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Mind-Controlled Wheelchair for ALS Patients: BCI Approach

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***Abstract* - This paper presents the development of a mind-controlled wheelchair designed to assist individuals affected by Amyotrophic Lateral Sclerosis (ALS). The primary goal of this endeavor is to propose a compact wheelchair prototype operable through brainwave commands. The methodology employed centers around a Brain-Computer Interface (BCI), utilizing non-invasive electroencephalogram NeuroSky technology to capture brainwave activity. Within the BCI system, specialized biosensors capture EEG/EMG signals, subsequently processed using the ThinkGear module in MATLAB. Specifically, alpha and beta signals are isolated for wheelchair control. Eyeblink strength and attention levels serve as inputs for directing the wheelchair's movement. These command signals are then generated through MATLAB, and transmitted to the ARDUINO UNO via a Bluetooth module (HC-05) [6]. This prompts movement in the PMDC motor, linked to the MCU through the L293D motor driver. Ultimately, this innovation greatly enhances the independence and maneuverability of individuals with disabilities.**

Keywords - BCI, EEG/EMG, MATLAB, Arduino UNO

I. INTRODUCTION

The number of registered persons with disabilities in India is on the rise, as indicated by statistical data from the Ministry of Home Affairs, with a total of 3,11,07,960 [5] individuals registered as of the latest available information. Among this population, 88,87,988 people are coping with physical disabilities, making it the second-largest category among disabled individuals. Many of these individuals face challenges when it comes to independent mobility.

To address this issue, wheelchairs are commonly used, and they can be controlled through traditional input methods like joysticks, mouse devices, voice commands, and keyboards. However, individuals with neuromuscular disorders often struggle to efficiently use these conventional input methods. To address this challenge, Brain-Computer Interface (BCI) technology comes into play, eliminating the need for traditional communication interfaces by establishing a direct connection between the user's brainwaves and the wheelchair's control.

Among the various technologies available for capturing brain activities, Electroencephalogram (EEG) is the most suitable due to its portability and non-invasiveness. This technique involves placing electrodes on the scalp to record electrical signals generated when millions of neurons in the brain fire together. Each cerebral state generates distinct patterns of activity, making it possible to control external devices.

In this research, both EEG and EMG (Electromyogram) signals are extracted to capture attention and eyeblink patterns, which are then used to control the wheelchair. EEG primarily focuses on capturing signals from the brain, while EMG monitors the electrical activity of the eye muscles.

II. DESIGN AND IMPLEMENTATION

A. *System Overview*

The proposed intelligence in wheelchair consists of three modules [1]. They are

a) BCI System Module
b) Data Processing Module
c) Robotic Wheelchair Module

The block diagram of the work is given below in figure 1, figure 2, figure3.

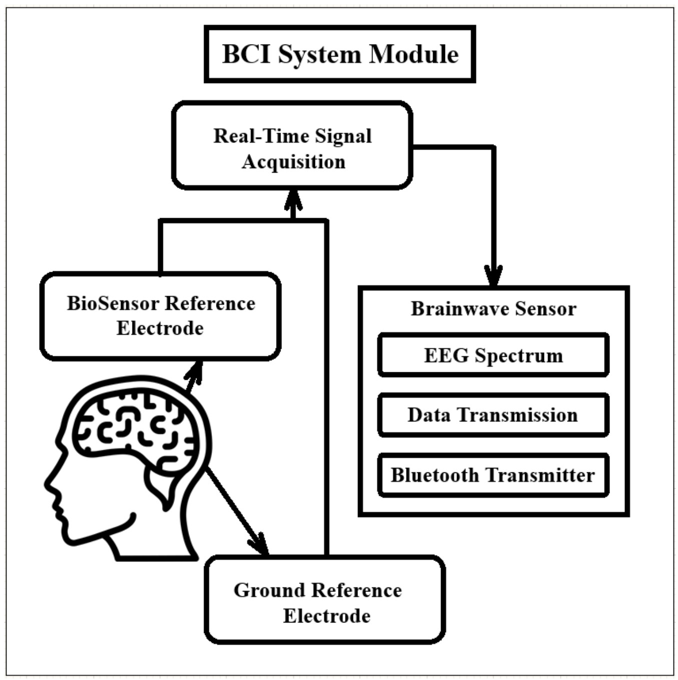

Figure 1. BCI System Module

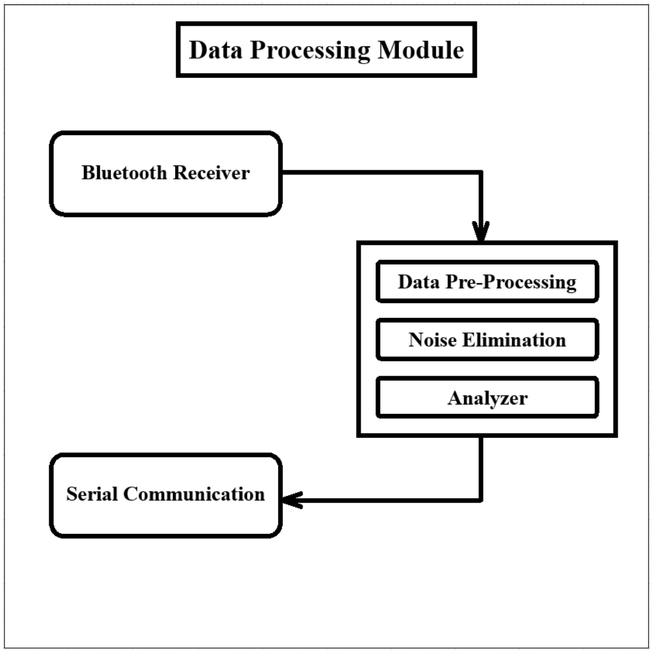

Figure 2. Data Processing Module

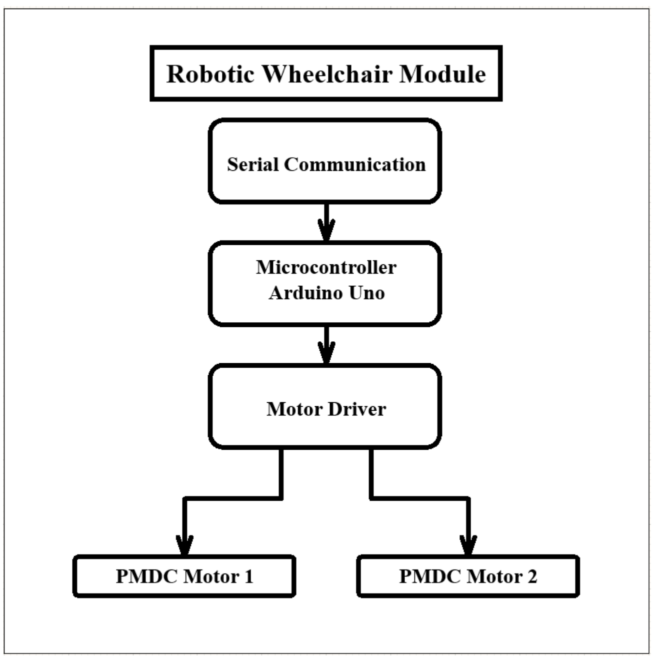

Figure 3. Robotic Wheelchair Module

II.A.1. BCI System Module

The NeuroSky MindWave Mobile [7] is a wireless EEG device that incorporates a single-channel, dry biosensor. This biosensor is employed to capture both EEG and EMG signals as shown in figure 1, specifically those related to attention and eye blinks. It is positioned on the FP1 frontal lobe of the cerebral cortex as shown in the figure 4. Additionally, a separate ground electrode is positioned on the earlobe. The figure illustrates the placement of the EEG sensor for recording the neuro signals, and Table 1 provides detailed specifications for the NeuroSky MindWave Mobile.

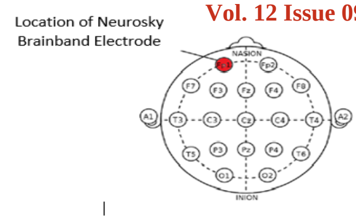

Figure 4. Sensor placement in Frontal Lobe FP1

Dry EEG System	NeuroSky
Sensor Type	Dry
Bandwidth	(3-100) Hz
Resolution	12 bits
Channels	1
Sampling Rate	512Hz
Transfer	Wireless
Weight	90g
Battery Life	8 hours

Table 1. NeuroSky system description

Signal processing is carried out within the data processing module, utilizing the MATLAB tool for assistance. The signals captured are then subjected to preprocessing by ThinkGear before being transmitted to the PC.

II.A.2. Data Processing Module

Artifacts and noise within the system can be effectively eliminated through FFT analysis. Following this, the levels of attention and blinking signals are discerned using the level analyzer technique. These processed signals are subsequently transmitted to control the wheelchair as shown in the figure 2.

II.A.3. Robotic Wheelchair Module

It consists of an ARDUINO UNO [4] to control the movement of the wheelchair by capturing the command received as shown in figure 3.

B. Electroencephalogram (EEG) Acquisition

An event-related potential (ERP) provides valuable sensory information about the brain's response at a particular latency time. The P300 component, for instance, is consistently evoked every 300 milliseconds following a specific event. P300 is widely utilized in the field of Brain-Computer Interfaces (BCI) for its effectiveness in target detection.

In this research, EEG (Electroencephalogram) and EMG (Electromyogram) were employed to capture signals. EEG primarily focused on recording electrical activity within the brain, while EMG was more concerned with monitoring muscle activities, such as eye blinking.

Typically, EEG signals exhibit rhythmic patterns of activity, and different frequency bands within these patterns indicate various levels of rhythmic activities. Table 2 provides detailed information about the different frequency bands and their associated rhythmic activities.

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Band	Frequency	Applications
Delta	1-3 Hz	Found during continuous attention tasks
Theta	4-7 Hz	Drowsiness in adults
Alpha 1 Alpha 2	8-9 Hz 10-12 Hz	Relaxed Closing the eyes
Beta1 Beta 2	13-17 Hz 18-30 Hz	Active thinking, Hi-alert Focus
Gamma 1 Gamma 2	31-40 Hz 41-50 Hz	Shown in short-term memory matching and in cross modal sensory

Table 2. BrainWaves differentiation

The ThinkGear technology was utilized to determine level analyzer values for assessing attention and eye blink strength. Concentration or focus could be visually assessed by fixating on a specific point. When a user is concentrated, the attention level falls within a range from 1 to 10014. Blink strength is graded on a scale of 0 to 255, where 0 signifies a small blink and 255 indicates a substantial one. An attention level between 40 and 60 is regarded as "neutral" or at a baseline level. Between 60 and 80 is classified as "slightly heightened," while anything above 80 is considered "elevated."

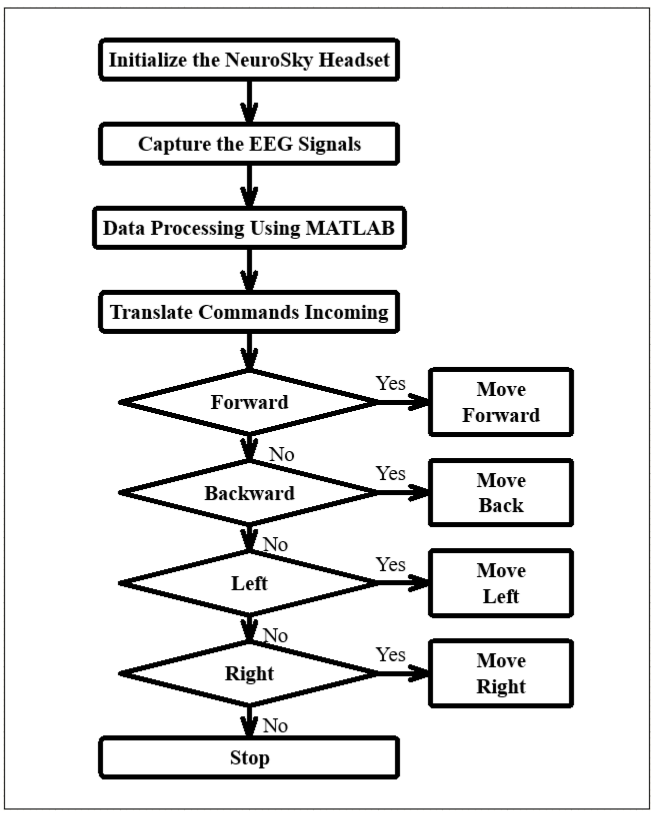

Fig. 5. Flowchart of Entire System

The raw EEG signal is subject to offline processing using MATLAB [2]. Within MATLAB, a C programming script was devised to effectively eliminate any unwanted artifacts and noise from the EEG electrical signals. Only the Alpha (8-12 Hz) and Beta (13-30 Hz) frequency ranges are selected for subsequent analysis. The Level Analyzer technique is applied to both signals for signal categorization.

Steps to be followed for signal Classification:
1. Assign the appropriate COM port number as num1.
2. Initialize the EEG headset.
3. Receive Neuro signals wirelessly from the EEG headset via the Bluetooth module.
4. Verify if the Blinking Strength is greater than 40 and the blink level is equal to 3. If true, send an interrupt to initiate wheelchair movement.
5. Next, check if the Focusing level is greater than 50 for forward movement.
6. If Blinking Strength is greater than 90, send an interrupt for a rightward movement.
7. If none of the above conditions are met:
8. Check if Blinking Strength is less than 60, and if true, send an interrupt for a leftward movement.
9. Return to Step 6 for further processing.

Through MATLAB programming, specific threshold levels for interrupts are defined for various conditions. These thresholds are determined by acquiring the appropriate interrupt functions for both Blink and Attention. Subsequently, these values are sent to the Microprocessor via the Bluetooth module to facilitate wheelchair movements.
This paper outlines a range of interrupts tailored for different actions to steer the wheelchair. Users have the flexibility to switch between modes based on their preferences for operation and control. Table 3 provides a comprehensive list of interrupt names along with their associated actions.

Interrupt	Corresponding actions
F	To move forward
B	To move backward
R	To turn right
L	To turn left
S	Stop

Table 3. Interrupts assignment for Wheelchair

C. Design Flow

The process flow outlines the sequential steps involved in operating the brain-controlled wheelchair. Figure 5 illustrates the design flow of this system.

1. Initially, the NeuroSky headset is powered on, enabling it to collect neuro signals.
2. The EEG biosensor, which is of the dry type, captures the signal and transmits it to the ThinkGear technology for preprocessing the raw EEG data.
3. Following the analysis, digital signals are relayed to the MATLAB computing environment, where the alpha and

beta wave signals are extracted for subsequent classification.

4. The Level Analyzer technique is employed for signal processing. This involves evaluating the eye blink and focusing levels to further the analysis process.
5. Based on the determined levels of eye blink and focusing, the corresponding interrupt is dispatched to the processor through the RF module.
6. The processor, in conjunction with two DC motors, governs the movement of the wheelchair.
7. Each interrupt corresponds to a specific control operation, such as moving forward, turning right, turning left, or stopping, among others.

III. Result and Discussion

In this innovative system, the Arduino Uno serves as the central control unit, orchestrating the various functions of the brain-controlled wheelchair. The HC-05 Bluetooth module plays a crucial role in data transmission, enabling seamless communication between different components. This communication infrastructure ensures the smooth exchange of vital information.

The heart of the system lies within a personal computer, which functions as a signal processing hub. The power of the MATLAB computing environment is harnessed to process and analyze the incoming neuro signals. This computational platform provides the necessary processing capacity and flexibility for handling the complex data obtained from the NeuroSky technology.

The NeuroSky technology itself is instrumental in capturing intricate neuro signal patterns directly from the user's brain. This remarkable technology employs a single-channel, dry biosensor strategically positioned at the FP1 frontal lobe. The design minimizes the need for extensive hair coverage, enhancing user comfort and practicality. Nevertheless, it's important to note that the raw EEG signals gathered can often be tainted by noise and artifacts, which necessitates further processing.

To establish a seamless connection between the NeuroSky headset and the personal computer, the NeuroSky software must be initially installed. Once this software is in place, it takes charge of connecting to the PC via Bluetooth, ensuring a reliable and consistent data transfer.

The ThinkGear technology is a pivotal component in this system, as it plays a dual role in signal acquisition and preprocessing. It enables the headset to measure EEG signals and meticulously preprocess them. During this preprocessing stage, unwanted noise and artifacts are carefully removed from the data packets collected from the biosensor. This meticulous data refinement is essential for obtaining clean and reliable signals.

Sample training signals are then extracted from a buffer and subjected to preprocessing to extract the Alpha and Beta signals. These signals are particularly important, as they are associated with aspects such as focusing and eyeblink activity. To make sense of this data, the Level Analyzer Technique is employed. This sophisticated analysis technique categorizes the signals based on predefined condition levels, distinguishing between various levels of eyeblink and focusing or attention.

The processed information, now distilled into meaningful data, is transmitted from MATLAB to the Arduino Uno in the form of interrupts. This communication takes place through the Bluetooth module, ensuring that the control unit of the system is informed in real-time about the user's intentions and needs.

The robotic platform, a critical component of this system, consists of Arduino coupled with two PMDC motors. These motors are responsible for the precise control of the wheelchair's movement. The direction and intensity of the wheelchair's motion are determined by the received interrupt value from MATLAB. Each interrupt corresponds to a specific control function, facilitating actions such as moving forward, turning right, turning left, or coming to a stop. This level of granularity in control ensures that the user can navigate the wheelchair with precision and ease.

Ultimately, this EEG-based technology empowers individuals with disabilities to regain a significant degree of independence. It simplifies the process of controlling their wheelchairs, removing complexity and reducing the need for external assistance. By offering wireless, portable, and low-power-consumption control, it greatly enhances their quality of life, providing them with newfound freedom of movement and a sense of autonomy.

IV. Conclusion and Future Work

This groundbreaking project introduces a novel and highly effective solution tailored for individuals facing physical disabilities and those struggling with neuromuscular disorders. By empowering them to independently perform tasks without relying on external assistance, it significantly elevates their overall quality of life. Moreover, it fosters a sense of self-sufficiency and autonomy.

Although the Brain-Computer Interface (BCI) system is currently in its initial phase, there exists immense potential for refinement. Specifically, efforts can be directed towards minimizing noise levels within the system. Additionally, there is a substantial opportunity for improvement in accurately detecting irregular eyeblinks in real-time. These advancements hold the promise of making the system not only more reliable but also capable of delivering outcomes that align seamlessly with real-world requirements and expectations.

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