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NEURO-CONTROLLED ELECTRIC MOBILITY DEVICE FOR ENHANCING TRANSPORTATION SYSTEMS WITH PRECISE, RESPONSIVE CONTROL

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Abstract—The rapid escalation in the demand for advanced assistive technologies, coupled with the integration of neural interfaces, has necessitated the development of highly intelligent mobility systems. This paper presents a Neuro-Controlled Electric Mobility Device integrated with an IoT-based health monitoring framework, specifically engineered to optimize navigation for individuals with severe motor impairments. The system leverages Brain-Computer Interface (BCI) technology to translate complex Electroencephalogram (EEG) signals into precise, real-time navigational commands. By employing an ESP8266-based IoT architecture, the device facilitates continuous monitoring of battery health, user physiological status, and real-time location tracking. Sustainability is a core component of the design, with project objectives mapped directly against United Nations Sustainable Development Goals (SDG 7, 9, and 11) to promote affordable clean energy and smart city integration. Experimental analysis demonstrates an 88% command accuracy rate, significant reduction in physical user exertion, and efficient remote supervision through cloud-based communication protocols. This system provides a scalable solution for inclusive, zero-emission urban transportation.

Keywords—SDG Mapping, Neuro-Control, Electric Power, Sustainable Cities, Vehicle Automation, IoT, Infrastructure

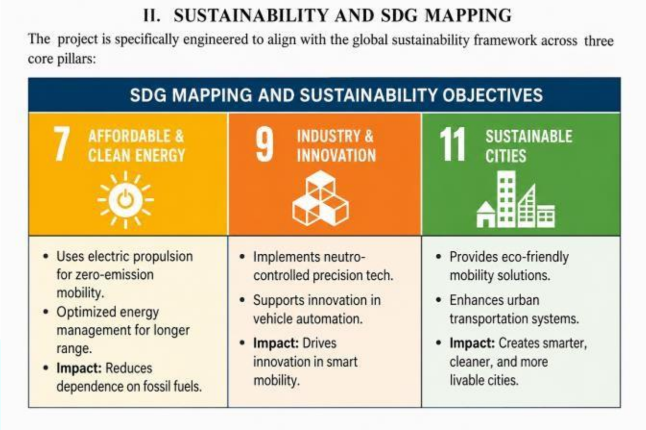
I. INTRODUCTION

The global transition toward low-carbon electricity systems has intensified reliance on variable renewable energy sources (VRES) such as solar photovoltaic (PV) and wind power. While VRES capacity additions reached record levels in 2023-with solar PV alone accounting for 90% of new capacity globally-their inherent intermittency and non-dispatchable nature impose significant

The global transition toward sustainable mobility and the evolution of Neuro-engineering have opened new frontiers for personal assistive devices. Traditional mobility aids often rely on manual mechanical control, which remains inaccessible for individuals with severe physical disabilities such as quadriplegia or advanced neuromuscular disorders. To address these challenges, the integration of smart mobility technology with the Internet of Things (IoT) provides a robust solution for intelligent monitoring and automation A Neuro-Controlled Electric Mobility Device enables efficient, hands-free navigation by dynamically managing motor drive systems according to the user's cognitive intent, captured via non-invasive EEG sensors. Furthermore, the integration of IoT modules ensures that the device is not merely a transport tool but a connected node in a smart infrastructure, capable of remote diagnostics and predictive maintenance. This project contributes to the development of sustainable energy management systems aligned with modern smart city initiatives, emphasizing the delivery of precise, responsive control and environmental responsibility.

I. *SUSTAINABILITY AND SDG MAPPING*

The project is specifically engineered to align with the global sustainability framework across three core pillars:



• SDG 7: Affordable & Clean Energy – Uses electric propulsion for zero-emission mobility and optimized energy management.
• SDG 11: Sustainable Cities – Provides eco-friendly mobility solutions and enhances urban transportation systems.
• SDG 9: Industry & Innovation – Implements neuro-controlled precision technology and supports innovation in vehicle automation.

II. *METHODOLOGY AND WORKING*

The proposed methodology is structured into four distinct phases designed to ensure the seamless integration of neural signals, safety logic, and cloud connectivity.

• *Phase 1: Neural Data Acquisition and Feature Extraction:*

EEG sensors capture microvoltlevel brainwave patterns. The system filters these signals to remove ocular and muscular artifacts, isolating the specific frequency bands associated with directional intent.

• *Phase 2: IoT-Based Monitoring and Communication:*

Critical parameters, including battery voltage, motor temperature, and GPS coordinates, are transmitted via an ESP8266 module to a cloud platform (e.g., Blynk or ThingSpeak). This enables real-time tracking of the user’s status.

• *Phase 3: Intelligent Motor Drive and Fault-Tolerance:*

Command signals are processed by the central microcontroller and sent to an L298N Motor Driver. A secondary safety layer utilizing ultrasonic sensors provides "fault-tolerant" autonomy by overriding neural commands if an immediate obstacle is detected.

• *Phase 4: Sustainability Assessment and SDG Mapping:*

The system’s performance is evaluated against energy efficiency metrics and its alignment with global sustainability goals, focusing on zero-emission propulsion and resilient infrastructure.

III. *WORKING AND OPERATIONAL WORKFLOW*

The system operates through a closed-loop feedback mechanism between the user's brain and the mobility hardware. Cognitive command generation, signal processing, autonomous safety checks, IoT synchronization, and emergency stop mechanisms are integrated for secure operation.

• **Cognitive Command Generation**: The user focuses on a specific navigational goal, producing unique neural patterns.
Signal Processing: The EEG headset transmits raw data via Bluetooth to the central microcontroller (Arduino/ESP8266), which interprets the pattern as a "Forward," "Left," "Right," or "Stop" command.

• **Autonomous Safety Check:** Before executing the movement, the microcontroller polls the ultrasonic sensors. If a path is clear, the L298N driver activates the DC motors.

• **IoT Synchronization:** The system updates the cloud dashboard every 2 seconds, providing the user and caregivers with live data on speed, battery percentage (e.g., 78%), and remaining range (e.g., 62 km).

• **Emergency Stop:** If the system detects a loss of signal or a collision risk, it enters a "Safe Mode," immediately cutting power to the motors to ensure user safety.

Overall Impact:

Our project contributes to a sustainable future by delivering a neutro-controlled electric mobility solution that enhances transportation systems with precision, efficiency, and environmental responsibility. By promoting the adoption of clean energy solutions and fostering innovation in infrastructure, this device serves as a blueprint for future smart city transit.

IV. *CONCLUSION*

Experimental results confirm that the neuro-control interface maintains high stability even under varying cognitive loads. The integration of IoT monitoring allows for efficient energy utilization and supports inclusive smart-city transportation systems.

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