Control of Implantable Robotic Arm using Unsupervised Brain Computing Interface Approach

***Abstract-* This paper deals with building a multi-dimensional control system to aid the deployment of robust systems for physically challenged and also for gamification domains. The designed appliance functions based on the neuro-signals acquired using low-cost, portable, single-sensor Electroencephalogram (EEG) device and employs low cost hardware, microcontrollers and motor drivers. Though multi-channel EEGs render high resolution signals, we deliberately employ a low resolution EEG due to its many advantages over its conventional counterparts. The deployment of multi degrees of freedom trajectories for the appliance, i.e. the motion commands, was achieved with the aid of effective features like the engagement indexes, presence of eye blinks and its associated intensities, etc. of the neuro-signals. Twenty-two right handed engineering students volunteered for the study. The results obtained, i.e using direct (EEG signals) and indirect (via questionnaire) techniques were indicative of the success rates and ease of usage of the proposed design. A user study to assess the metric of the time of adaptability with the system requirements was done. This was essential to model and derive subject specific variances in building a generic application. The application is intended to serve subjects with motor dysfunctions to be able to control basic appliances for reduced dependability and where the reduced training time is of utmost importance.**

Index Terms – EEG, microcontrollers, BCI, Atmega8, L293DNE.

I. INTRODUCTION

Human computer interaction has seen mass deployment with systems like Brain Computer Interface (BCI), recommender systems, natural language processing [6], face recognition [7], etc. A Brain Computing Interface (BCI) is a mediatory agent aiding the communication between a brain and a computer. A BCI device captures neurosignals, interprets them, process them into particular mental state values.

Currently BCI applications are becoming affordable with the advent of low cost EEG devices like Neurosky [1]. Such devices are being deployed to aid trainers and students through gamification due to its ease of usage and portability [2, 3].

The present world offers varieties of methods and procedures to control a robotic arm by using a BCI device. All the procedures work efficiently without a doubt, but come with expensive hardware. This paper proposes a cost effective and easier way of deploying a humanoid arm controlled by neurosignals.

The current methodologies of controlling a humanoid robot, robotic arm or a humanoid arm consist of both wired and wireless connectivity. Following the wireless connectivity, work is yet to be done on controlling the degree to which the robotic arm must rotate, bend, and the amount of pressure, the fingers of the robotic arm must apply on an object while grabbing or holding it.

The paper is organized as follows. Section II throws light on the related work in this domain. The section III describes about the hardware, i.e. Neurosky's Mindwave Mobile, Atmega8 microcontroller, L293DNE dual motor driver, etc., and software which can be used for the proposed venture. The section 2 also explains the connection establishment between the hardware devices. The section IV comes with the complete explanation about the proposed system architecture, process flow, control flow, and APIs that can be used to achieve the required operability. The algorithm for implementing is also discussed. The results and discussions of this work is given in Section V. The paper concludes in Section VI.

II RELATED WORK

There have been multiple approaches on controlling a robot, or a robotic arm, [8] Talks about accelerating or decelerating attention values using Neuroksy's Mindset, and controlling the whole robot by collecting the values from Emotiv Epoc headset. [9] Talks about controlling a 6 degree of freedom robotic arm by using an appropriate model of dry electrode BCI Headset. [10] Proposes a method of controlling a 7 degrees of freedom robotic arm using 14 dry electrodes EEG headset. When we need to make the implantable robotic arm controlled by brain come true, we have to make it cost effective so that it is available to and affordable for all those who are in. to achieve that this paper propses a cheaper hardware and robotic arm, and the easy way to implement it, and make the learning curve of the particular user. The paper proposes a low cost parts easily available and simple microcontroller.

III. HARDWARE AND SOFTWARE USED

A. EEG used

The hardware includes a basic laptop or desktop computer, and an EEG device- Neurosky Mindwave Mobile [1] (see Fig. 1). The EEG data was rendered between BCI device and Computer over a bluetooth connection, and the data was parsed using ThinkGear package imported in C Program.The ThinkGear API running in the background continuously reads the data received from the device.

The EEG device is comprised of a dry, single lobe sensor that collects brain wave data at frontal cortex, the contact and the reference points on the ear pad.

The EEG device used by the author gives better Usability Index (*UI*) given by equation (1):

Fig. 1 NeuroSky Mindwave Mobile EEG

$$UI=EQ+DL \qquad (1)$$

where *EQ* refers to the ergonomics quality (subject's level of unobtrusiveness for the experimental setup) and *DL* corresponds to the difficulty level faced while setting up the experiment using the device. This metric was used to compare different EEG devices based on cognitive load calculation [4]. Two EEG devices, namely , Emotiv Epoc , and Neurosky Mindwave Mobile were compared and it was found that *UI* was higher for the latter. Since our implementation required only the analysis of eye blinks and Attention values, and not the rest of the brain waves, we selected the Neurosky EEG owing to its optimal *UI* score obtained in [4]. Also, the easy to use APIs provided by this device have been used in test case generation for face recognition software [5

B. ATmega8 microcontroller

ATmega8 microcontroller is AVR RISC based microcontroller, with 8KB of Flash memory, 1KB of SRAM, 512K of EEPROM, and 6 or 8 channel 10bit A/D converter. The device supports throughput of 16 MIPS at 16MHz and operates between 2.7 to 5.5 volts. This 28 pin chip is very cost effective when compared to other microcontrollers.

C. L293DNE dual motor driver

L293DNE dual motor driver is again a low cost chip built to control two bidirectional dc motors. It contains 6 input and 4 output ports. Among the 6 input ports, 2 ports are for enabling the motors and 4 ports are for deciding the direction of rotation of the motors (section IV. C). TABLE 1 describes the required connections between Port B of Atmega8 microcontroller and input ports of L293DNE dual motor driver.

TABLE 1. Pin connections between Atmega8 microcontroller and L293DNE dual motor driver

PORT B	**L293DNE**
PIN 0	Enable A
PIN 1	Input A1
PIN2	Input A2
PIN3	Enable B
PIN 4	Input B1
PIN 5	Input B2
PIN G	GND
PIN R	VCC

D. Miscellaneous hardware and software

A simple pick-and-place robotic arm can be built using plastic gears and metallic parts. The required power supply to the motors can provided by batteries. Thinkgear software is used to invoke APIs to connect and receive signal values from BCI device. WinAVR platform is used to code the ATmega8 microcontroller.

IV. IMPLEMENTATION

As Fig .1 describes the overall system architecture, the BCI device captures the neurosignals and sends the signal values to the computer to which it is connected to, via Bluetooth, at the rate of one value per second. By using the appropriate programming tools, the hardware (section II. D) are coded, i.e. the instructions are sent to the microcontroller and then in turn to motor driver (section II. C) which triggers or controls the actions of the robotic arm. The logical flow or the workflow of the proposed system is given by Fig.3.

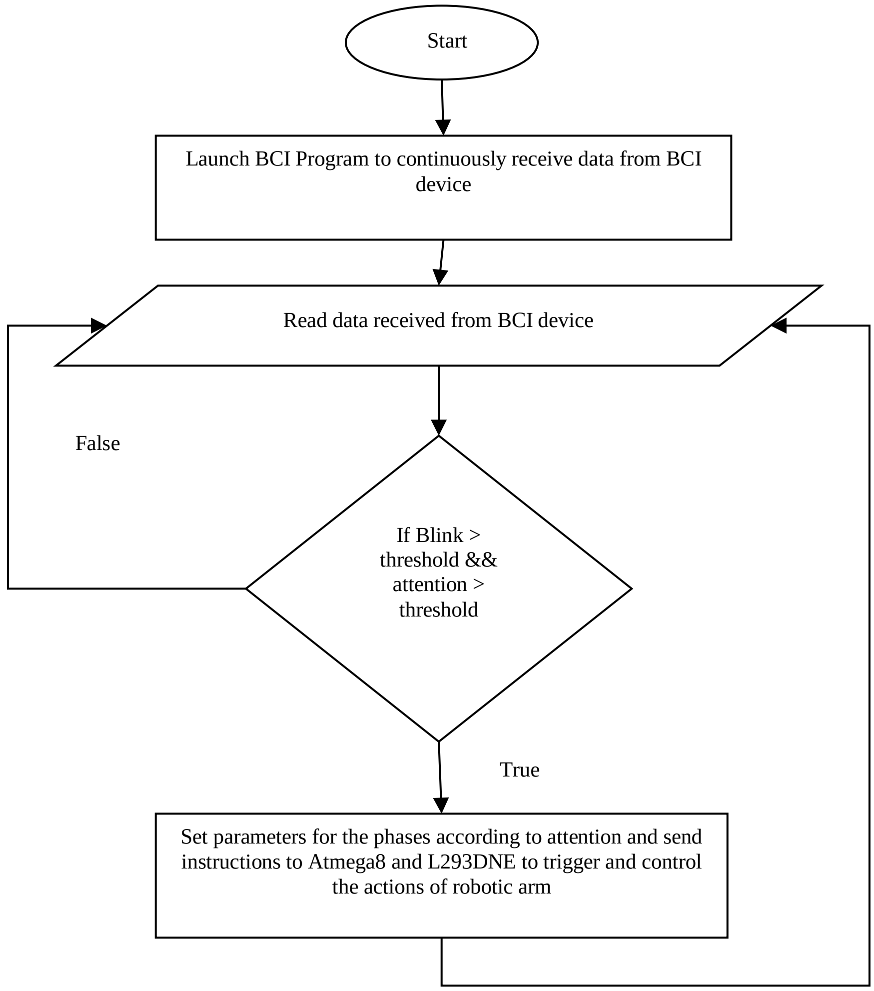

Fig. 3. The workflow of the system

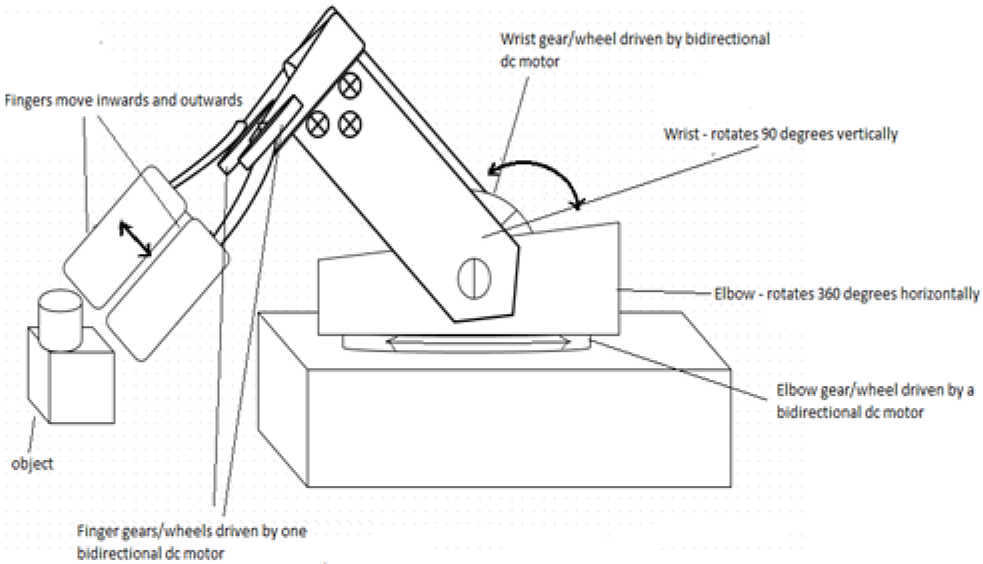

Fig. 4. Mechanical components in the designed pick-and-place robotic arm

Fig. 4 describes how a simple pick and place robotic arm would look like which is assembled using the low cost plastic gears, metals and screws. The elbow and wrist are made of simple spur gears driven by dc motors and metal bars attached to them, the elbow can rotate complete 360 degrees, and wrist up to 180 degrees both clockwise and anti-clockwise. The fingers are comprised of worm and wheel gears to facilitate the loosening and gripping of the object.

The degree of rotation of the particular parts of the robotic arm are calculated using the below (1)

$$D=(a/100)*max \quad \text{Eq(1)}$$

Where D represents the degree of rotation, a represents the attention value captured for the particular phase of action, *max* represents the maximum possible degree of rotation for the particular phase. TABLE 2 describes the phase and particular part in action and respective maximum possible degree of rotation

TABLE II. Different phases in actions performed by robotic arm

PHASE	**PART OF ROBOTIC ARM**	**MAXIMUM DEGREE (*max*)**
Direction/position of object	Elbow	360
Height of object	Wrist	90
Gripping	Fingers	180

A. ALGORITHM

The steps to implement the system are given in this section.

Step1: Start
Step2: Connect to the BCI device via Bluetooth
Step3: Continuously check for the intentional eye blink
Step4: If intentional eye blink = Yes, then go to Step 5, else go back to Step 3.
Step5: Continuously receive the attention value from the device
Step6: If attention value > some pre-decided threshold value, then go to Step7,
Else go back to Step5.
Step7: Send instructions to microcontroller
Step8: Repeat Step 3 till Step 7 to pick and place the object.
Step9: End

First, the BCI headset is connected to the computer via Bluetooth. Intentional eye blink is set as the trigger to start the reception of the attention values from the device. The values are transferred from the device to the computer at the rate one value per second. The attention values are received by the computer every second and they are compared against some small threshold value. A small value for the threshold can be decided so that the user does not have to put more effort to increase his/her attention value. Once the attention value becomes greater than the threshold value, appropriate instructions are sent to microcontroller.

B. CALCULATING AND USING MENTAL STATES TO CONTROL THE ROBOTIC ARM

The Neurosky's Mindwave Mobile can detect attention, meditation levels of the person, and an intentional blink performed by the person wearing the device.

Thinkgear software receives data from the BCI device as asynchronous serial stream of data values. A Thinkgear packet consists of 3 parts namely, Packet header, Packet payload, and payload checksum. The packet structure is described by Fig .5.

```
[SYNC] [SYNC] [PLENGTH]  [PAYLOAD...]    [CHKSUM]
_______________________  ___________  ____________
^^^^^^^^(Header)^^^^^^^  ^^(Payload)^^  ^(Checksum)^
```

Fig.5 Thinkgear packet structure

The [PAYLOAD…] section is allowed to be up to 169 bytes long, while each of [SYNC], [PLENGTH], and [CHKSUM] are a single byte each. The [SYNC] bytes in packet header are to signal the beginning of new packet with a value 0xAA. The synchronization is two bytes long to, reduce the chance that 0xAA is misunderstood as the beginning Fig.7. The [CODE] definitions table

A program to continuously detect for intentional blinks is launched at first. The intentional blink is the trigger which decides when to start taking the attention values of the person. As soon an intentional blink is detected, the program to receive the attention values from the device is launched which continuously receives values from the device and displays it on the screen. The attention value is written to a text file. The attention values are used as secondary triggers to avoid the involuntary start of the actions of robotic arm in case if the person does intentional blink for purposes other than moving the robotic arm, such as, blinking the eyes if something fell in his/her eye.

C. CONTROLLING THE ACTIONS OF ROBOTIC ARM

A robotic arm is controlled by controlling the bidirectional motors, and the gears which are driven by the motors. Referring the pin-connections given in TABLE I and TABLE III, how L293dne motor driver

of packet. The [PLENGTH] byte indicates the length, in bytes, of the Packet's Data Payload [PAYLOAD…] section, and may be any value from 0 up to 169. The [CHKSUM] byte must be used to verify the integrity of Packet's Data Payload. The Payload's checksum is described as, summing all the bytes of Data Payload, extracting lowest 8 bits of the sum, and performing one's compliment on those 8 bits. The mental state values are extracted from Data payload of the packet. The Data payload consists of series of Data Values, each contained in series of bytes called Data Row. Data Row provides information about what the Data Value represents, the length of Data Value, and the bytes of Data Value itself. Fig.6. gives the structure of Data Row

```
([EXCODE]...) [CODE]  ([VLENGTH])  [VALUE...]
___________________  ___________  __________
^^^^(Value Type)^^^^  ^^(length)^^  ^^(value)^^
```

Fig.6. Structure of Data Row

The number of [EXCODE] bytes indicate the Extended Code Level which is used in conjunction with the [CODE] byte to determine the type of Data Value. The mental state values are determined using the [CODE] section of the Data Row. The [CODE] definitions table is given by Fig. 7. , referring which the received signals are processed for required mental state values

enables a bidirectional motor and decides its direction of rotation can be explained.

Table III. Decision table for direction of rotation of a bidirectional motor

INPUT1	INPUT2	DIRECTION OF ROTATION
Low	Low	No Rotation
Low	High	Clockwise
High	Low	Anti-clockwise
High	High	No Rotation

While picking an object, first the robotic arm must widen the fingers, then bend forward, close the fingers to grab the object, and bend backwards to hold the object up. While placing an object, the arm is bent forward first, the fingers are widened to leave the object, then the arm is bent backward, and finally the fingers are closed to come to the original position.

V. RESULTS AND DISCUSSIONS

The attention values are different in different users. The Fig.8 shows the graphs for the attention values captured for person-1 and person-2.

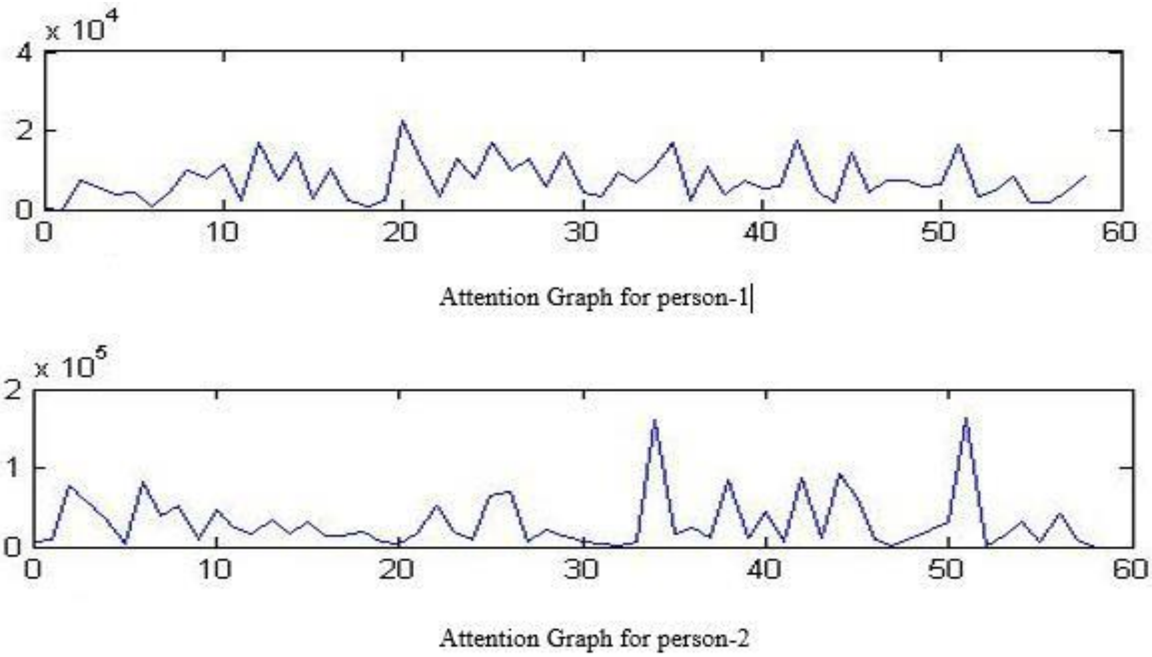

Fig.8. Attention level graphs for person-1 and person-2

The time taken to cross the given threshold may vary from person to person. A survey is conducted upon 33 subjects of different age and different gender, and at different scenarios, and a chart as given in Fig.9 is created for the average time taken by each subject to attain a particular threshold value.

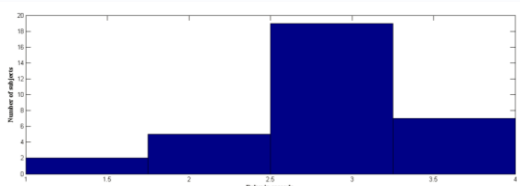

Fig. 9. Histogram for delay in attaining threshold

Based upon the average values we can decide the threshold value to be put for certain person so that there would be no delay.

VI. CONCLUSIONS AND FUTURE SCOPE

The approach proposed here, provides a very cost effective, easy to code and control, an implantable robotic arm using a BCI device. The person wearing the device, say user, can decide when to pick up an object, by doing an intentional blink, and maintaining a single thought to increase the attention value over a particular threshold. The similar set of actions are performed by the user to place the object.

ACKNOWLEDGEMENTS

The authors are immensely thankful to all the subjects for participating in the experiment.

REFERENCES

[1] Neurosky Mindwave Mobile.
Available at: http://www.Neurosky.com (last accessed: 15/08/2015)
[2] Geeta Navalyal, Rahul Gavas, “A dynamic attention assessment and enhancement tool using computer graphics”, Human-centric Computing and Information Sciences 2014 4:11, Springer.
doi:10.1186/s13673-014-0011-0
[3] Geeta N., Rahul Dasharath Gavas, “Enhanced Learning with Abacus and its Analysis Using BCI Technology”,I.J. Modern Education and Computer Science, 2014, 9, 22-27.
DOI: 10.5815/ijmecs.2014.09.04
[4] Das, Rajat, et al. "Cognitive load measurement-A methodology to compare low cost commercial EEG devices." *Advances in Computing, Communications and Informatics (ICACCI, 2014 International Conferenceon*. IEEE, 2014.
[5] Shankar, Sheela. "Assessment of the effect of variations in Eye Blinks on a face recognition algorithm." *Advance Computing Conference (IACC), 2015 IEEE International*. IEEE, 2015.
[6] Reddy, V. Ramu, and K. Sreenivasa Rao. "Better human computer interaction by enhancing the quality of text-to-speech synthesis." *Intelligent Human Computer Interaction (IHCI), 2012 4th International Conference on*. IEEE, 2012.
[7] Sheela Shankar, V R Udupi, “Achieving Robustness in Face Recognition by Effective Feature Acquisition”, IJIGSP, 2015, 9, 41-48, MECS.
DOI: 10.5815/ijigsp.2015.09.06
[8]Vourvopoulos, Athanasios, and Fotis Liarokapis. "Brain-controlled NXT Robot: Tele-operating a robot through brain electrical activity." Games and Virtual Worlds for Serious

Applications (VS-GAMES), 2011 Third International Conference on. IEEE, 2011.
[9] Astaras, Alexander, et al. "Towards brain-computer interface control of a 6-degree-of-freedom robotic arm using dry EEG electrodes." Advances in Human-Computer Interaction 2013 (2013): 2.
[10] Wenjia Ouyang; Cashion, K.; Asari, V.K., "Electroencephelograph based brain machine interface for controlling a robotic arm," in Applied Imagery Pattern Recognition Workshop (AIPR): Sensing for Control and Augmentation, 2013 IEEE , vol., no., pp.1-7, 23-25 Oct. 2013