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Mind Controlled Robotic Arm

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Abstract: *Electro Encephalo Gram based Brain-Computer Interface robotic arm can help as a powerful support for severely disabled people in their regular activities, especially to aid them to move their arm voluntarily. This paper proposes and implements a brain signal (mind) controlled robotic arm to yield different movements in robotic arm. The scheme uses a single electrode pair acquisition scheme, microcontroller based robotic arm module. The key lies in the mapping of the EEG signal to the robotic arm to achieve the objective. In this project we are developing a cost effective BCI robotic arm that will help the physically challenged to lead an independent life with the help of their brain signals using non-invasive techniques.*

Keywords: *Brain Computer Interface (BCI), Brainwaves, EEG sensor, Neurosky Mindwave Headset, Robotic arm.*

I. Introduction

In India, there are about 5 million disabled people (in movement/motor functions). For disabled people with severe neuromuscular disorders such as brainstem stroke, brain or spinal cord injury, cerebral palsy, multiple sclerosis or amyotrophic lateral sclerosis (ALS), we must provide basic communication capabilities in order to give them the possibility to express themselves. One solution that has been developed over time: Brain Computer Interface (BCI) systems. A BCI is a non-muscular communication channel that enables a person to send commands and messages to an automated system such as a robotic arm or prosthesis, by means of his/her brain activity.

Early prosthetics were simple. They were frequently only small digits that were immovable, or more famously, pegs and hooks. Later advances enabled the movement of the prosthesis, but they looked very different from a human hand. They were claws that would not have looked out of place on industrial robots. As technology advanced, the hands became more natural. However, they still required cables and harnesses to be attached to the working arm to pull them. Myoelectric prostheses were developed, providing more freedom of movement and more movement in general. However, myoelectric prostheses are very expensive. In addition, they rely upon the nerves of the arm to be undamaged. Should the nerves be damaged, the myoelectric is useless.

But what if the electrical signals could be received at the source? By reading the electrical signals and brainwaves directly from the cranium, the major drawback of expensive myoelectric prostheses can be avoided entirely. However, reading of electrical signals directly from the brain requires multiple unwieldy electrodes to be placed on or in the brain.

That's where BCI comes into picture. The basic idea of BCI is to translate user produced patterns of brain activity into corresponding commands [10]. A typical BCI is composed of signal acquisition and signal processing (including pre-processing, feature extraction and classification). One of the most important features in a BCI system is represented by acquisition [14]. The most spread acquisition technique is EEG, and it represents a cheap and portable solution for acquisition. The EEG technique assumes brainwaves recording by electrodes attached to the subject's scalp [1]. EEG signals present low level amplitudes in the order of microvolts and frequency range from 1 Hz up to 100 Hz. Specific features are extracted and associated with different states of patient brain activity, and further with commands for developed applications. Using EEG one more drawback can be eliminated (i.e. dangerous surgery can be avoided for invasive method where electrodes are placed inside of brain called implants).

The electrical waves will be sensed by the brain wave sensor (EEG headset) and it will convert the data into packets and transmit through Bluetooth medium. PC/Laptop will receive the brain wave raw data and it will extract and process the signal using Mat lab platform. Then the control commands will be transmitted to the robotic arm to process and perform the actions.

Thus the mind controlled robotic arm is a low cost Prosthetic, a Brain Control Interface (BCI) device that can be fitted onto amputees' limbs. Mind Waves–or more precisely the ability of the mind to focus and to concentrate – controls the Prosthetic. It is an upper extremity prosthetic arm that uses a microcontroller to measure the brainwaves registered by an EEG headset, and has servos in the arm and the fingers of the prosthetic hand based on those measurements. It uses signals from the brain to affect the function of the arm.

II. Methods

2.1 System Design

This system can be broadly dived into four stages. Figure 1 shows the schematic outline of these four stages. These four stages are EEG signal detection, EEG signal acquisition, Signal transmission and mapping into appropriate robotic arm actions [2].

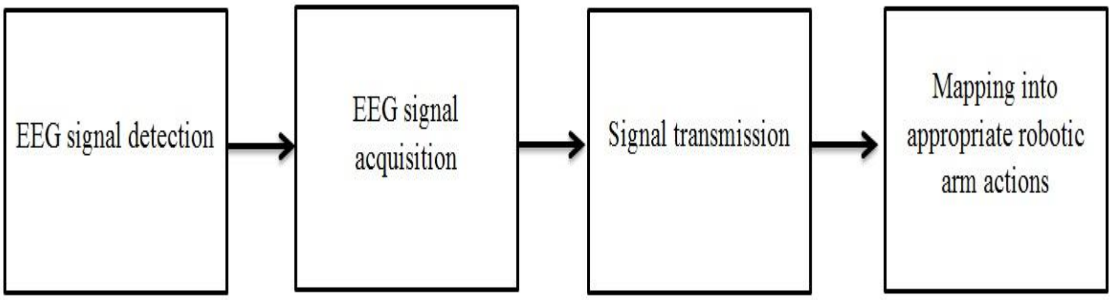

Fig. 1: Schematic outline of various stages involved

2.1.1 NeuroSky Mindwave Headset

2.1.1.1 NeuroSky Technology

Fig. 2: Mindwave Headset provided by Neurosky

In figure 2, the Mindwave Headset which is provided by Neurosky Technologies and those signals will be transferred by using Bluetooth which is there in the Mindwave headset, for this Mindwave headset need to give power using an AAA battery [5]. The Mindwave headset comes with Power switch, a sensor tip, flexible ear arm and a ground connection Ear clip. In this Headset they use Non-invasive sensor that won't cause any pain to the User who were the headset. After inserting an AAA battery switch on the Mindwave headset using the power switch the LED indicator will blink and if the Red color light not blinking the headset is powered on but not connected to with the computer’s Bluetooth. If the Blue color not blinking that means the headset is powered on and connected. If the red or blue color blinks it shows that the Battery getting low.

As shown in figure 4, the Data transmitted by the Mindwave headset will be received by the Computer’s Bluetooth receiver. And then all these data will be analyzed by the Matlab. The Matlab will help in extracting the raw data. In the Matlab the data will be received from the port pin which they are giving the same port number for the Bluetooth receiver and Matlab in the back panel. After the analysis of this data, this data will be sent to the robot module using serial data transmission i.e. using RF module. As shown in figure 3in the robot module there will be an RF receiver which will receive the data, transmitted by the RF transmitter. According to the data received by the RF the PIC microcontroller will give the directions to the servo motors which are connected with a robotic arm.

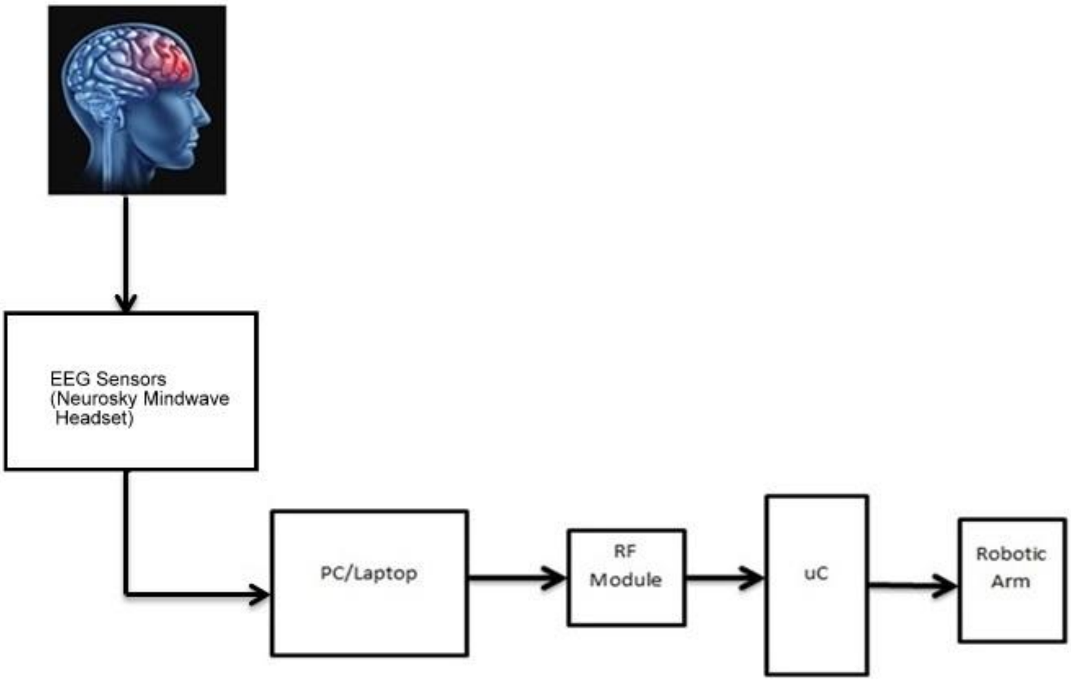

Fig. 3: Block Diagram

2.1.1.2 Brainwaves

The last century of neurobiology analysis has greatly hyperbolic our information regarding the brain and significantly, the electrical signals emitted by neurons firing within the brain. The patterns and frequencies of those electrical signals may be measured by inserting a detector on the scalp. The Mind Tools line of receiver product contains Neurosky ThinkGear technology that quantifies the analog electrical signals, ordinarily remarked as brainwaves, and exercises them into digital signals. The ThinkGear technology then makes those computations and signals out there to games and applications. The Table I provides a general precise of a number of the commonly- known frequencies that tend to be generated by differing kinds of activity within the brain.

Table 1: Frequencies Generated By Different Types of Activities in the Brain.

Brainwave Type	**Frequency range**	**Mental states and conditions**
Delta	0.1Hz to 3Hz	Deep, dreamless, non-REM sleep, unconscious
Theta	4Hz to 7Hz	Intuitive, recall, fantasy, imaginary, dream
Alpha	8Hz to 12Hz	Relaxed, but not drowsy, tranquil, conscious
Low Beta	13Hz to 15Hz	Formerly SMR, relaxed yet focused, integrated
Midrange Beta	16Hz to 20Hz	Thinking, aware of self & surroundings
High Beta	21Hz to 30Hz	Alertness, agitation

The fundamental frequencies of the human EEG waves are:

- **Delta**: has a frequency of 3 Hz or below. It tends to be the highest in amplitude and the slowest waves. It is typical as the dominant beat in infants up to one year and in stages 3 and 4 of sleep. It is typically most prominent frontally in grown-ups (e.g. FIRDA - Frontal Intermittent Rhythmic Delta) and posterior in children e.g. OIRDA - Occipital Intermittent Rhythmic Delta).

- **Theta**: has a frequency of 3.5 to 7.5 Hz and is classified as "moderate" movement. It is perfectly typical in children up to 13 years and in sleep however irregular in wake grown-ups. It can likewise be seen in generalized circulation in diffuse disorders, for example, metabolic encephalopathy or some instances of hydrocephalus.
- **Alpha**: has a recurrence somewhere around 7.5 and 13 Hz. It is generally best found in the back districts of the head on every side, being higher in sufficiency on the overwhelming side. It shows up when shutting the eyes and unwinding, and vanishes when opening the eyes or alarming by any component (considering, figuring). It is the real cadence found in ordinary loose grown-ups.
- **Beta**: Beta movement is "quick" action. It has a recurrence of 14 and more prominent Hz. It is generally seen on both sides in symmetrical conveyance and is most clear frontally. It is emphasized by narcotic trance-like medications particularly the benzodiazepines and the barbiturates. It might be non-attendant or lessened in zones of cortical harm. It is large viewed as an ordinary beat. It is the prevailing cadence in patients who are ready or restless or have their eyes open.
- **Gamma:** Gamma waves are in the recurrence scope of 31Hz and up. It is believed that it mirrors the instrument of awareness. Beta and gamma waves together have been connected with consideration, recognition and insight.

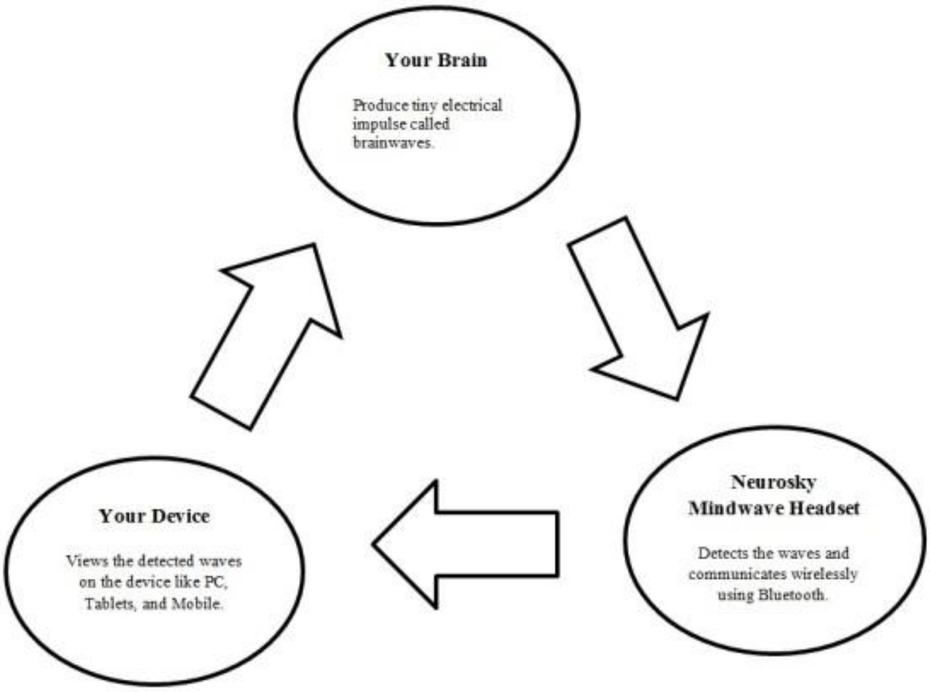

Fig**. 4:** Working of Neurosky Mindwave headset

2.1.1.3 ThinkGear

ThinkGear is that the technology within each NeuroSky product or partner product that empowers a tool to interface with the wearers' brainwaves. It includes the detector that touches the forehead, the contact and reference points settled within the ear clip, and also the on-board chip that processes all of the info. Each the raw brainwaves and also the eSense Meters square measure computed on the ThinkGear chip.

2.1.2 PC/Laptop

PC/Laptop is used as a platform to run MATLAB code for acquiring the raw brainwaves signal from Neurosky Mindwave Headset. Matlab helps in extracting the real time raw brainwaves which will help in controlling the robotic arm. The acquired raw brainwaves will be sent to the microcontroller using the RF module.

2.1.3 RF Module

RF Module is used for wireless communication between the laptop and microcontroller. It helps to transmit the attention and meditation levels acquired using Matlab to the microcontroller. The microcontroller will perform the robotic arm action according to the predefined levels.

2.1.4 PIC Microcontroller

Early models of PIC had read-only memory (ROM) or field-programmable EPROM for program storage, some with provision for erasing memory. All current models use Flash memory for program storage, and newer models allow the PIC to reprogram itself. Program memory and data memory are separated. Data memory is 8-bit, 16-bit and in latest models, 32-bit wide. Program instructions vary in bit-count by family of PIC, and may be 12, 14, 16, or 24 bits long. The instruction set also varies by model, with more powerful chips adding instructions for digital signal processing functions.The hardware capabilities of PIC devices range from 8-pin DIP chips up to 100-pin SMD chips, with discrete I/O pins, ADC and DAC modules, and communications ports such as UART, I2C, CAN, and even USB. Low-power and high-speed variations exist for many types.

We will be using PIC18F microcontroller to control robotic arm action by using levels of attention and meditation send from laptop. The RF module is used to transmit levels of attention and meditation to the microcontroller for controlling the robotic arm. The attention and meditation level are mapped to a specific action in a robotic arm. When one of the predefined levels is attained then the microcontroller will take the specific action. This movement of fingers is controlled by servo motor mechanism. The servo motor will be controlled using the microcontroller.

2.1.5 Robotic Arm

Robotic arm consist of 5 servo motors used to move the fingers of the arms. The PIC microcontroller will help to control the servo motors. The fingers are controlled by attention and meditation levels. When the predefined levels are acquired the microcontroller will take the respective actions to move the fingers of the robotic arm.

2.2 DESIGN FLOW

The project flow diagram of Mind Controlled Robotic arm is shown in figure 5. It shows various stages of the working of mind controlled robotic arm. After switching on the Mindwave headset and the Robotic arm, the headset will initialize and will starts sensing the neuron signals. At each sensing of the signals, it will transfer them to laptop using the Bluetooth. The sensed raw data will be read and displayed by the Matlab [16]. It will also help in sending these raw data to microcontroller of robotic arm using the RF Transmitter. Two types of data can be measured by the Neurosky mindwave headset i.e. Attention level and Meditation level. These levels will be received by microcontroller which will help in controlling the robotic arm actions. The microcontroller should continuously analyze the incoming brainwaves and map them into the appropriate actions.

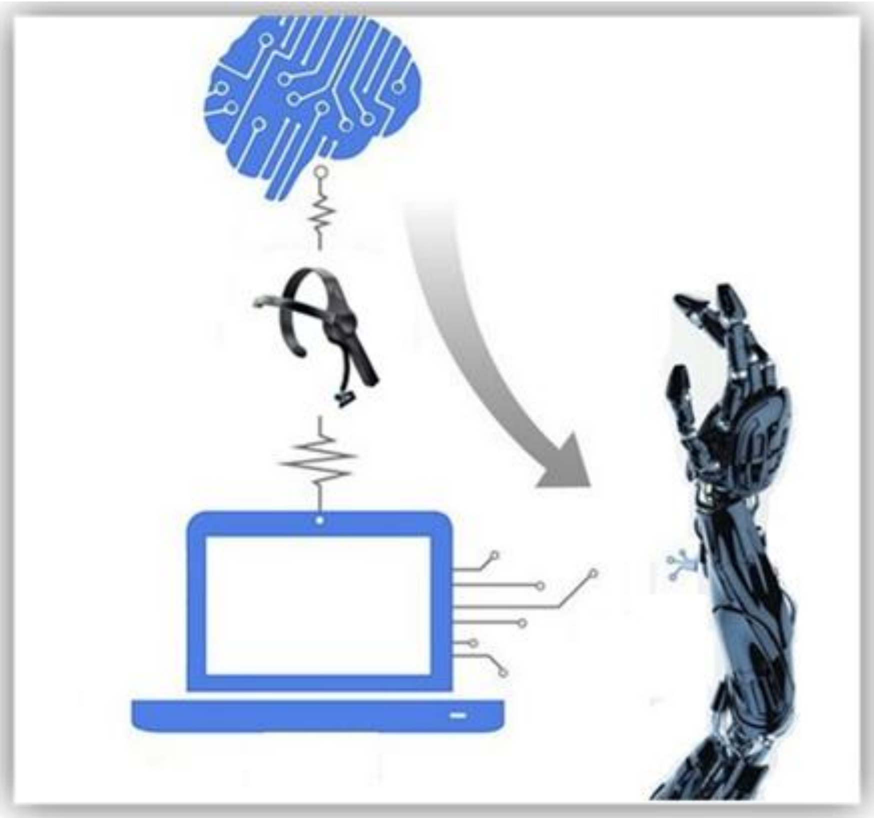

Fig. 5: Project Flow

2.3 Experimental Study

This system uses PIC18F microcontroller to continuously analyze the incoming brainwaves and map them into the appropriate actions. This system consists of three important sections. One is brainwave headset provided by Neurosky, the other one is Robotic arm and the Signal acquisition section in PC which is done using Matlab. This Headset and the PC will be interlinked with the help of Bluetooth wireless communication and the PC and Robotic arm interlink with the RF module. The RF modules will transfer brainwaves from laptop to microcontroller. Also Bluetooth will transfer raw brainwaves from headset to laptop.

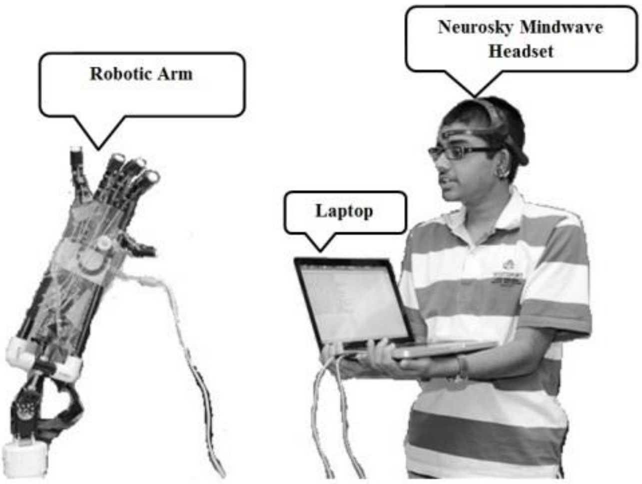

Fig. 6: The Experimental Setup

Firstly one needs to connect the headset to laptop using Bluetooth and set its comp port. Then using Matlab program acquire the raw brainwaves from headset and send it to microcontroller using RF module [16]. The attention and meditation level are the two parameters to control different actions of the robotic arm. These values can be classified into different levels. For each level a specific action will be set. According to raw brainwaves sent to the microcontroller, which it will check against the classified levels and perform the predefined action. The table below will help to understand the classified levels and its actions.

Table 2: The commands for the proposed robotic arm.

Commands	Extracted signal
Move Index Finger	ATTENTION:20-45
Move Middle Finger	ATTENTION:45-70
Move Ring Finger	ATTENTION:70-95
Move Pinky Finger	MEDITATION:20-45
Move Thumb Finger	MEDITATION:45-70
Closing all fingers at once	MEDITATION:70-95

III. Result And Discussions

The research and development of brain-controlled robotic arm has received a great deal of attention because they can help physical handicapped people improve their quality of life. In this paper, we presented a comprehensive up-to-date review of the complete systems, design of this system, and evaluation issues of brain-controlled mobile robots. After implementing the Mindwave Controlled robot I've checked the results with NeuroSky headset, as I expected the headset doesn't give the 100% accuracy of brainwaves but it is too good for its price and it can give up to 80% accuracy of brainwaves. This is due to single EEG sensors. Greater accuracy can be achieved by using more number of sensors. After connecting the Headset with PC using Bluetooth, we need to wear the headset on the head and then we need to run the code for acquiring raw brainwaves using Matlab. The command window in Matlab shows the attention values detected by the headset. The figure 7 below shows the detected values.

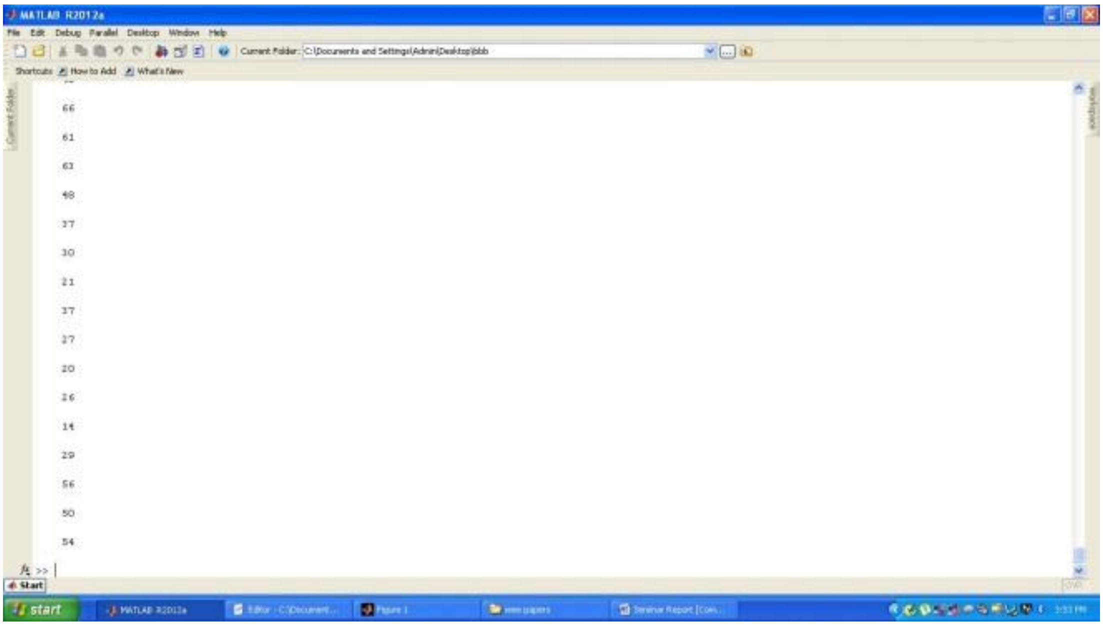

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Fig. 7: Screenshot of Attention values

After getting these attention values a graph will be generated. The graph is shown in figure 8. From here these signals will be transferred to the Robotic arm through RF wireless transmission, the signals will be collected by RF receiver and sends to the microcontroller. The microcontroller reads the brainwaves sent and maps it to the predefined actions. Then accordingly gives commands to the servo motor of robotic arm. Thus the robotic arm can be controlled using brainwaves voluntarily.

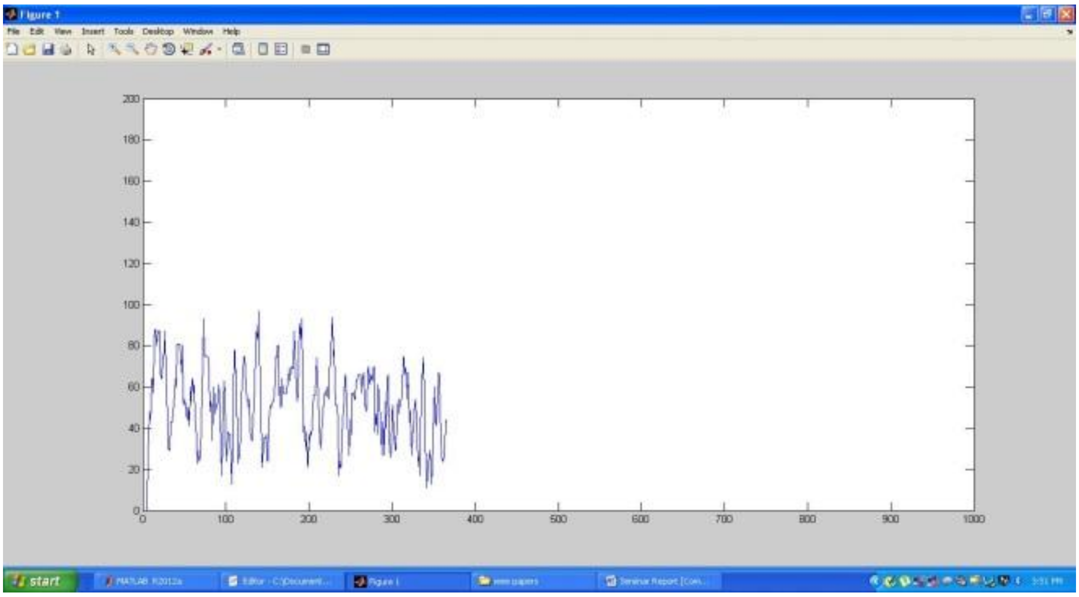

Fig. 8: Screenshot of Graph showing attention values

IV. Conclusion

The system that we developed for controlling the robotic arm through electroencephalographic data shows promise. We were able to classify user data to 6 outputs given by the Neurosky Mindwave headset system. Unfortunately, we were unable to control the arm with the accuracy necessary to complete our movement task. In order to complete the given task, we will need to either reduce the complexity of the task or improve the effectiveness of our classification system. Our system could be further improved through gathering more data and using different optimization techniques to increase the classification of ranges. A longer training time for the user would allow the user to easily control the arm more accurately. Also more number of EEG sensors would improve the accuracy and would help in classifying it into more ranges. If the accuracy could be increased, then we believe the robot arm could be successfully controlled in a real world situation. For future work, we would like to explore these techniques to increase the accuracy so that we could start running trials on the effectiveness of this control system. We could also then evaluate the use of the system on different people, and in different experimental environments.

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