Electroencephalography Based Control Approaches to Wheelchair and Robot Arm Control

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Abstract

Neural Control Interface is a distinct and global technology that has revolutionized the world of control and signal processing. This technology has helped link humans and computers to achieve goals that are difficult to achieve for certain patients or people. In the proposed experiment, brain signals are utilized to move the automated arm and perform various assignments such as moving any finger of the hand. To provide movement to the 3D arm robot in real-time, we acquired EEG data based 10-20 international system and forwarded these signals to the processing computer using OpenBCI Wi-FI, OpenBCI board and controlled the servo motors using OpenBCI GUI and Arduino Uno. Also, this paper presents an electroencephalogram (EEG) - a smart wheelchair control system to assist the handicapped and the elderly. The paper aims to control an electric wheelchair with a Brain-Computer Interface (BCI) headset. This wheelchair might be beneficial to disabled people who are unable to use their hands or legs due to cerebromedullospinal disconnection. The basic goal is to match diverse face expressions to wheelchair movement. The system consists of a NeuroSky Mind Wave EEG sensor coil that is paired with Android as well as connected to a voice interrupt circuit to deter the wheelchair from being involuntarily malfunctioning or auto moving. The Brain computer Interface designed system was evaluated by a real-time experiment study and applied on man and woman were induced by opening and closing hands, also the validation process has been done with different frequencies and voltages where the experimental results demonstrate that the process will operate as designed with extreme precision and high-performance.

Keywords- Electroencephalography (EEG), NeuroSky Mind Wave EEG; Brain Computer Interfaces (BCI), Wheelchair, OpenBCI GUI, OpenBCI board.

1. Introduction

Brain Computer Interface (BCI) is a new, rapidly expanding technology that connects the brain to computers and is now widely used as a detection and diagnostics tool. EEG-based BCIs can be used for a variety of tasks, including moving a cursor on a screen, picking letters from a keyboard, playing games, and operating a prosthetic arm. Noise from the scalp, skull, and a considerable contribution from background noise all impair the quality of EEG readings. The user aims to extract neuro-electrical activity that differs among EEG-based BCIs [1]. According to the World Health Organization, around 15% of the world's population lives with some sort of disability. Such disabilities include brain or spinal cord injuries, multiple sclerosis, brainstem stroke, amyotrophic lateral sclerosis, myasthenia gravis, and cerebral palsy paralyzed people face many difficulties in their daily lives, it is difficult for them to make use of motor neurons to control muscles [2]. Developments in medical engineering and neuroscience have led to the creation of precise brain imaging techniques, and so the process of linking the human brain to other components has become a reality, especially with the development of electrical signal measurement techniques in the brain. Present neuro-prothetic surgery trials show the potential for future related procedures, whether for retinal grafting, blind stem cell transplantation, or artificial organ monitoring through brain activity recorders. Nonsurgical interfaces that rely on electroencephalography between the human brain and the system have been effective in restoring communication skills in paralyzed patients.

People with motor disabilities can sometimes be so stiff they can't speak as well as they want to. They need the help of others to perform daily activities. Patients who are completely paralyzed may need someone to help control a wheelchair. In the past, many technologies were made ready for disabled people to interact with physical devices, brine wave controller (BWC), Anger gestures and a voice-controlled wheelchair are recognized [3-5]. Using BCI technology Depending on the points of waves from the user's brain or by the cortex is the brain's outer layer, that generates an EEG indicates electrically active locations in the brain in real time, and can provide information on brain function in medical, [6] take pictures of an individual's brain wave activity (EEG) while they engage in normal activities like relaxing, reading or solving math problems. Quantitative EEG (qEEG) as shown in Fig. 1, commonly known as Brain Mapping, is a computer-assisted study of the EEG data employing 19 or more simultaneous EEG channels. The raw EEG data is obtained first, then processed and compared to a human of "normal". This form of assessment is utilized in conjunction with EEG to The brain activity between the cortex and the thalamus is represented by the rhythmic cycles seen in the EEG recording, The procedure for creating a qEEG brain map A qEEG brain map consists of a cap laced with electrodes that will be used to monitor brain activity while you are completely still. The test is done with both eyes open and closed, and the results are compared to a neutral baseline and reviewed by a qualified clinician [7].

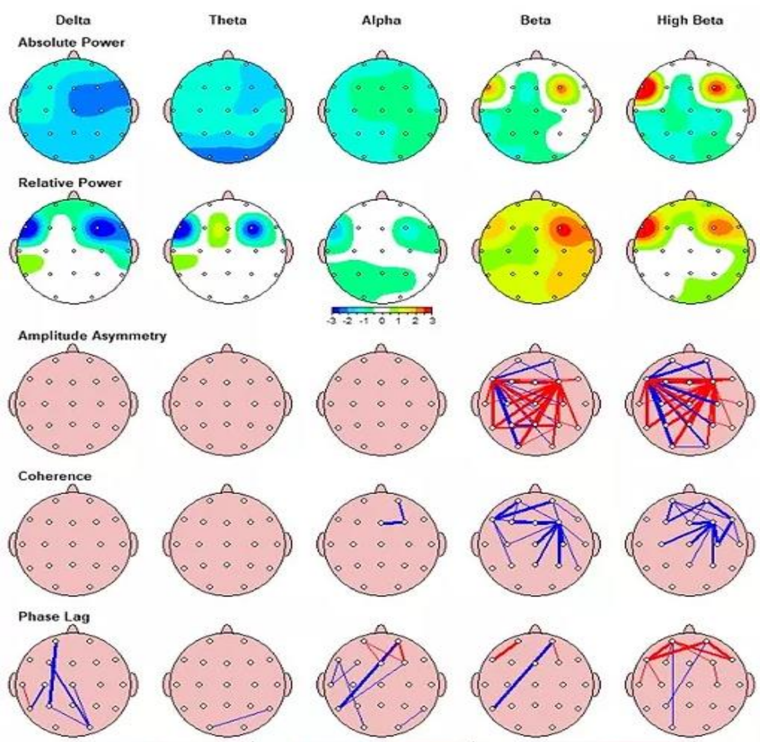

Fig. 1. QEEG brain map

The goal is to use EEG signals using BCI technology to monitor an artificial robot arm and assistant smart the wheelchair as shown in Fig. 2. Our design's primary aim is to build a BCI that can control a wheelchair and a robotic arm that can support a disabled person. The paper is structured in the following manner: Section two present the Electroencephalography (EEG), Section three present the system component, Section four cover theory and design, Section five includes design and simulation, section six present the experimental study and testing with participants, and section seven display the conclusion.

Fig. 2. EEG controlled robotic arm

2. Electroencephalography (EEG)

The signals from the cerebrum are registered invasively or non-invasively. EEG is the most commonly used non-intrusive account technique because it is affordable, lightweight, readily accessible, and has a high temporal resolution. Via tests with microelectrodes, the mission. Ganglia cell possibilities almost vanished by heading farther away than 1μm from the cell. In this way, in any case, when estimating actions directly on the cortex, the operational possibilities are evaporated, thus raising the problem of what are the genuinely anticipated EEG wellsprings. In this way, in any case, the operation possibilities are evaporated when estimating behavior directly on the cortex, increasing the issue of what are the truly anticipated EEG wellsprings [8].

A. Sources of EEG

The neural relation is an additional source of changes in the electrical potential where the introduction of neurotransmitters induces a potential tendency in the neighborhood that can be quantified around the focal point of motion. The EEG quantifies the possible changes in the cortical field caused by the summation of postsynaptic possibilities. It may very well be inscribed on the skull surface when the frequency of these field possibilities reaches a particular strength. Dipoles and the direction of the electrical field influence the integration of possibilities. The vertically masterminded pyramidal cells are essentially the EEG's strongest supporters. As many vertically oriented cells are activated at the same time, many field potentials that are equally directed can be summed up to form a strong field. For EEG inferences, only those dipoles are important. The key generator contributing to the EEG is the total postsynaptic potential, as shown in Fig. 3 [8,9].

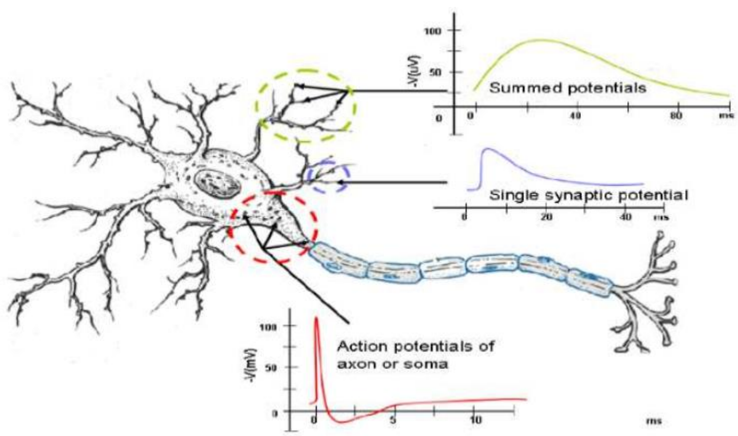

Fig. 3. Sources of EEG [10]

B. Recording technique of EEG

By setting electrodes on the subject's scalp, EEG accounts are obtained. Usually, to reduce anomalous impacts that arise from high impedance between electrodes, the scalp must be set up specifically. Conductive gel, light grating glues, and ethanol are used to improve the conductivity of the skin and electrodes. In this way, it is important to define sets of cathodes that are contrasted with each other. EEG estimates voltage contrasts. Each pair is associated with a differential EEG intensifier that intensifies the voltage difference up to 100,000 times the gain voltage up to 100 dB. In general, when measured on the scalp, the overall amplitude of the nonpathological EEG does not exceed 100 V. The EEG deduction involves the importance of reference terminals. In most EEG experiments, there are a variety of techniques that are used, the most important approach is common reference. Each recording electrode reflects the voltage difference between all chronicle anodes in the same reference determinations and a single reference electrode. At a neutral spot, It is necessary to set the reference electrode. Neutral here means a position that decreases the brain and muscle potential effects, such as ear lobes or right/left mastoid, as these are relatively electrically neutral places. One of the key disadvantages of referential montage chronicles is that the reference point may always not be completely unbiased. The left parasagittal chain of five terminals is shown in Fig. 4 as it can very well be seen in a referential montage: Fp1-ref, F3- ref, C3-ref, P3-ref, O1-ref. As used here, the word ref suggests a reference anode, such as the nose, the jawline, the rear of the neck [8,11].

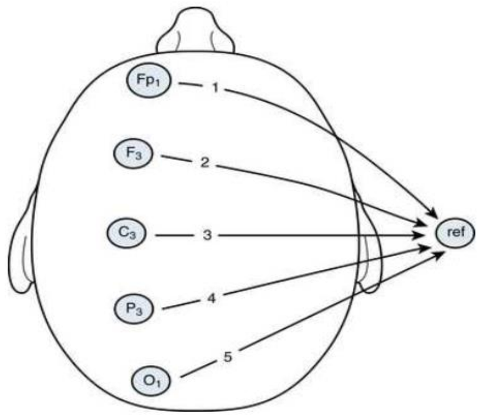

Fig. 4. EEG electrodes and channels [11]

C. Rhythmic activity of EEG

The EEG amplitude is 1 µV to 100 µV when taken over the scalp and 1 mV when measured directly from the outside of the brain and its frequency is up to approximately 100Hz [12]. As shown Table 1 and Fig. 5. the amplitude of any rhythm has a specific range and the strength or estimate of the amplitude depends on certain factors, such as the state of the patient as well as the area of the terminal on the scalp [8,13]. Brain waves are oscillating electrical voltages in the brain measuring just a few millionths of a volt. There are five widely recognized brain waves, and the main frequencies of human EEG waves are:

Table 1. The details wave

Frequency Band	Frequency	Brain states
Gamma (γ)	> 35 Hz	Concentration
Beta (β)	12–35 Hz	Anxiety dominant, active, external attention, enjoy
Alpha (α)	8–12 Hz	Very relaxed, passive attention
Theta (θ)	4–8 Hz	Deeply relaxed, inward focused
Delta (δ)	0.5–4 Hz	Sleep

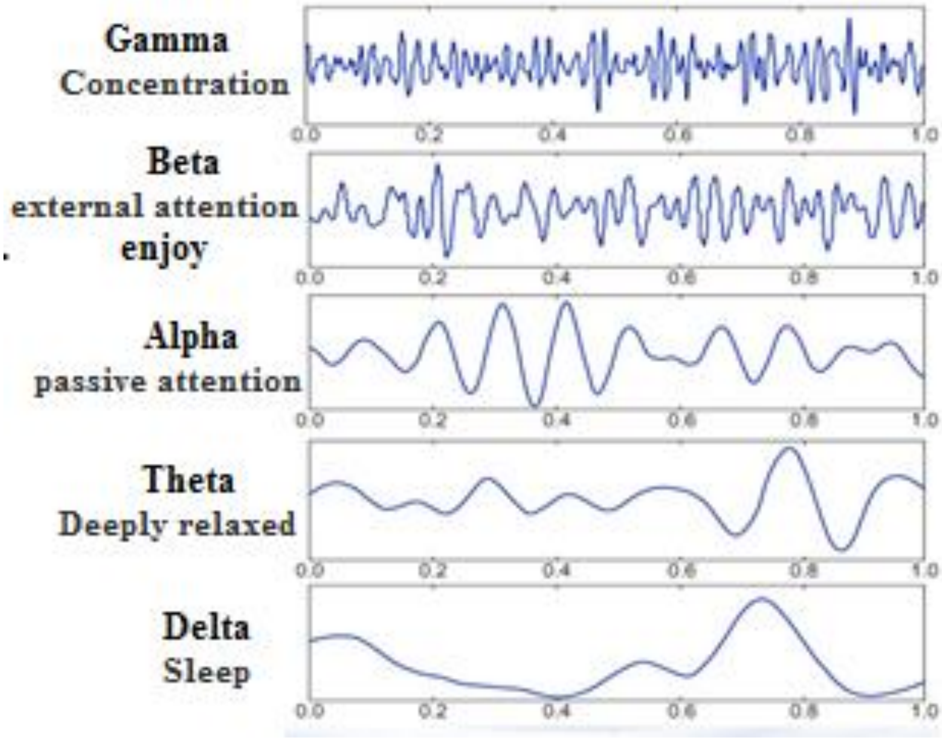

Fig. 5. Waves forms

3. System Components

A. NeuroSky Mind Wave Headset

The headset is powered by a single 1.5 dc volte battery that allows the headset to have a low overall weight of ~90 g, making it suitable for various remote and portable applications, as well as wireless biomedical applications [14-15]. The dry sensor of the headset extracts 12-bit raw-brainwaves in the range of 3 – 100 Hz with a sampling rate of 512 Hz. The on-board Think Gear chip is used to process and filter the brainwaves from the sensor, and to interface the headset with other devices via Bluetooth. Sensing is achieved by measuring the electrical potential between the electrode placed on the forehead and the reference point (ear clip). NeuroSky EEG algorithm has the ability to perform signal processing to measure the power spectrum density of 7 frequency bands, namely, delta, theta, alpha, low beta, midrange beta, high beta, and gamma.

B. Microcontroller (Arduino)

It is an electronic circuit and is a small computer that can interact and control the surrounding environment better than other microcontrollers. It contains a large number of digital input/output pins, 16 analog inputs, a USB connection, a power connector, and a reset button. It comes with everything you'll need to get started with the microcontroller; simply plug it into a computer with a USB connection or power it with an AC-to-DC converter or battery. This board's enormous number of pins makes it ideal for applications that require a large number of digital inputs or outputs (like lots of LEDs or buttons).

C. Bipolar Digital Integrated Circuit ULN2803

The way ULN2803 works when receiving a signal from the Arduino connects the ground line to the relay so that the complete nutrition. Fig. 7 shows this type of the circuit. Uln2803 this has Eight darling tons with common emitters make up ULN2803. Each Darlington can handle up to 500 mA of load current. A 50V output voltage is possible with this chip. To keep the circuit simple, inputs and outputs are pinned opposite one other. For a larger current rating, the output pins can be paralleled.

D. L298N Motor Driver

It’s a controller that uses an H-Bridge to easily control the direction and speed of up to 2 DC motors. The input voltage of a DC motor may be changed to alter its speed. PWM is a frequent method for accomplishing this (Pulse Width Modulation) PWM is a method of adjusting the average value of an input voltage by transmitting a series of ON-OFF pulses, Duty Cycle, which is proportional to the width of the pulses, determines the average voltage, The average voltage applied to the dc motor (High Speed) increases as the duty cycle increases, whereas the average voltage applied to the dc motor decreases as the duty cycle decreases (Low Speed).

E. HC-05 Bluetooth Module

The HC-05 module is a Bluetooth SPP (Serial Port Protocol) module, which means it communicates with the Arduino via the Serial Communication. Bluetooth serial modules allow all serial-enabled devices to interact wirelessly, There are six pins on it, Key/EN: This command is used to switch the Bluetooth module to the AT commands mode. This module will function in command mode if the Key/EN pin is set to high, Otherwise, it's in data mode by default. In command mode, the HC-05's default baud rate is 38400bps, while in data mode, it's 9600bps, There are two modes on the HC-05 module. First the Data mode: Data transfer between devices, second Command mode: AT commands are used to adjust the HC-05's settings. The module serial (USART) port is utilized to deliver these commands ,Command Mode ,When we want to change settings of HC-05 Bluetooth module like change password for connection, baud rate, Bluetooth device’s name etc ,To do this, HC-05 has AT commands. ,To use HC-05 Bluetooth module in AT command mode, connect “Key” pin to High (VCC) ,Default Baud rate of HC-05 in command mode is 38400bps ,Following are some AT command generally used to change setting of Bluetooth module ,To send these commands, we have to connect HC-05 Bluetooth module to the PC via serial to USB converter and transmit these command through serial terminal of PC. All command used to inter face between Bluetooth and brine wave sensor.

F. Voice recognition

Voice or speaker recognition is the ability of a machine or program to receive and interpret dictation or to understand and carry out spoken commands. The Speak (Voice) Recognition Module V3 for Arduino is a small and simple to use speech recognition board. The Speak (Speech) Recognition Module V3 product is a voice recognition module that is reliant on the speaker. In all, it supports up to 80 voice commands. At most, seven voice commands might be active at the same time. Any sound might be programmed to serve as a command. Before allowing the module to recognize any voice command, users must first train it, there are two ways to control this board: Serial Port (full function) and General Input Pins (part of a function). The board's General Output Pins could produce a variety of waves when the matching voice command was acknowledged.

G. OpenBCI Cyton board

OpenBCI is an open-source instrument that forms a collection of components and biosensors that can be used to monitor brain activity (EEG), heart activity (ECG) and muscle activity (EMG). The OpenBCI Cyton Board is compatible with Arduino, and the device can also communicate wirelessly with a computer through the Open BCI dongle (USB programmable) to any Bluetooth Low Energy compatible smartphone or tablet (BLE) [8].

H. Open BCI WiFi Shield

The OpenBCI WiFi Shield is a hardware product that allows biodata streaming over wifi, intended to work with the OpenBCI Interface software and to be paired with any OpenBCI board. The benefit of wifi over bluetooth is the increased rate of sampling. By transmitting the data through WiFi as opposed to Bluetooth, the WiFi Shield increases the sample size [8].

I. Open BCI GUI software

The OpenBCI Interface is the powerful software tool used by OpenBCI to visualize, document and stream data from OpenBCI boards. Data can be viewed in live time, played back, saved in .txt format to your device, and streamed to third-party applications such as MATLAB in live time [8,16].

J. 3D-Printable Arm

The primary goal is to support patients in their daily lives by giving them a customized product in which they feel secure. 3D printed prostheses are mostly made of plastic and remain very basic. To offer other more advanced functionalities, some prosthetic devices incorporate circuitry. In the creation of prostheses, there is a significant gap: while we strive to simulate technology to simulate human movement. When it comes to simulating human touch, this job is a lot less work done [8,16].

4. Theory and Design

The components of the approved system will be assembled, so that at the forefront of the system will be the voice gate that will act as the interrupt commands of the system that we been entered words stop as well as the voice clapping hand for once and more than once All of these inputs are processed by microcontroller within the system as executive orders So that a signal is sent to the processor output to which the relay, which has the role of turning off and turning on to the system ,This is one of the advantages of this system in order to avoid making a mistake resulting from the sudden change of waves emanating from the user's brain, which in turn will give random movements or functions to the wheelchair, but after controlling to stop the system by sound and with several audio inputs, we will excellently overcome the obstacle to changing the waves, after that we will contacted the hc-05 Bluetooth with micro controller and contacted the Transmitter and receiver pins, next we Mack protocol remotely between the hc-05 and the mind wave, nyorske after the explained a head of the headset that picks up brain waves from user , then we constated waves operation ,beta wave (β) Activated this wave when makes the user appear at the beginning or think or think negatively in the sense of fear, This means for a system as Command To send a signal to the relay by using the L298N Motor Driver for the purpose of connecting the power supply to motor No. 1 to operate it to movement the wheelchair to right and Alpha wave (α)- Active this wave in user brain when he makes himself or his senses enjoying So happy until the smile appears on the face, This means for a system as Command To send a signal to the relay by using the L298N Motor Driver for the purpose of connecting the power supply to motor No. 2 to operate it that means movement the wheelchair to left, Theta (θ)- Actived this wave in user brain when n he makes himself or his senses in a way that indicates relaxation and reassurance, This means for a system as Command To send a signal to the relay by using the L298N Motors Driver for the purpose of connecting the power supply to motor No. 1 and 2 to operate it that means movement the wheelchair to forward, Delta wave (δ) - Actived this wave in user brain when he makes himself or his senses in a sleepy, This means for a system as Command to stop sending any signal to Motors Driver m this case turning off system. Fig. 6 and Fig. 7 shows the mechanism of communication between the user's mind and the system.

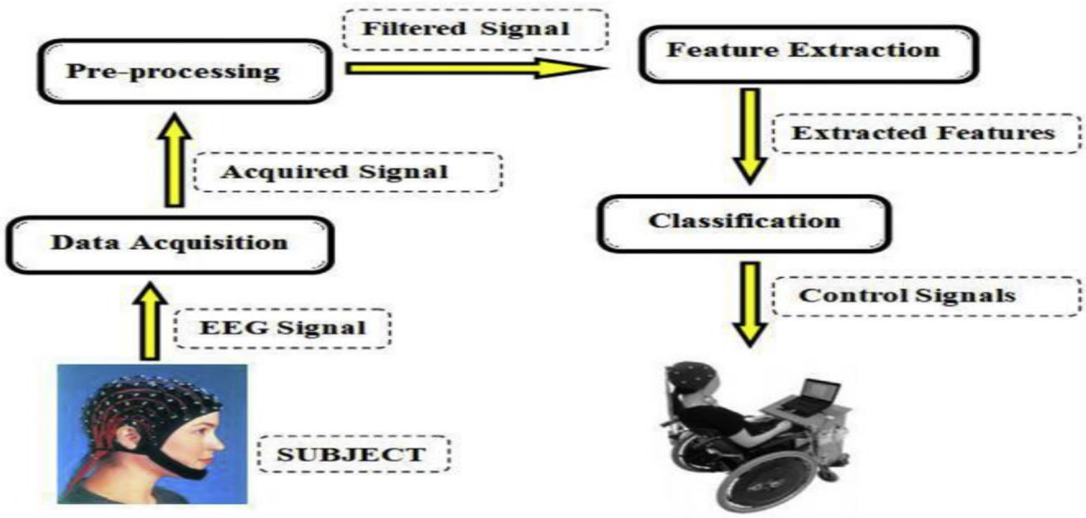

Fig. 6. Mechanism of wheelchair control

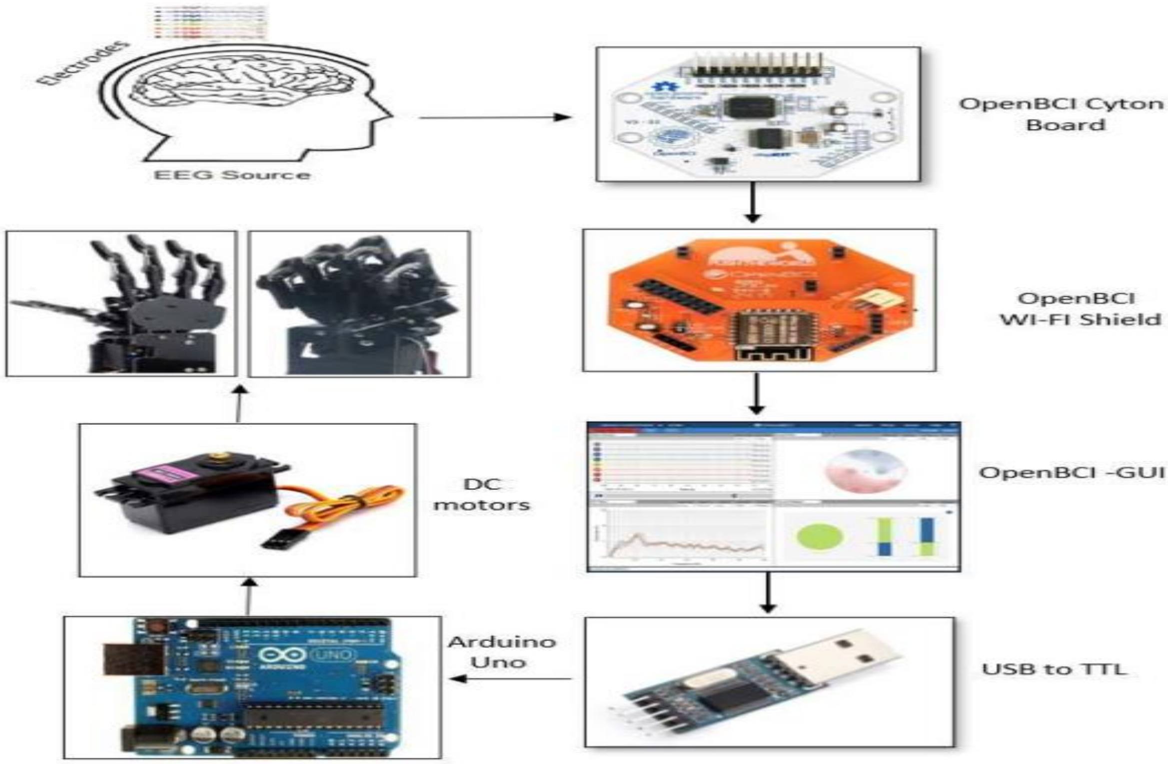

Fig. 7. Block Diagram for robot arm Implementation

5. Simulation Results

Electronic electrical workshops usually verify the functioning of any electrical circuit to ensure the circuit's performance for the function specified for her to obtain. Matching findings in order to establish a link between them. The proteus program, which is one of the most well-known research projects in the subject of control engineering, has an electronic library that contains most of the electronic parts required by the designer. The pieces are chosen and then connected to the microcontroller, with the accuracy of the connection to the concerned parties whose tasks are determined during programming, and this software allows users to write and compile programs, with the programs compiled in micro-Basic being directly uploaded into the Proteus design suite's microcontroller chip. As a result, the So, the microcontroller-based circuit analysis is easy and simple in Proteus [9]. This simulation in Fig. 8 explains how the Arduino UNO interfaced with EEG sensor is used to control the wheelchair. The data that was received from the system on the Arduino programming window, the microcontroller converts the data using the analog to digital wave technology and then sends it to the outputs specified in the code and according to its format in the underlying hardware wheelchair as shown in Fig. 9. The headset is able to transmit the EEG signal wirelessly via Bluetooth to the PC (personal computer). By using the PC software, the EEG signals are processed and converted into mental command. According to the mental command (e.g., forward, left...) obtained, the output electrical signal is sent out to the electrical wheelchair to perform the desired movement. Thus, in this project, a computer software is developed for translating the EEG signal into mental commands and transmitting out the controlling signal wirelessly to the electrical wheelchair.

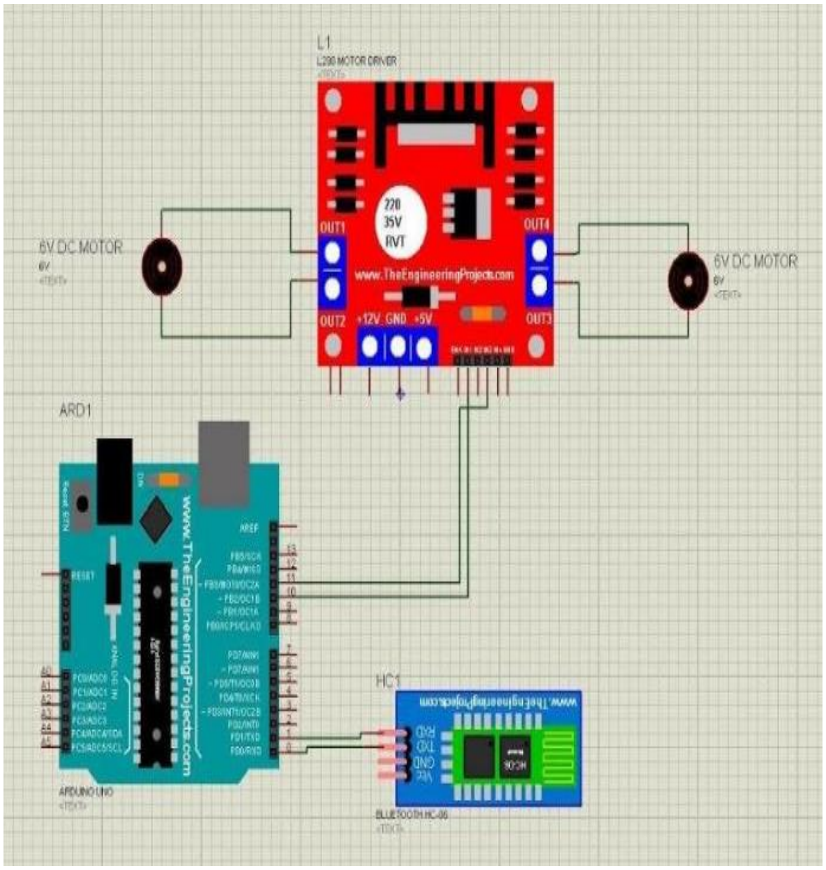

Fig. 8. Proteus simulation

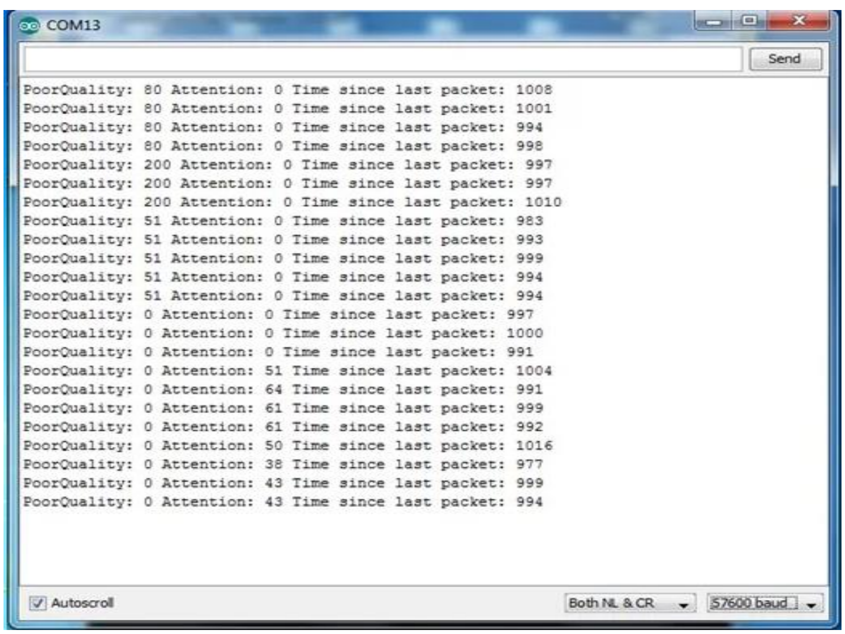

Fig. 9. Data received

6. Experimental Study and Testing With Participants

The widely accepted procedure for identifying and applying the position of scalp electrodes in the sense of an EEG exam is the International 10-20 scheme as shown in Fig. 10. The method is focused on the correlation between an electrode's position and the brain's underlying region, specifically the cerebral cortex. The electrode placement and the 8-channel ID number. The numbers and colors of the Open BCI GUI channels are also presented Fig. 11.

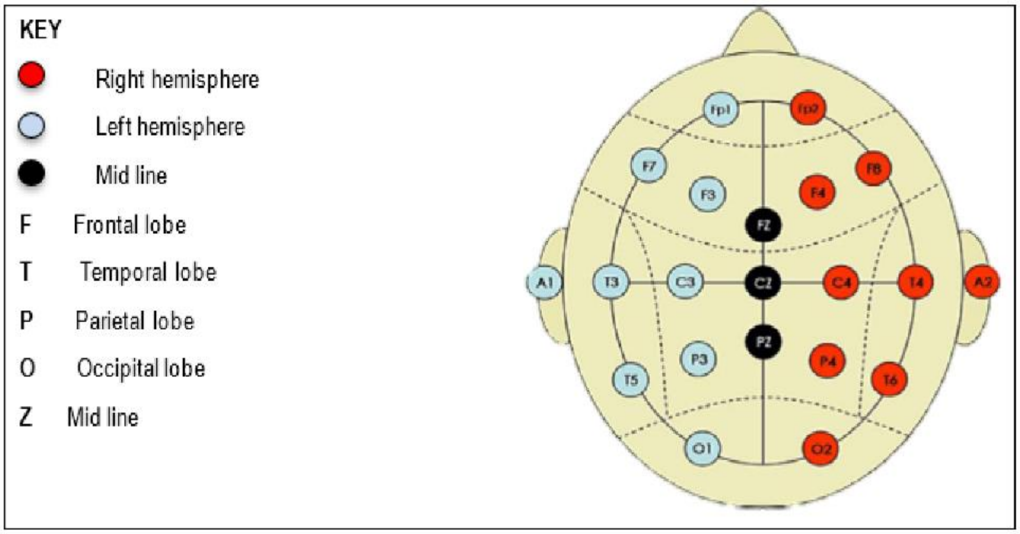

Fig. 10. A.10-20 EEG placement

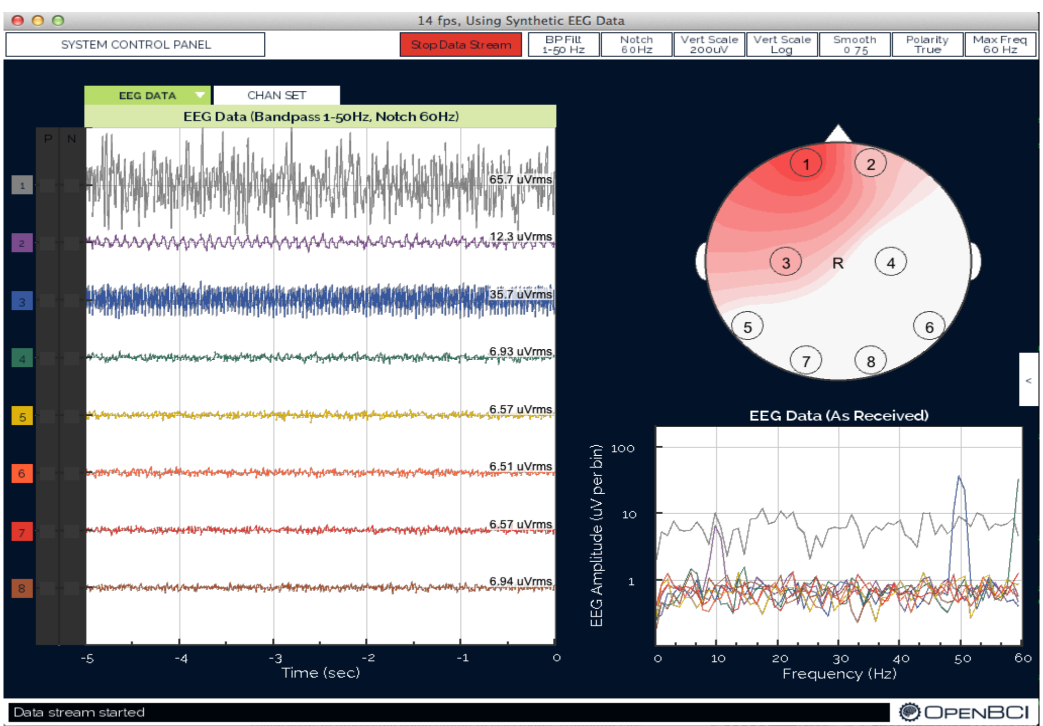

Fig. 11. Open BCI GUI show signals form channels

The BCI creates a connection between the brain and a computer, then converts the function into control signals. The BCI-enabled Robotic Arm was designed and tested to actuate all joints in every direction. The concepts of the brain-computer interface are presented, which convert electrical activity in the human brain into commands for a computer to use an artificial arm to do various tasks. The experiment was put to the test on March 1, 2022, by two participants, one female and one male. The participants ranged in age from 20 to 40 years old. Fig. 12 and Fig. 13 show the Visualization OpenBCI GUI with synthetic data streams for a man's and a woman's closed hands, respectively [8].

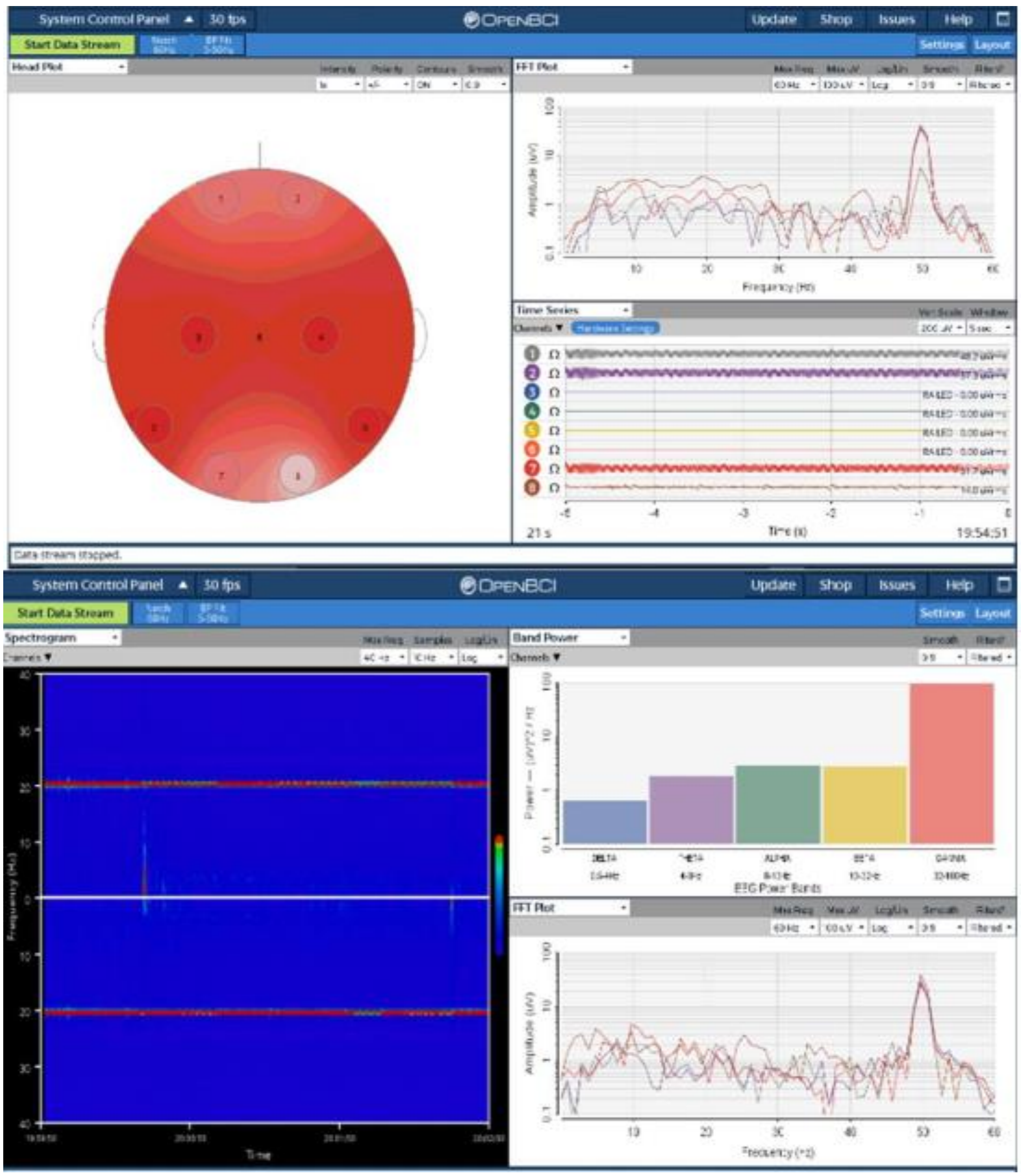

Fig. 12. Visualization OpenBCI GUI with synthetics data stream for the closed hand of a man

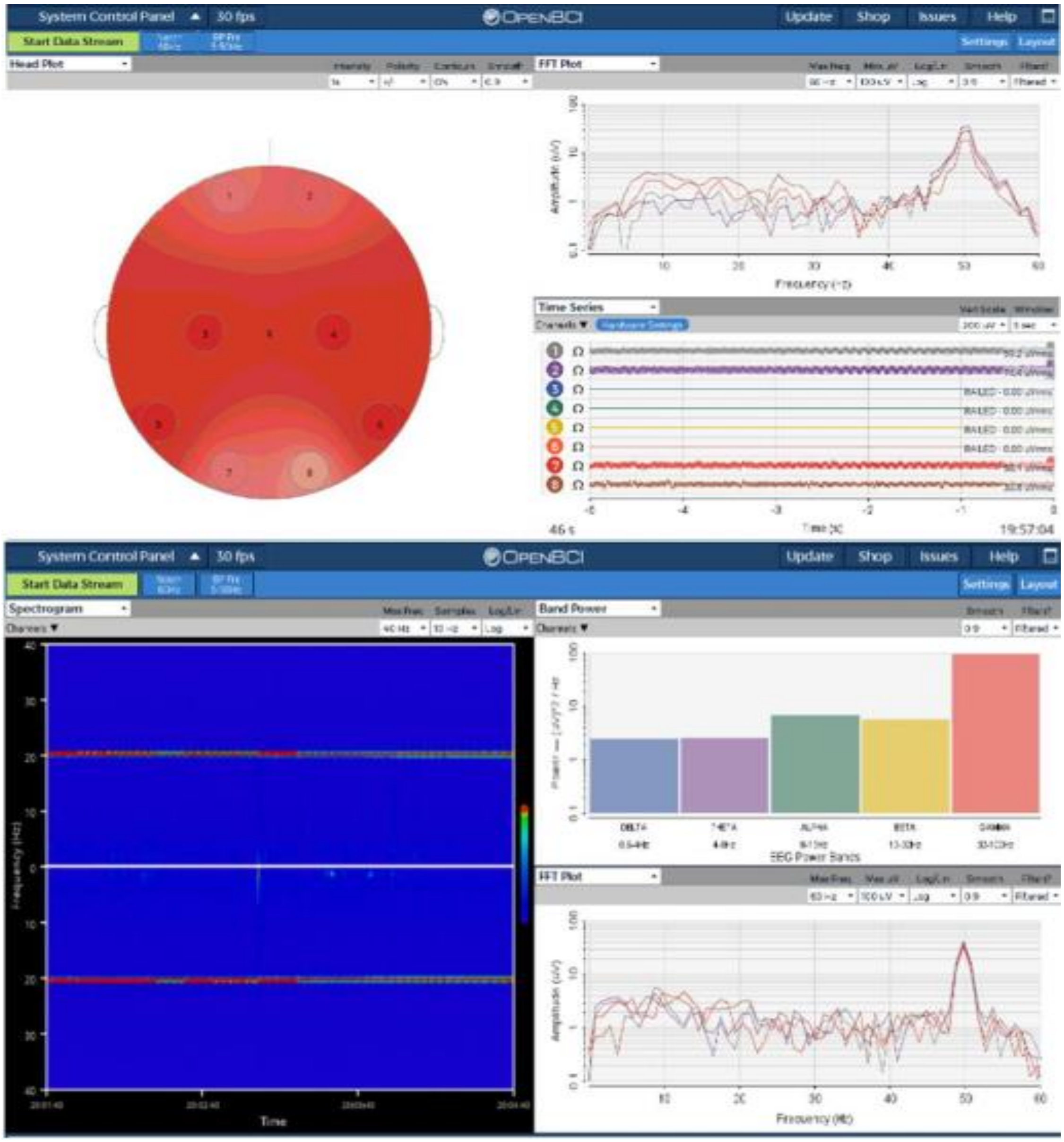

Fig. 13. Visualization Open BCI GUI with synthetics data stream for the closed hand of a woman

7. Conclusion

Electroencephalography (EEG) is a widely used neuroimaging technique, owing to its high temporal resolution, low cost, high portability and has become a practical choice for BCI. We address the progress of EEG-based BCI approaches for controlling wheelchair and robot arm in this paper, as well as our case study on a low-cost robotic arm model. The development of a brainwave-controlled wheelchair is described in this publication. The primary goal of this study is to design a wheelchair that can be controlled entirely by the brain without the need for physical feedback from the user. The Brain-Computer Interface (BCI) is the mechanism used in this paper, which allows direct connection between the brain and the electrical wheelchair. Electroencephalogram (EEG) is the greatest technology for recording brain activity and the headset is the equipment that captures the EEG signal. This system will be developed in the future to include several other functions to overcome all the obstacles facing the disabled with the help of technology and in order to interact with the surrounding environment as if there is no disability.

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