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Brain Wave Controlled Robotic Arm for Paralytic and Physically Impaired Patients

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Abstract: ***There are approximately 21 million disabled folks in India, which is equivalent to 2.2% of the total population. These disabled individuals are impacted by numerous neuromuscular disorders. To enable them to express themselves, one can supply them with alternative and augmentative communication. For this, a Brain Computer Interface system (BCI) has been put together to deal with this particular need. The fundamental presumption of the project reports the design, building as well as a testing imitation of a man's arm which is designed to be dynamically as well as kinematically accurate. The delivered device tries to resemble the motion of the biological human hand by analyzing the signals produced by brain waves. The brain waves are actually sensed by sensors in the Neurosky headset and generate alpha, beta, and gamma signal. Then this signal is analyzed by the microcontroller and is then inherited on to the synthetic hand via servo motors. A patient that suffers from an amputee below the elbow can gain from this particular bio robotic arm.***
Keywords: Brain Computer Interface, Brainwaves, EEG sensor, Neurosky Mindwave Headset, Robotic arm, Arduino Uno, BCI

I. INTRODUCTION

In India, there are around 21 million people (in movement/motor function) suffering from one or other kind of disability. The specially-abled people affected with varied debilitated disorders as induration disorder or maybe amyotrophic lateral sclerosis (Medulla spinal, brain, or ALS), myasthenia, brain stem stroke, encephalopathy, etc. that we are likely to provide a simple communication so they can have an opportunity to express themselves.

Today with the growing technological improvements, new gadgets in the industry are reaching great heights. Every concept is basically seeking for fewer human interference and more automation. What concerns us is the fact that how everything will happen with these modern ideas that support this? Two main systems have been created over time: Brain computer interface (BCI) and Electrooculography (EOG) primarily based operating system. The EOG primarily based layout might be a method for estimating the possibility of the membrane by analyzing the encompassing muscles, whereas BCI might be a non-muscular line that enables a person to send emails or commands to an instant system such as robots or even prosthetic devices, by means that of his brain exercise to cater itself. With the launch for interfacing of a brain in 1970, brain computer interface (BCI) is currently experiencing plenty of growth and is thereby gaining a consequential reach everywhere the world. The brain computer interface interacts with the external parameters and hence the absolute technique follows real time strategies. Brain computer interface was created to endorse disabled people who felt it was troublesome to convey information to others. In case they were provided with appropriate communication methodologies that did not involve some reasonable muscular motion, they will have the ability to operate it by their bio mechanical artificial arm and BCI plays an enormous part in this. It has been proven to act like a boon to every or perhaps some disabled masses. Besides, it has led to advancements in technologies and universal philosophy to a new level. With the help of the encephalogram signals, the handicapped person gets the charge of external parameters. The indispensable building blocks for the interfacing are precisely: signal extraction, signal acquisition, and also signal distribution. There is a diverse number of brain choices that could enhance or boost communication and event connected bodily function rhythm. As and when the impaired individual is unable to exert some chiefly essential activity then these alternatives happen to prove beneficial to them. There are generally varied classes within that the human brain signal is classified. This distinction completely supports the frequencies they possess. These signal indicators are theta, gamma, beta, and alpha rays. Over establishing these frequencies the signals could be distinct to different sessions. The neurons area unit is in continual action inside the human body and there is a reduced amount of ionic current that passes through them. The attributes which play a substantial role in the transit of a BCI system area unit are the brain signals, options extracted through it, orders allotted to associate output device, along with the realization of style.

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II. METHODOLOGY

A. System Design

EEG (Electroencephalogram) based brainwave management arm might be a brain management interface process which regulates the activity of the robotic arm by using brainwaves for the portion of the commanding signal. Whereas, the area unit is useful as it is exactly as that of the normal individual's hand.

Figure 1 indicates the fundamental block diagram of the brainwave controlled system. This shall provide the familiarity with all the components which shall be used for interfacing a robotic arm.

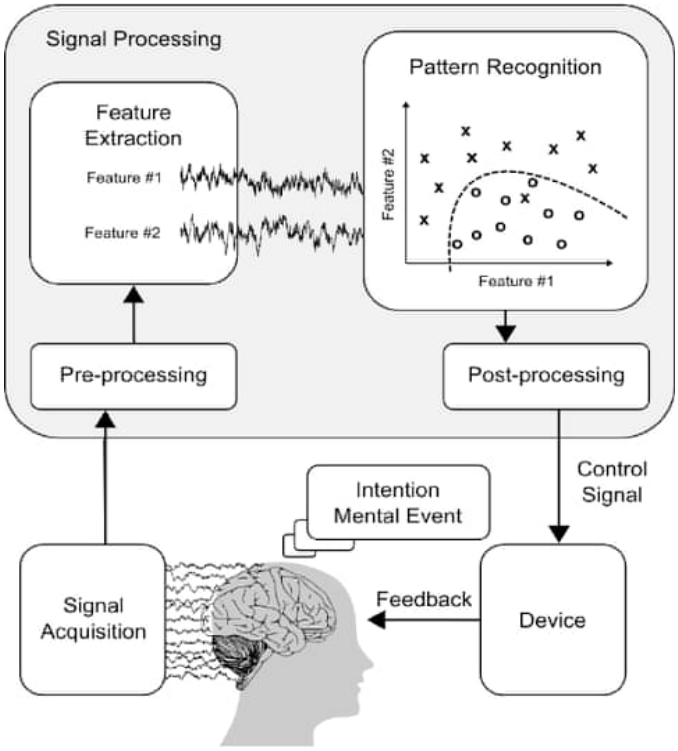


Fig. 1.Basic block diagram of BCI System.

This particular process is briefly classified into the following 4 stages as shown in Figure 2. They are Signal detection, Signal transmission, Signal acquisition, and Mapping signal to the arm.

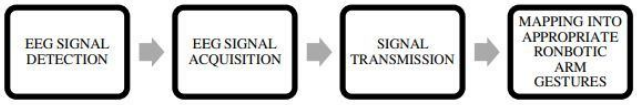


Fig. 2.Four stages of an EEG based Robotic Arm

B. Signal Detection

This stage firstly targets at the very careful detection of the EEG signal from the human mind. The human mind consists of a million neurons. Each nerve cell is linked to one another by axon and also dendrites. Every single time we believe, move, feel, and sense, our neurons are actually at work. These signals are basically produced by an electrical potential, these are completed by ions on a membrane of individual neurons. In the course of identifying a variety of signals, these may assist in interpreting whatever these signals mean and wearing the device to control the robotic arm or device connected with it. EEG measures voltage fluctuations emerging from ionic current within the neurons of the human brain. In the brain, there are many millions of neurons, each one of which generates very small electric voltage fields. EEG is truly a superposition of several elementary signals. The fundamental of an EEG signal in a normal adult generally ranges from one μV to hundred μV. These signals are usually represented in frequency ranges.

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Brainwave rate is measured in Hertz or cycles per second. They are apportioned within bands and can be classified as delineating fast, moderate, and slow waves.

TABLE I. BRAIN ACTIVITY (FREQUENCY RANGE OF BRAINWAVES)

Brainwave type -Frequency Range			
Delta Wave	1-3Hz	L-Beta Wave	13-17Hz
Theta Wave	4-7Hz	H-Beta Wave	18-30Hz
L-Alpha Wave	8-9Hz	L-Gamma Wave	31-40Hz
H-Alpha Wave	10-12Hz	H-Gamma Wave	41-50Hz

1) *Alpha Waves:* Alpha brainwaves are dominant throughout softly moving thoughts and in a section of thoughtful states. Alpha would be the strength of being hither, within the current or present situation. It is the dormant or resting phase of the human brain. Alpha waves aid overall mental coordination, alertness, calmness, mind/body integration, and learning.
2) *Beta Waves:* Beta brainwaves endure our normal waking state of consciousness. It is a fast activity or action. It is present once we are aware of our surroundings, attentive, interested in problem solving, decision making, as well as interested in some concentrated psychological activity. Beta brainwaves are subdivided into three bands: Lo Beta could possibly be viewed as a fast idle, or perhaps musing. Beta would be excessive engagement or active computation at one point. Hi-Beta is quite advanced thought, group action, new experiences, high levels of anxiety, and excitement. Continual high frequency method is not an associate economical way to drive the brain since it requires an incredible amount of energy.
3) *DeltaWaves:* Delta brainwaves are really slow, loud brainwaves (low frequency as well as deeply penetrating, like a drumbeat). They are produced in profound meditation moreover as untroubled sleep. Delta waves suspend outside awareness. Besides, they are the source of sympathy. Healing and regeneration are encouraged during this specific state. That is why deep regenerative sleep is therefore necessary to the healing technique.
4) *Gamma Waves:* Gamma brain waves are probably the fastest brain waves. This relates to the simultaneous processing of data from various brain areas. It passes info rapidly. In gamma waves, the very subtle of the brainwave frequencies are in the head which needs to be peaceful to get into it. Gamma is also beyond the frequency of neuronal firing, so how it's produced remains a mystery. Gamma rhythms modulate consciousness and perception. The higher the presence of Gamma relates to expanded consciousness as well as spiritual emergence.
5) *Theta Waves:* Theta brainwaves befall most often in sleep however are also dominant in profound relaxation. It functions as our entry to learning. In theta, our senses are remarkably withdrawn from the outside world additionally as focused on signals originating at intervals. It is that twilight condition that we are likely to only expertise the level as we are likely to wake or perhaps doze off to sleep. In theta, we are likely to be actually in a dream; vivid representational process, understanding, and intuition on the far side of our traditional conscious awareness. It is every moment we are likely to hold our stuff, the fears of ours, troubled history, as well as nightmares.

Figure 3 depicts the overall system architecture how exactly the detection of waves work with hardware.

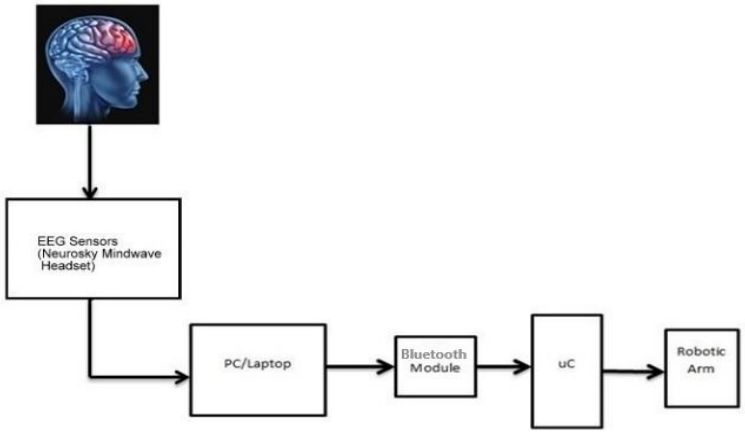


Fig. 3. System Architecture

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The following components are required to detect mind waves:

a) *Neurosky Mind wave Headset:* The human mind is formed up of enormous numbers of interconnected neurons; the patterns of interaction between the neurons are characterized as psychological states and ideas. Every interaction between associate discharge is produced by neurons. On this, the charges aren't likely to live from outside the cranium. The activity produced many thousands of synchronic discharge aggregates into waves which might be assessed entirely differently. Various brain waves square measure the outcomes of several patterns of the neural interaction. These patterns result in waves characterized by different amplitudes and frequencies. The contraction of muscles is also related to distinctive wave patterns. Nevertheless, out of these patterns, devices observe blinks.



Fig. 4.Neurosky Mind Wave Headset

b) *Think Gear:* The Think Gear connector runs as a background technique on the personal computer. This is usually responsible for directional telephone receiver data from the serial port to an open network socket. It is readily available on each Windows and Mac OS X. Any language has a socket library that is prepared to communicate with it.

C. Signal Acquisition

Signal acquisition is the technique of sampling signals that will measure universe conditions. This changes the resulting samples into digital numeric values that may be manipulated by a computer.

The signals scanned by the Neurosky Mind wave headset are distributed to the Bluetooth module. The headset detects, processes, as well as changes the signals into digital type.

D. Signal Transmission

Signal transmission is done between the Bluetooth HC-05 module and microcontroller. Bluetooth HC-05 module provides a wireless communication protocol. It is utilized in two devices for sending as well as receiving the information. It incurs no cost to use it within the wireless communication protocol whereas the assortment of the Bluetooth is smaller than different wireless communication protocols such as Zigbee and Wi-Fi. It works at the frequency of the 2.41 GHz.

The HC -05 Bluetooth module is the most widely used Bluetooth module within the Indian electronics community. It is mostly employed in embedded projects. It is easy to work with and is very simple, its cost is also very low. These modules are specifically made for the clear wireless communication setup. It is incredibly easy to use within the Bluetooth interface protocol.

E. Mapping signal to Robotic/Prosthetic Arm :

The signal received from Bluetooth HC-05 module transceiver has to be delineated to the robotic arm connected to the microcontroller (i.e. Arduino Uno). The received signal is going to act as a command signal to manage the arm.

1) *Arduino Uno:* Arduino boards are designed to make use of a variety of microcontrollers and microprocessors. The boards are facilitated with sets of digital and analog input and output pins which could be interfaced with many expansion boards along with other circuits. The microcontrollers are normally programmed using features from the programming languages such as C++ and C. Arduino Uno is an 8-bit microcontroller board based on the ATmega328P. It has 14 digital input/output pins (out of which 6 can be configured as pulse width modulated outputs), a 16 MHz quartz crystal, a USB connection, a power jack, a reset button as well as an ICSP header. It has everything required to help support the microcontroller; just connect it to a laptop with a USB cable or perhaps to a battery. This microcontroller is very easy to use for learners and could also be operated on Mac, Windows, and Linux. It also supports cross-platform programming environment.

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2) *Robotic/Prosthetic Arm:* A robotic/prosthetic arm is a man-made gadget that is incorporated into a human to supplant a natural organ, with the end goal of copying a particular function so that the disabled patient can perform that particular function using the robotic arm and can live a normal life. The new type of plastics and different materials, for example, carbon fiber has permitted prosthetic arms to get stronger and lighter, limiting the amount of additional energy required to run the arm. This technological innovation has been used to help humans as well as animals. This robotic arm has servo motors each exclusively connected to the 5 fingers. These servo motors will help in controlling various complex functions like flexion and extension. These movements will be managed by the command signal generated from Arduino Uno based on the brainwave's value received. Hence, the arm is managed by utilizing the command signal on a real-time basis.

III. EXPERIMENTAL STUDY

This robotic arm uses the Arduino Uno platform continuously for examining the incoming EEG signals and charts them to suitable actions. This system consists of three important components. The very first one is the brainwave headset provided by Neurosky and the other one is the HC-05 Bluetooth module that is used for reception of the signal. Signal acquisition is accomplished by Bluetooth module HC-05. The third important component is the Arduino UNO which processes the incoming data as well as maps it into the robotic arm. Neurosky mind wave headset and Arduino Uno will be linked together with the assistance of Bluetooth wireless communication and on the other hand, the prosthetic arm or robotic arm is serially connected to the Arduino Uno.

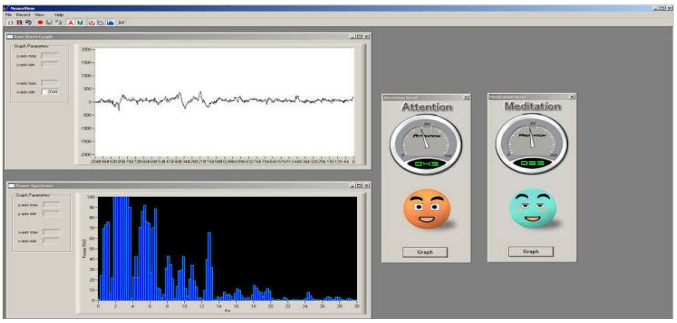


Fig. 5. Real-time graphs based on Neurosky kit

The meditation and attention level are the parameters to manage the 3 different actions of the robotic arm. These values could be classified into two distinct ranges. For this particular two ranges, a definite action is set. These actions will be executed by the Arduino Uno based on the incoming raw EEG signals. The table shown below represents the classified ranges.

IV. RESULTS

The proposed brainwave controlled robotic arm system was completely designed and implemented. For this particular research, the attention value has been distributed into two different sets, which controls the two main actions of the robotic hand. The first action is flexion (i.e. closing of all fingers) for which the attention range was set as 68 above. The second action is extension (i.e. opening of all fingers) for which the attention range was set as 69 below. For the elbow movement at the meditation level, the attention range was set as 51 above.



Fig. 6. Design of Robotic Arm

As per the above-mentioned ranges, the results were recorded for 35 different people. Each one of them was able to accurately perform different tasks such as grabbing and releasing of various objects using the robotic arm.

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TABLE II. COMMANDS FOR THE CONTROL OF THE ARTIFICIAL ARM

Actions	**Range Assigned**
Flexion (Closing Fingers)	68 above
Extension(Opening Fingers)	69 below
Elbow Movement	51 above

V. CONCLUSIONS

The above-developed robotic arm system has shown promising results and can be used in near future to help disabled people easily perform day-to-day tasks so that they can live an independent and dignified life. We were successfully able to classify user data into three outputs provided by the Neurosky Mind wave headset system. However, we were not able to regulate the arm with the veracity essential to finish all the various kinds of motion. To perform such complex motion, we need to perhaps rehabilitate the design of our system. The system could be further revised and enhanced by collecting more information and using various optimization strategies to upsurge the distinction of different ranges.

Also, equipping the system with few more EEG sensors would enhance the accuracy of the whole system and provide a better overall output. For future work, we would like to experiment with these techniques to enhance the accuracy of this system so that it can be successfully implemented in diverse real-world environments.

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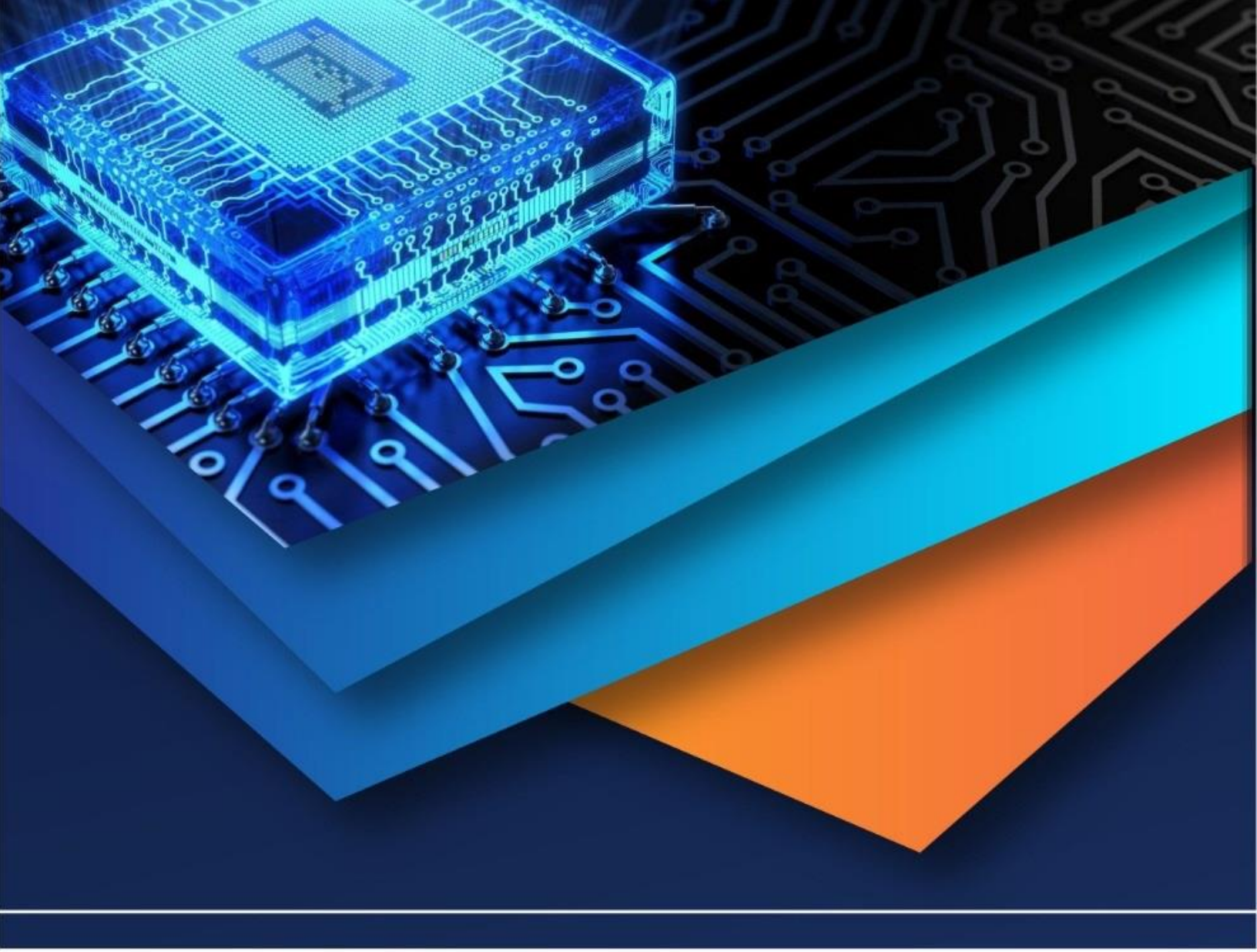
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