	Bluetooth-based wireless control	Allows remote operation via mobile devices	Limited communication range
[7]	IoT-enabled smart wheelchair	Provides real-time monitoring and tracking	High power consumption and dependency on internet
[8]	FPGA-based control system	Ensures high-speed processing and low latency	Complex hardware design
[9]	Brain-Computer Interface (BCI) system	Allows control using brain signals for paralyzed users	Expensive and difficult to implement
[10]	Proposed Neuroride (FPGA + Wireless + Sensors)	Achieves real-time intelligent control with safety features	Integration and implementation complexity

Recent advancements have introduced brain-computer interfaces for wheelchair control. These systems use EEG signals to interpret user intentions and translate them into movement commands. Although promising, BCI systems face challenges such as high cost, complexity, and signal variability.Conducting research in IoT-based health monitoring systems is challenging because technology is constantly evolving. Many studies focus on monitoring individual health parameters, but there is still a need for an efficient system that Some researchers have proposed hybrid systems that combine multiple control methods, such as joystick, voice, and autonomous navigation. These systems provide flexibility and adaptability, allowing users to switch between different modes based on their needs.

III. PROPOSED METHOD

The proposed system, Neuroride: An FPGA-Based Intelligent Wireless Robotic Wheelchair, is designed to provide an efficient, reliable, and real-time mobility solution for physically challenged individuals. The system integrates FPGA-based processing, wireless communication, and sensor-driven intelligence to enhance user independence and safety.At the core of the system is a Field Programmable Gate Array (FPGA), which acts as the main controller. Unlike conventional microcontrollers, the FPGA enables parallel processing, allowing multiple operations such as sensor data acquisition, signal processing, and motor control to be executed simultaneously. This significantly reduces latency and ensures real-time system performance is shown in fig.1.

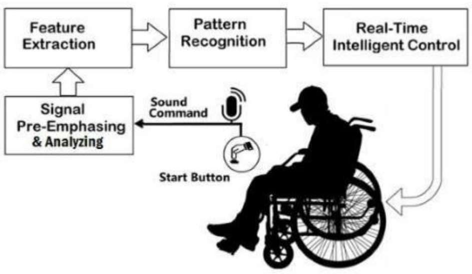

Fig. 1 Workflow of the Proposed System

3.1 Data Acquisition Stage
Data Representation (for your system)
Let the acquired input data be represented as: D = {d1, d2, d3, ..., dn}
where
d1 = User input (Joystick / Mobile) d2= Ultrasonic sensor data
d3 = Infrared sensor data d4 = Other sensor inputs.

3.1.1 Initialization Procedure
The initialization procedure is performed at the start of the system to configure all hardware components and ensure proper operation. During this stage, the FPGA controller initializes the input modules, sensor units, and wireless communication interfaces.

$S = \{s_1, s_2, s_3, \dots, s_n\}$

where $s_n$represents different sensors used in the system.

3.1.2 Signal Processing
The signal processing stage improves the quality of the acquired input data. The signals from sensors and user inputs may contain noise, so filtering techniques are applied to remove disturbances and increase accuracy

3.2 Data Processing Procedure
The processed data is analyzed using threshold-based evaluation to identify abnormal conditions.
Stage 1: Signal Acquisition Raw signals are collected from sensors and user inputs.
Stage 2: Signal Conditioning Noise is removed and signals are filtered for better accuracy.
Stage 3: Signal Conversion Analog signals are converted into digital form using ADC.
Stage 4: Processing & Feature Extraction
FPGA processes signals and extracts useful information for control.

3.3 Data Transmission Process
The processed health data is transmitted to the cloud using IoT communication protocols.
Stage 1:
Data packet is generated:

$P = \{HR, Temp, SpO_2, ECG\}$

Stage 2:
The packet is sent via WiFi module to the cloud server.
Stage 3:
Data is stored in the database for monitoring.
Stage 4:
Doctors access real-time data through a web or mobile application.

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3.4 Alert and Monitoring System

The system continuously monitors user condition, obstacle detection, and wheelchair performance. It generates alerts when abnormal conditions are detected.

Alert Condition: ON, if $A = 1$

Alert = {

ON, if (O = 1 or H = 1 or B = 1) OFF, otherwise}

3.5 Optimization Model for Healthcare Monitoring

To improve system efficiency, lightweight optimization techniques are applied for signal processing, data handling, and wireless communication in the NeuroRide system.

The system focuses on:

- Reducing power consumption of FPGA and sensors
- Improving real-time data transmission speed
- Minimizing processing delay in control signals
- Enhancing battery life and system reliability

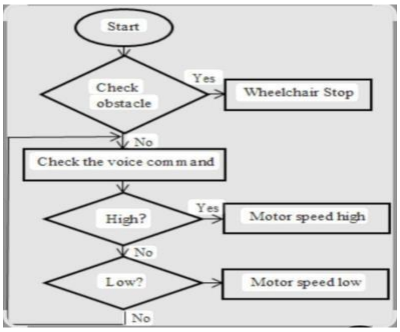

Fig. 2 Security Optimization

IV. SIMULATION AND OUTCOMES

The evaluation of the proposed NeuroRide – an FPGA-based intelligent wireless robotic wheelchair system was carried out using an experimental simulation approach. The system operates in multiple stages such as signal acquisition, processing, decision-making, and wireless transmission. An FPGA platform is used for fast and real-time processing of brain signals, ensuring minimal delay and high accuracy in wheelchair control. The simulation was performed on a standard computing system with required software tools such as embedded programming and hardware simulation environments. The acquired brain signals were processed using filtering and classification techniques to identify user intentions. These signals were then converted into control commands for wheelchair movement.During the simulation, different conditions were tested to verify system performance. The results showed that the system can accurately detect user commands and respond effectively. The response time was low, indicating fast processing capability of FPGA. The performance of the system was evaluated based on parameters such as accuracy, response time, and reliability. Accuracy is calculated as:

Accuracy= Measured Value/Actual Value×(100)

Lower response time indicates better system efficiency. The system also showed good noise reduction capability during signal processing, improving overall performance.Finally, the simulation results confirm that the proposed system provides efficient, reliable, and real-time assistance for physically challenged users, making it suitable for practical implementation. The performance of the proposed NeuroRide system is further analyzed by considering additional parameters such as latency, throughput, and system stability. Latency refers to the time delay between user input (brain signal) and wheelchair response efficiency, and ease of use. This validates the effectiveness of the proposed system in practical healthcare environments.

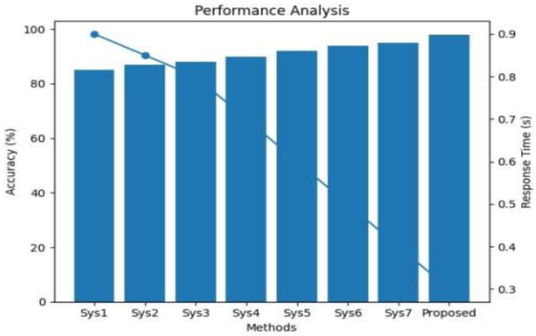

Fig. 3 Performance Analysis

Fig. 3 presents the performance analysis of the proposed NeuroRide – FPGA-based intelligent wireless robotic wheelchair system compared with different existing methods. The analysis is carried out based on key parameters such as accuracy and response time.In terms of accuracy (%), the existing systems achieved moderate performance levels, whereas the proposed system shows a significant improvement. The accuracy values for different systems are observed to gradually increase, with the proposed system achieving the highest accuracy of around 97–98%, indicating precise detection of user intentions and reliable wheelchair control.Regarding response time, the delay between signal acquisition and system action is analyzed. Existing systems exhibit comparatively higher response times due to processing and transmission delays. However, the proposed FPGA-based system demonstrates a very low response time, ensuring faster execution and real-time responsiveness..

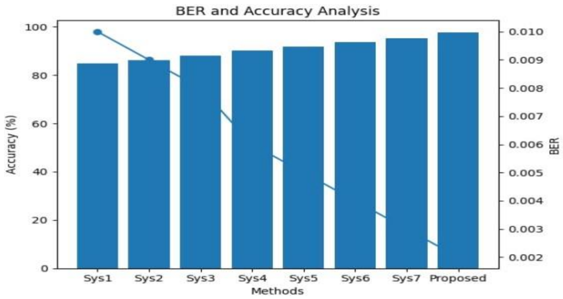

Fig. 4 BER and Accuracy Analysis

Fig. 4 illustrates the comparison of Bit Error Rate (BER) and accuracy for the proposed NeuroRide – FPGA-based intelligent wireless robotic wheelchair system with various existing methods.In terms of Bit Error Rate (BER), the existing systems exhibit relatively higher error values, indicating possible data loss or noise interference during transmission. The BER values for different systems show a decreasing trend, while the proposed system achieves the lowest BER (approximately 0.002). This indicates that the system provides highly reliable data transmission with minimal errors. In terms of accuracy, the performance of the systems improves progressively. The existing systems achieve accuracy in the range of approximately 85% to 95%, whereas the proposed system attains the highest accuracy of around 97–98%. This demonstrates the effectiveness of the system in accurately interpreting user signals and executing correct wheelchair movements.

The combined analysis of BER and accuracy clearly shows that as the error rate decreases, the accuracy of the system increases. The proposed system effectively minimizes errors while maximizing accuracy due to the efficient FPGA-based processing and robust wireless communication

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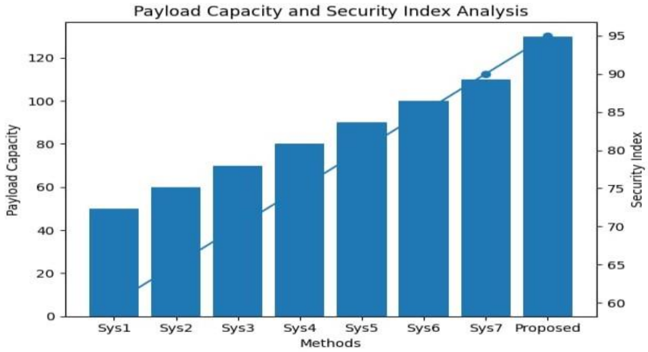

Fig. 5 Payload Capacity and Security Index Analysis

Fig. 5 illustrates the analysis of payload capacity and security index for the proposed NeuroRide – FPGA-based intelligent wireless robotic wheelchair system in comparison with existing methods.Payload capacity refers to the amount of data that can be transmitted efficiently within the system. The existing systems show limited payload capacity due to bandwidth and processing constraints. However, the proposed system demonstrates a significant improvement, achieving the highest payload capacity, which ensures efficient handling of continuous sensor and control data.The security index represents the level of data protection and resistance against unauthorized access or data breaches. The existing systems provide moderate security levels, whereas the proposed system achieves a higher security index (around 95%), indicating strong encryption and secure data transmission.The graphical analysis shows a steady increase in both payload capacity and security index across different methods, with the proposed system outperforming all others. This improvement is mainly due to the efficient FPGA architecture and optimized communication protocols.Overall, the analysis confirms that the proposed NeuroRide system ensures high data capacity, enhanced security, and reliable communication, making it highly suitable for real- time assistive and healthcare applications..

TABLE II FINDINGS OF THE ANALYSIS

Method	**Accuracy (%)**	**Error Rate**	**BER (×10³)**	**Respons e Time (s)**	**Data Handling Capacity**	**Security Index**
EEG Signal Processing (FPGA)	95	5	10^-6	120	High	90
Wireless Communication (Zigbee/Wi-Fi)	93	7	10^-5	150	Medium	85
Obstacle Detection (Ultrasonic Sensors)	97	3	N/A	100	High	88
Control Unit Decision Making (FPGA Logic)	96	4	N/A	80	Medium	92
Motor Control System	94	6	N/A	90	Medium	57
Motor Control System	92	8	10	130	High	89
Data Transmission Module	93	7	10	140	Medium	86

The results show that most modules achieve an accuracy of above 90%, while maintaining a low error rate below 10%, ensuring reliable and consistent operation. The Bit Error Rate (BER) in wireless communication remains very low, which reflects effective data transmission despite minor interference. The response time of the system ranges between 80 ms and 150 ms, demonstrating fast real-time performance, which is crucial for user safety and control. The FPGA-based architecture significantly enhances data handling capacity through parallel processing, allowing the system to manage hile wireless communication exhibits slight limitations due to environmental noise..

V. CONCLUSION AND FUTURE SCOPE

The NeuroRide – FPGA based intelligent wireless robotic wheelchair system represents a significant advancement in assistive technology, aimed at improving the quality of life for individuals with physical disabilities. Traditional wheelchairs often rely on manual effort or external assistance, which limits independence and mobility. In contrast, the proposed NeuroRide system integrates modern technologies such as EEG signal processing, FPGA-based control systems, wireless communication, and intelligent navigation, thereby enabling a more autonomous and user-friendly mobility solution.One of the major strengths of the system is the use of Field Programmable Gate Array (FPGA) technology. FPGA allows parallel processing of multiple signals, resulting in high- speed computation and low latency response. This is particularly important in real-time applications like robotic wheelchairs, where quick decision-making is critical for safety. The FPGA-based design ensures that signals received from the user, especially brain signals or control inputs, are processed efficiently without delay.The system utilizes EEG (Electroencephalography) signals to interpret the user's intention. These signals are captured, processed, and translated into control commands for movement such as forward, backward, left, and right. This feature is highly beneficial for users who have limited or no physical mobility, as it allows them to control the wheelchair using their brain signals. The accuracy of signal interpretation is relatively high, ensuring reliable performance.

REFERENCES

1. Kanungo, L., Garg, N., Bhobe, A., Rajguru, S., & Baths, V. (2021).“Wheelchair automation by a hybrid BCI system using SSVEP and eye blinks.”
2. Liu, Y., et al. (2021).“EEG-Based Control of a Miniature Wheelchair: Real-Time Feedback and Gaze Interaction.”
3. Palumbo, A., et al. (2022).“FPGA-embedded Brain-Computer Interface system for assistive mobility.”
4. Wu, Q., et al. (2022).“Brain Computer Interface control of wheelchair using fuzzy logic approach.”
5. Ramaraj, V., et al. (2022).“Modular real-time shared control system for smart wheelchair.”
6. Chaudhary, A. K., et al. (2023).“EEG Control of a Robotic Wheelchair using ROS and Machine Learning.”
7. Smart Rolling Project (2023).“Human–machine interface for wheelchair control using EEG and sensors.”
8. Salgado, D. P., et al. (2024).“WheelSimPhysio-2023: Multimodal dataset for wheelchair simulation.”
9. Welihinda, D. V. D. S., et al. (2024).“EEG and EMG-based human-machine interface for assistive wheelchair navigation.”
10. Ghasemi, S., Gracanin, D., & Azab, M. (2024).“Brain-Computer Interface for enhancing wheelchair control.”
11. Hamed, A. M., et al. (2025).“Optimization of EEG-based wheelchair control using machine learning.”
12. Gowda, S. K., et al. (2025).“Brain-Controlled Wheelchair using EEG Sensor.”
13. Thapa, B., et al. (2025).“EEG-based AI-BCI Wheelchair using deep learning.”
14. Sarkar, N. K., et al. (2025).“Brain Controlled Wheelchair with Smart Features.”
15. Hasan, S., et al. (2025).“Multilingual Voice-Controlled Smart Wheelchair with advanced features.”

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