International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 09 | Sep 2020 www.irjet.net p-ISSN: 2395-0072

EEG Controlled Prosthetic ARM

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Abstract - *The field of prosthetics has showed a significant improvement over last few years, due to advancement in technologies. However, they have certain problems either with being really expensive, does not provide full motor functions, may require surgical approach or does not look like an arm. This project describes how the Brain waves can be used to control a prosthetic arm using Brain Computer Interface (BCI). The BCI system consist of Electroencephalogram (EEG) sensors placed on the headset to capture the brain waves, which will be extracted using Thinkgear library in MATLAB. The Brain signal act as command signals and transmitted to microcontroller. This command signal is based on concentration level and eye blink strength of the subject. The prosthetic arm consists of microcontroller coupled with servo motors to perform flexion and extension of fingers. The Brain Computer Interface (BCI) system will administer the disabled people to control their prosthetic arm using their Brain.*

Key Words: EEG, BCI technology, Mindlink Headset, Prosthetic arm, Brainwaves.

1. INTRODUCTION

In India, there are about 5 million disabled people (in movement/motor functions). The disabled people affected with neuromuscular disorders such as multiple sclerosis (MS) or amyotrophic lateral sclerosis (ALS), brain or spinal cord injury, Myasthenia gravis, brainstem stroke, cerebral palsy, etc.; in order to express themselves one must provide them with augmentative and alternative communication [6][7]. There are over 10 million amputees worldwide, out of which 30% are arm amputees. The only solution that is there is prosthetic arms. Early prosthetics were simple. They were immovable prosthesis like wooden shaft, pegs and metal hooks. Later advances facilitate the movement of the prosthesis, but they looked very different from a human hand. Emphasis was given on the improvement in both the function and appearance of prosthesis. As technology advanced, the hands became more natural. But the problem is they are unable to control or move as desired. Myoelectric prostheses were developed, which provided greater range of motion and freedom. But myoelectric prostheses are very expensive and need to undergo a critical nerve surgery. And if nerves get damaged its useless.

The communication of human with the machines can be done using BCI (Brain Computer Interface) technology. Recent advancements in BCI have presented new opportunities for development of new prosthetic arm interface for such people based on thought or brain signals [3]. The basic idea of BCI is to translate user produced patterns of brain activity into corresponding commands [1]. BCIs systems elude the conventional channels of communication which is muscles and speech instead they provide direct communication and control between human brain and physical devices by translating the brain activity into commands in real time. The BCI uses non-invasive EEG sensors to acquire signal from the brain, being a relatively low cost solution and also avoids dangerous surgery for invasive method where electrodes are placed inside of brain called implants. The EEG technique assumes brainwaves recording by electrodes attached to the subject's scalp [3].This system comprises of four distinct stages; which are extracting the raw brainwaves, processing the signal, classifying them into different command signals and interfacing them to the prosthetic arm.

EEG-based BCI system can be implemented to overcome the problem of prosthetic arm. EEG-based brain controlled prosthetic arm is a BCI system that controls the actions of the prosthetic arm using brainwaves as command signal. This BCI system implemented is same as how a regular human control the movements of his/her hand. The system will detect the brain waves that can be used as command signals to control the movement of prosthetic arm that is flexion and extension. The Flexion and Extension depends on the concentration levels and eye blink of the subject. The control of the prosthesis is determined by the ability of one's mind to focus and to concentrate. This can be achieved with a few days of training. The project presented in this paper aims to develop a low-cost and versatile human-like prosthetic arm controllable via brain activity using EEG neuro-feedback technology.

2. METHODOLOGY

2.1 System design

EEG controlled prosthetic arm is a BCI system that uses brainwaves as a command signal to control the prosthetic arm. This system works on the basis of how humans normally control their arm. The EEG sensor on the mindlink headset is used to capture the brainwaves of the subject. This brain waves are then transmitted to the laptop via Bluetooth. The brain signals form mindlink head is then extracted using Thinkgear Library in MATLAB. These signals are then mapped to Arduino UNO for executing the commands of flexion and extension. Figure 1 shows the block diagram of EEG controlled prosthetic arm. This block diagram shows all the component needed by the system and working of the system. This project basically uses only two parameters of subject's brain signal that is attention level (concentration level) and eye blink strength to control the arm.

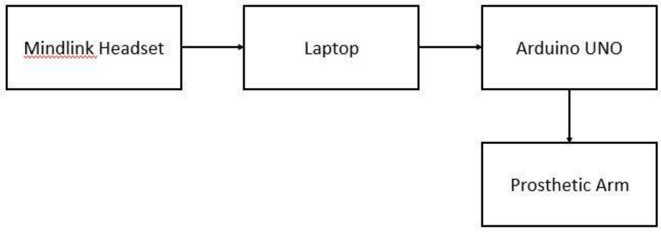

Fig -1: Block Diagram

To understand the system properly we can divide the system into three modules. These three modules are Signal detection, Signal extraction and Command execution.

2.1.1. Signal Detection

Human brain consists of millions of neurons, each nerve cells connected to one another by dendrites and axons. Every time we think, feel, sense, move, or remember something, our neurons are at work. That task is carried out by small electric signals that zip from neuron to neuron as nimble as 250 mph [6]. In the brain, there are millions of neurons, each of which creates small electric voltage fields. These electrical signs are generated due to the flow of ions between the different neurons of the brain. When a neuron is activated, it is polarized, generating an action potential that can be propagated to other neurons, provoking a flow of information. The aggregate of these electric voltage fields generates an electrical potential difference which electrode on the scalp are able to detect and record. This process of monitoring and recording electrical activity of the brain is known as Electroencephalography (EEG). EEG measures the potential differences between regions of the cortex that are generated due to flow of ions. The records acquired through the electrodes represent the intensity of brainwaves. They can vary between 0 µV and 100 µV and they have frequency ranging from 0.3 Hz to 100 Hz. This EEG signals are divided using different frequency ranges.

Table -1: Frequency ranges and activities associated to them

Brainwave Type	**Frequency Range**	**Mental state**
Gamma	32 to 100 Hz	Heightened perception, cognitive processing,
Beta	13 to 32 Hz	Normal state, concentration, integrated, all five sense
Alpha	8 to 13 Hz	Relaxed, conscious, creative, super learning,
Theta	4 to 8 Hz	Light sleep, deep meditation, creative, recall, dreaming
Delta	0.4 to 5 Hz	Deep dreamless sleep, Non-REM sleep, Unconscious

The classic names of these EEG bands are Delta, Theta, Alpha, Beta, and Gamma. Table 1 gives a general synopsis of some of the commonly-recognized frequencies that tend to be generated by different types of activity in the brain.

2.1.1.1. Mindlink Headset

Mindlink headset is an affordable and portable Brain Computer Interface Headset that safely measures and outputs the EEG power spectrums (Delta, Theta, Alpha, Beta, Gamma), NeuroSky eSense meters (attention and meditation) and eye blinks. Mindlink consists of dry electrodes and a specifically designed electronic circuit for the dry electrodes to accurately detect brainwave function. It uses the TGAM chipset. The device consists of three electrodes: reference, ground electrodes and the EEG electrode (EEG Sensor) is resting on the forehead above the eye (FP1 position). It uses a single Lithium ion 3.7v 180mAH rechargeable battery with 8 hours of battery life. The headset builds a wireless connection between the human brain and devices such as smart phones and computers via Bluetooth BT/BLE dual mode module (10 meters range). It outputs 12 bit Raw-Brainwaves (3 - 100Hz) with Sampling rate at 512Hz.

Fig -2: Mindlink Headset

2.1.1.2. ThinkGear

The headset contains ThinkGear technology, which measures the analog electrical signals, commonly referred to as brainwaves, and processes them into digital signals to make the measurements available to the applications. ThinkGear is the technology inside product that enables a device to interface with the wearer's brainwaves. It includes the sensor that touches the forehead, the contact and reference points and the on-board chip that processes all of the data. Both the raw brainwaves and the eSense Meters (Attention and Meditation) and Eye blink are calculated on the ThinkGear chip. eSense is a NeuroSky's proprietary algorithm for characterizing mental states. To calculate eSense, the NeuroSky ThinkGear technology implies the raw brainwave signal and removes the ambient noise and muscle movement. eSense algorithm is then applied to the remaining signal, resulting in the interpreted eSense meter values. ThinkGear technology also measure eye blink strength.

2.1.2. Signal Extraction

Mindlink headset detects the brain signals and send it to Laptop via Bluetooth. The headset only captures the brain waves and convert them into digital format that can be used by different applications. After receiving this signal from the headset, the extraction of data is done in laptop using MATLAB.
The laptop is use to run the MATLAB code for extracting the data from Mindlink headset. Neurosky provides ThinkGear module to extract the values in real-time that is used to control the prosthetic arm. The values must satisfy certain conditions for execution of command for flexion and extension of prosthetic arm. These values are then transmitted to microcontroller for execution of command signals via serial connection.

2.1.3. Command execution

The signals receive from laptop is then mapped to prosthetic arm coupled with servo motors using microcontroller (Arduino UNO). These received signals act as command signal to control the prosthetic arm.

2.1.3.1. Arduino UNO

The Arduino Uno is an open-source microcontroller board based on the Microchip ATmega328P microcontroller and developed by Arduino.cc. It has 20 digital input/output pins (of which 6 can be used as PWM outputs and 6 can be used as analog inputs), a 16 MHz resonator, a USB connection, a power jack, an in-circuit system programming (ICSP) header, and a reset button. To power it, simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery. It accepts voltages between 7 and 20 volts (suggested voltage is 9V).

Fig. 3- Arduino UNO

It creates a development environment to interact with hardware components and executes the processing languages. It provides a user friendly yet powerful IDE to control the microcontroller, which can run on any OS. Arduino UNO is less expensive, cross-platform support, open source and easy to use yet powerful makes it a perfect choice for this project.

2.1.3.2. Prosthetic Arm

The prosthetic arm is 3D printed using plastic as it will be durable and light weight as well. The material used is PLA plastic. It has all five movable fingers each attached to a different servo motor. As the servo motors gets commands from Arduino UNO the movement of flexion and extension is executed.

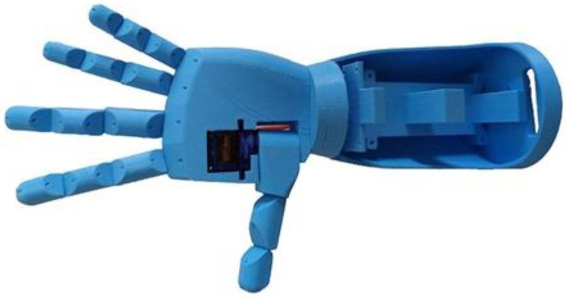

Fig -4: Prosthetic Arm

2.1.3.3. Servo Motors

The prosthetic arm is coupled with MG90S servo motors. It is a micro servo motor with metal gear. This small and lightweight servo comes with high output power. This servo can rotate approximately 180 degrees (90 in each direction), and works just like the standard kinds but smaller. The operating voltage (Torque) is 4.8V: 30.60 oz-in (2.20 kg-cm), 6.0V: 34.70 oz-in (2.50 kg-cm) at the Speed of 4.8V: 0.11 sec/60°, 6.0V: 0.10 sec/60°.

Fig -5: Servo Motor

2.2 Experimental Setup

The working of system is simple, Mindlink headset is placed on subject's head which continuously captures the brain signals (brainwaves). The TGAM chipset in the headset converts the analog values into digital from and transmit it to the Laptop. The headset and laptop are connected wirelessly via Bluetooth. The value extraction is done in laptop using MATLAB. The ThinkGear module by Neurosky is use to extract the values and run the code in MATLAB. These values must satisfy certain criteria's or parameters in order to act as command signals to control prosthetic arm. If the values satisfy the parameter then it gets transmitted to the microcontroller. The Arduino UNO and the laptop is connected serially through a USB wired connection. Once Arduino UNO receives the signal it maps the signal to the servo motors. Servo motors are responsible for the execution of the movements: flexion and extension. Each servo motor is associated to one finger. All the servos work in synchronization as they receive commands at the same time. As all the servo motor get the flexion command, they result in closing of the prosthetic arm similarly as the gets extension command, the result in opening of the prosthetic arm. The experimental setup is shown in Fig. 6

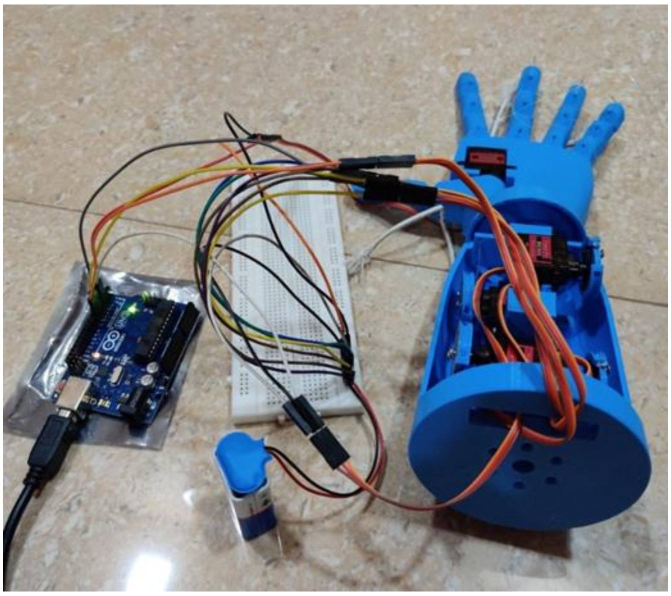

Fig. 6- The Experimental Setup

The hole systems working depends on two main parameters that is attention level (concentration level) and Eye blink strength. In order to execute the command for flexion and extension of the prosthetic arm these two parameters much satisfy the conditions. The values form the subject is classified in two different ranges. Each range is associated with a particular movement. The microcontroller will give the command signal to the servo motors to execute the action on the basis of attention levels of the subject. Table 2 shows the range of values and action associated with it. If the subject's attention value lies between 40 to 60 then flexion is performed and if it lies between 61 to 80 then Extension is performed. In order to increase the accuracy of the control the user need to focus on something to increase the attention level and get distracted in order to decrease the attention level.

Table-2: Commands on the basis of value range.

Attention value range	Action
Between 40 to 60	Flexion (Closing of fingers)
Between 61 to 80	Extension (Opening of fingers)

There was problem with just using the attention level of the subject. If the subject is concentrating on another thing and doesn't want the command to get executed, this was not possible. As the command will get executed automatically even the subject does not intend to do so. Therefore, there is another parameter as Eye blink strength of the subject. In order to get command executed the subject needs to fulfill both the parameters. If the attention level of the subject is in range of any action and the subject's Eye Blink strength is less than 50 then the action will not get executed. Similarly, if the subject's Eye Blink strength is more than 50 but the attention level is not in range of any action then the action will not be executed. It is important to effectuate both the parameters in order execute the action.

3. RESULT

For this project the attention value is been divided into two sections for controlling the movements of the prosthetic arm that is flexion and extension. When the attention value of the subject is between 40 to 60 then flexion (closing of all fingers at once) occurs and if the attention value is between 61 to 80 then extension (opening of all fingers at once) occur. These movements were tested by the brainwave of 3 users of different age groups and different training time. When different subjects tried to archive same result, the consistency of their attention levels effected the result. As seen in the table the accuracy recorded by different users. It was observed that the user between age group of 10 to 40 is tend to perform better than other two users age groups. The least performing age group is below 10 followed by the age group above 40.

Table-3: Performance Analysis

USERS	**USER 1 (Age group between 10 to 40 years)**		**USER 2 (Age group below 10 years)**		**USER 3 (Age group above 40 years)**	
Action wanted to perform	Attention values	Result	Attention values	Result	Attention values	Result
Flexion	43	Flexion	17	-	43	Flexion
Extension	67	Extension	13	-	55	Flexion
Flexion	51	Flexion	19	-	58	Flexion
Extension	63	Extension	9	-	61	Extension
Extension	60	Flexion	13	-	55	-
Flexion	48	Flexion	27	-	49	Flexion
Extension	89	Flexion	25	-	83	Flexion
Flexion	41	Flexion	34	-	50	Flexion
Extension	75	Extension	39	-	61	Flexion
Flexion	44	Flexion	42	Flexion	45	Flexion
ACCURACY	80%		10%		60%	

4. CONCLUSIONS

The proposed system demonstrates the use of EEG to control the prosthetic arm and promises a feasible solution for amputee disability without undergoing any surgery. This gives it great potential in many applications whether related to the health care field or not. This idea could be expanded to other body parts as well. This is major upgrade form existing prosthetics. The system is cost efficient as compare to myoelectric prosthetics. All this can be archived without any health issues.

The system is tested with different types of users under different scenarios. It is found that the system can be used by any age group just the subject needs to get little training. It is also seen that children below age 10 lacks in accuracy and performance as they lack in concentration and this system runs on concentration levels and eye blink of the subject. Also, we are not able to archive full functionality of hand. In order to do so we need to use stronger EEG headset with a greater number of sensors. This will boost the accuracy of the project and will provide a greater range of motion. If the accuracy could be increase, then it can be implemented in real world.

This prosthetic arm can hold objects but can lift the weight exceeding 500g. As each motor has stall torque of 1.6kg-cm. Thus, in spite of having limitations to it this project could allow the disabled people to control their prosthetic arm with the help of their brain signals. This project is a peep hole in BCI technology and can be led to great automation and IOT products.

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