NITTE MEENAKSHI INSTITUTE OF TECHNOLOGY

(An autonomous institution affiliated to VTU)
Govindapura, Golahalli, Yelahanka, Bangalore – 560064

An Internship Report on

‘BRAIN COMPUTER INTERFACE’

Submitted by

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(USN: 1NT14EC050)

Internship carried out at

INDIAN INSTITUTE OF SCIENCE (IISc), BANGALORE

Under the Guidance of

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DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING
NITTE MEENAKSHI INSTITUTE OF TECHNOLOGY
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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING
Year: 2017-18

CERTIFICATE

This is to certify that the internship work entitled "**Brain Computer Interface**" has successfully completed by **Ganapathy U E (1NT14EC050)** at **Indian Institute of Science (IISc)** during the period **3rd June'17 to 20th July'17.** It is certified that all the corrections / suggestions indicated for internal assessment have been incorporated in the report deposited in the department library. The project has been approved as it satisfies the requirements in respect of Internship prescribed for Bachelor of Engineering Degree.

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Signature of Internal Guide	**Signature of HOD**	**Signature of Principal**
Dr. Raghunandan S	**Dr. Sandya S**	**Dr. H C Nagaraj**

External Viva

Name of Examiners	**Signature with date**
1. ______________________	__________________________
2. ______________________	__________________________

ACKNOWLEDGEMENTS

An internship is a golden opportunity for learning and self-development. We consider ourselves very lucky and honoured to have so many wonderful people who guided us in completion of this training.

We express our deepest thanks to our Principal **Dr. H C Nagaraj** and **Dr. N R Shetty,** Director **Nitte Meenakshi Institute of Technology,** Bangalore for allowing us to carry out the industrial & Research training and supporting us throughout.

We are thankful to **Dr.Rathna G N, Principal Research Scientist, Indian Institute of Science (IISc)** for providing us an opportunity to carry out this internship at **Indian Institute of Science**, Bangalore. We also thank for her continuous support, committed supervision and valuable guidance while carrying out our internship.

We are grateful to **Dr. S Sandya,** HOD, Department of Electronics and Communication Engineering NMIT, Bangalore for granting us the permission and guiding us through the internship programme.

We wish to convey our deep sense of gratitude to **Dr. Raghunandan S,** Professor, ECE Department, NMIT for his valuable guidance through the conduction of this internship.

Finally we thank all other who have helped us in various ways to gain knowledge and get a good training.

DECLARATION

I **Ganapathy U E (1NT14EC050)** hereby declare that the project work entitled **"Brain Computer Interface"** has been carried out by me under the guidance of Dr. Raghunandan S, Professor, Department of Electronics & Communication Engineering, Nitte Meenakshi Institute of Technology, Bangalore in partial fulfilment in the requirements of the degree of Bachelor of Engineering in Electronics & Communication Engineering of Nitte Meenakshi Institute of Technology affiliated under Visvesvaraya Technological University, Belgaum.

We further declare that we have not submitted this report in part or full to any other university for the reward of any degree.

Ganapathy U E

Place: Bangalore
Date: 26/09/2017

ABOUT INDIAN INSTITUTE OF SCIENCE (IISc)

The Indian Institute of Science (IISc), was established in 1909 by a visionary partnership between the industrialists Jamsetji Nusserwanji Tata, the Maharaja of Mysore, and the Government of India. Over the 107 years since its establishment, IISc has become the premier institute for advanced scientific and technological research and education in India. The Institute has laid a balanced emphasis on the pursuit of basic knowledge in science and engineering, as well as on the application of its research findings for industrial and social benefit. In the words of its founder, J. N. Tata, the objectives of the Institute are “to provide for advanced instruction and to conduct original investigations in all branches of knowledge as are likely to promote the material and industrial welfare of India.”

The **Department of Electrical Engineering** is among the first few departments to be started at Indian Institute of Science (IISc). It was started in the summer of 1911 with Prof. Alfred Hay as its chairman. The discipline of Electrical Engineering was a new and exciting area at the turn of last century and it is a testimony to the vision of the founders of IISc that the first engineering department started at the Institute is in this field. The department celebrated its centenary during 2011-12 and in December 2011, the department organized a Centenary Conference and a special Alumni-Get-Together as part of its centenary celebrations.

Over the last one hundred years, this department has contributed significantly to the growth of Electrical Engineering education and research in India. Many alumni of the department have distinguished themselves in academic institutions, research laboratories, industries and government organizations, both in India and abroad.

The vision of the department is to provide the leadership to enable India's excellence in the field of Electrical Engineering. The department is committed to advancement of the frontiers of knowledge in Electrical Engineering and to provide the students with a stimulating and rewarding learning experience.

Professors are actively engaged in publishing textbooks as well as research monographs, continuing education, execution of sponsored research projects for many government agencies as well as private industries and also provide leadership to professional societies. The department has a vibrant research environment and the students benefit immensely from the research flavor of the course work. The department attracts talented students from all over India to its Masters and Research degree programs. The graduates of the department find rewarding placement in many global companies and research labs as well as in many universities in India and abroad.

ABSTRACT

A **brain-computer interface (BCI)**, also referred to as a mind-machine interface (MMI) or a brain-machine interface (BMI), provides a non-muscular channel of communication between the human brain and a computer system. The electroencephalogram (EEG) is an electrical activity generated by brain structures and recorded from the scalp surface through electrodes. **BCI** (Brain-computer Interface) has been attracting attention as an interface to connect the brain to external devices.

The EEG or the brain activity can be used in real time to control external devices via a complete BCI system. A typical BCI scheme generally consists of a data acquisition system, pre-processing of the acquired signals, feature extraction process, classification of the features, post - processing of the classifier output, and finally the control interface and device controller. The post-processed output signals are translated into appropriate commands so as to control output device – wheelchair.

Hence, the above project describes a feasible way in which a device can be controlled using the brain driven signals that can be extracted accordingly with help of an EEG electrodes.

OBJECTIVES

The objective of the Project includes:

1) Extraction of EEG signals using electrodes.

The EEG signals from the brain is extracted using the fourteen electrodes of the Emotiv headset.

2) Using the Emotiv libraries to get meaning full data from EEG signals.

The signals from the Emotiv Headset is obtained using Emotiv libraries and the data is processed.

3) Transferring the data to microcontroller unit over internet.

The data obtained has to be transferred to the microcontroller unit in order to control the prototype.

4) Controlling the prototype using the microcontroller unit.

The prototype is controlled using the mental commands from the Emotiv Headset.

CONTENTS

Chapter 1

INTRODUCTION

Millions of people around the world suffer from Amyotrophic lateral sclerosis (ALS) and Mobility impairment among which many of them rely upon wheelchairs to get on with the daily activities of life. However many patients are not prescribed to use wheelchair either because they are physically unable to control the chair manually or because of lack of safety. However, these issues can be overcome by empowering the wheelchair with technology such that the people benefit from the Smarter Wheelchair. Technology provides a great scale of safety and additional assistance to the patient's such that they are able to get along with the activities efficiently.

The Project concentrates and collaborates on features that are important to analyse the environment such that it helps us to envision a system that could improve the quality and safety of many. This type of a system not just interacts mechanically but also responds upon the basis of brain activity in real time.

In our project, with the concept of a Smarter Wheelchair, we target about the brain signals which convey one's intention. This requires a high level of concentration such that it result with a quality signal which precisely control the movement of the wheelchair. Due to noisy nature of the brain signals, we may not be able to achieve the accurate results.

The electrical activities of the brain can be monitored in real time using different approaches. The output of the brain computer interface is the Electroencephalogram (EEG) signals which are synthesized and decoded using on-board sensing techniques. One important application of Electroencephalogram (EEG)-based brain computer interfaces (BCIs) is wheelchair control, which has attracted a great deal of attention because brain-controlled wheelchairs have the potentials to improve the quality of life and self-independence of the disabled users.

We are motivated to design this technology such that this innovative technology can provide a helping hand to paralytic patients who are unable to communicate to their near and dear ones. Hence, this technology has brought out an innovative technique, for paralytic or disabled patients to communicate and navigate independently.

__Chapter 2__

LITERATURE SURVEY

[1] Rui Zhang, Yuanqing Li, ***"An Intelligent Wheelchair Based on Automated Navigation and BCI Techniques"***

This paper proposes an intelligent wheelchair system that relies on a brain computer interface (BCI) and automatic navigation. This paper describes a method on which the user destinations and waypoints are automatically generated on the basis of the current environment. Then, the user selects a destination using a P300-based BCI. Finally, the navigation system plans a path and navigates the wheelchair to the determined destination. Also when the wheelchair is in motion, the user can issue a stop command with the BCI.

March 2014. IEEE.

[2] Nobuaki Kobayashi, Masahiro Nakagawa***, "BCI-based Control of Electric Wheelchair",***

This paper suggests a BCI system that accurately recognizes and isolates emotions like delight, anger, sorrow, and pleasure using an Emotion Fractal Analysis Method (EFAM), which can quantify emotions based on data obtained by electroencephalography, and control an electric wheelchair using the information. Using the EFAM circuit the speed of an electric wheelchair can be adjusted by the intensity of emotions.

2015 IEEE 4th Global Conference on Consumer Electronics (GCCE).

[3] Nikhil Shinde and Kiran George***, "Brain-Controlled Driving Aid for Electric Wheelchairs".***

This paper describes about the use & application of mental concentration (EEG signals) and eye blinks (EMG signals) of the user. This paper explains the study and usage of Neurosky BCI Headset that can be analysed and processed using a customized algorithm in android OS.

2016 IEEE.

[4] Brice Rebsamen, Etienne Burdet, Cuntai Guan, ***"Controlling a wheelchair using a BCI with low information transfer rate".***

This paper describes a method to drive a wheelchair using an interface with asynchronous and very low information transfer rate signal. This paper describes about the analysis that is done on a healthy subject using P300 Brain Machine Interface. This study describes a method in which a GUI is developed and the destinations are selected by the user’s brain signals. A path is traced in the GUI ascertaining the distance and the decision is traced back and sent to the wheelchair & thus navigating to the desired destination.

June 2007, IEEE.

[5] Pinos Eduardo,Guevara Daniel, Fátima López, ***“Electroencephalographic Signals Acquisition for the Movement of a Wheelchair Prototype in a BCI System”.***

This paper purely focuses on the study of ALP (amyotrophic lateral sclerosis) affected patients and how effectively a BCI system can be interfaced on them. Here, the brain signals are analysed to recognize tumours, epilepsy, degenerative diseases, and attention disorders emotion levels and to emulate artificial intelligence systems and neural networks. The obtained response is then implemented onto the wheelchair thus providing a user´s affective responses and visual feedback. Hence, a similar approach towards the implementation of BCI on a wheelchair has been explained in this paper.

October 2015, IEEE.

[6] Krishna Tejwani, Jaydip Vadodariya, Dipesh Panchal, ***“Biomedical Signal Detection using Raspberry Pi and Emotiv EPOC”.***

This paper describes an overview about the hardware and software interfacing for biomedical signal processing using raspberry pi. This paper tells about biomedical detection on raspberry pi using emotive epoc+. EPOC is EEG based BCI device which reads activity of brain and is helpful for user to understand any persons’ brain activity and can be programmed for any action based on certain activity as per person requirement. This paper also describes about the importance EEG signals which has great potential and the paper also describes about the disadvantages that are met to extract the EEG signals from a Linux or a Debian based operating system.

Chapter 3

HARDWARE & SOFTWARE REQUIREMENTS

The hardware requirements include the EEG (Electroencephalogram) headset, a Controller, DC motor and motor –drivers that help to control the motors from the Microcontroller.

The following are the specifications of the hardware:

1. **EMOTIV EPOC:** is a neuroheadset that is used in the field of research and industrial applications. It consists of 14 channels and is placed on the head such that all the 14 electrodes are in contact with the scalp to detect the EEG signal. The headset also consists of gyroscope which detects the orientation of the head. The headset can wirelessly connected to a computer using an USB transceiver which helps to transfer the brain signals and thus, it can be further analysed easily.

2. **XAVIER CONTROL PANEL**: The headset can be interfaced with emotiv SDK **Xavier Control Panel** which gives the quality of contact of electrodes with the scalp. The control panel also offers interfaces called EmoEngine which helps to connect directly to the headset and EmoComposer which can emulate the behaviour of EmoEngine without connecting to a headset.

Fig.1 - ***EMOTIV Headset***

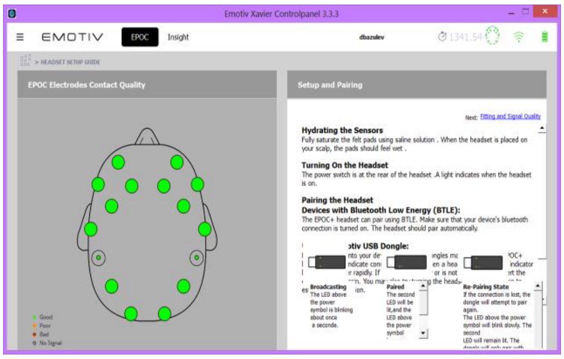


Fig.2 - ***Xavier Control Panel***

The signals from the headset can be extracted using the libraries that are defined by the headset. The libraries can be used such that the mental commands can be retrieved in real time.

3. **<u>MICROCONTROLLER</u>**: The various signals that are obtained from the headset can be used to control a real time situation using a microcontroller. The controller can be programmed such that each of the signals it receives can enable GPIO pins which are further connected to other external hardware.

   The signal that are obtained from the headset is transferred to a **Raspberry-pi** over Wi-Fi using socket connection and each of the data it receives makes the motor run in clockwise or counter-clockwise direction.

Fig.3 - ***Raspberry Pi 3B***

4. **<u>MOTOR-DRIVER</u>**: The voltage given at the output of Raspberry-pi is not sufficient to run a DC motor and hence the latter cannot be controlled directly through the GPIO pins. A motor driver is a device which can run the motor using an external power source and control its direction depending on inputs from the GPIO pins of Raspberry-Pi.

   The motor driver L-293D is a 16 pin IC which can supply a maximum current of 600mA and drive motors up to 36v and control two motors simultaneously. It works on the principle of H-bridge which is fabricated with 4 switches. The direction of the voltage can be determined by the orientation of connection between the switches.

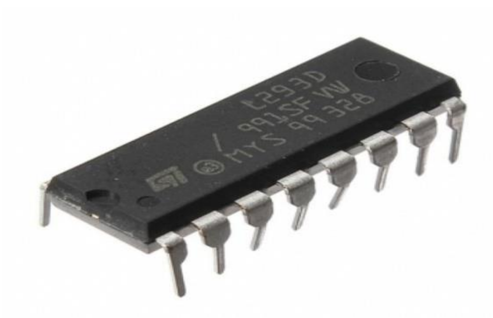


Fig.4 - ***L293D***

Chapter 4

EEG ELECTRODES

4.1 EEG

Electroencephalography (**EEG**) is an electrophysiological monitoring method to record electrical activity of the brain. EEG measures voltage fluctuations resulting from ionic current within the neurons of the brain. In clinical contexts, EEG refers to the recording of the brain's spontaneous electrical activity over a period of time, as recorded from multiple electrodes placed on the scalp. The electroencephalogram is a varying potential observed between two electrodes placed at two separate points on the scalp. Clinicians are interested in these signals for predicting disorders associated with the brain. Information which is useful for a clinician can be obtained by applying engineering techniques.

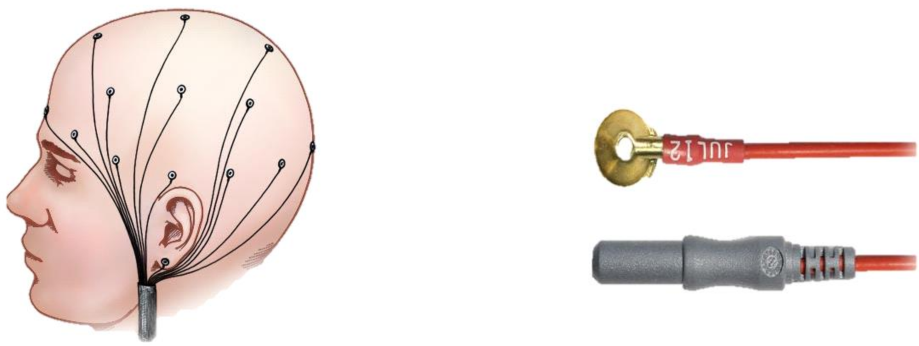


Fig. 5 – *EEG Electrodes*

EEG is used to diagnose epilepsy, which causes abnormalities in normal EEG readings. It is also used to diagnose sleep disorders, depth of anesthesia, coma, encephalopathy, and brain death. EEG is the method to diagnose of tumors, stroke and other focal brain disorders. Despite limited spatial resolution, EEG continues to be a valuable tool for research and diagnosis. It is one of the few mobile techniques available and offers millisecond-range temporal resolution which is not possible with CT, PET or MRI.

Similarly, simultaneous recordings with MEG and EEG have also been conducted, which has several advantages. EEG requires accurate information about certain aspects of the skull that can only be estimated, such as skull radius, and conductivities of various skull locations. It detects activity below the surface of the cortex very poorly, and like EEG, the level of error increases with the depth below the surface of the cortex one attempts to examine. It can receive signals from greater depth, albeit with a high degree of noise.

4.2 CORTICAL HOMUNCULUS

A cortical homunculus is a distorted representation of the human body, based on a neurological "map" of the areas and proportions of the brain dedicated to processing motor functions, or sensory functions, for different parts of the body. Homunculus is Latin for "little man", and was a term used in alchemy and folklore prior to the concept being utilized in scientific literature. A cortical homunculus, or "cortex man", illustrates the concept of a representation of the body lying within the brain**.**

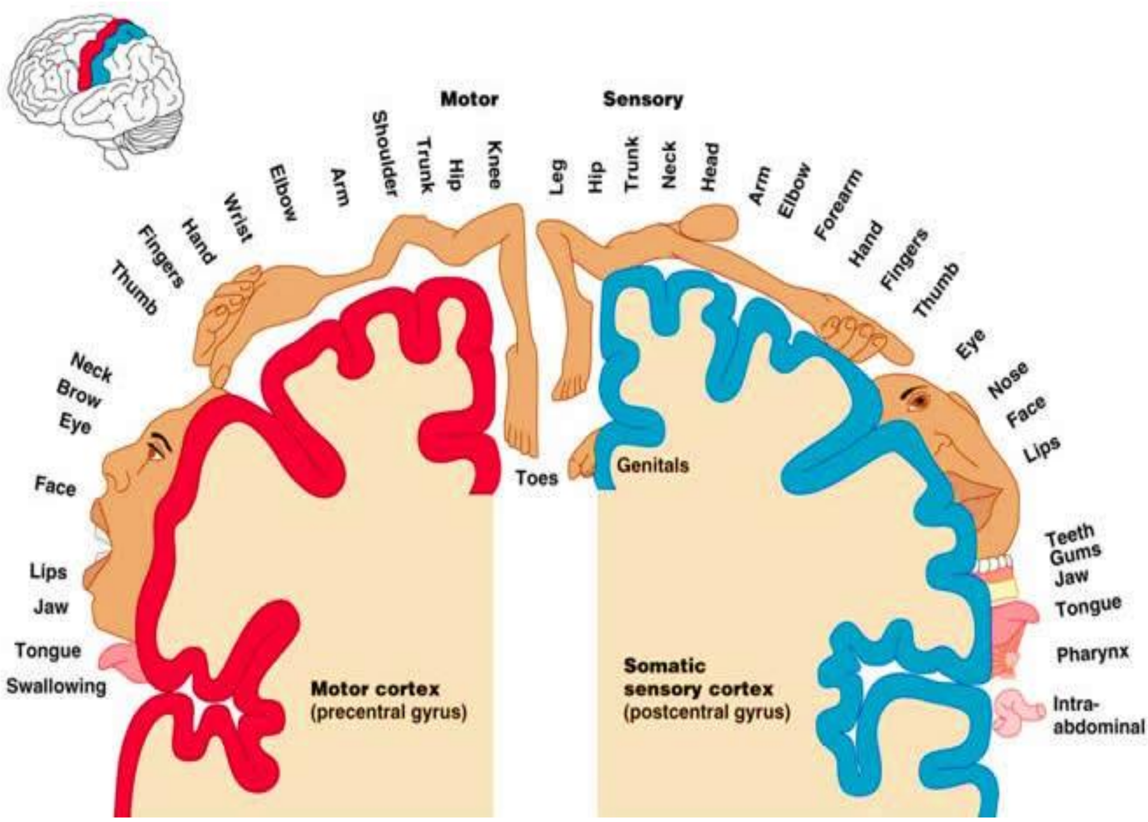


Fig. 6 – *Homunculus*

A ***motor homunculus*** represents a map of brain areas dedicated to motor processing for different anatomical divisions of the body. The primary motor cortex is located in the precentral gyrus, and handles signals coming from the premotor area of the frontal lobes.

A ***sensory homunculus*** represents a map of brain areas dedicated to sensory processing for different anatomical divisions of the body. The primary sensory cortex is located in the postcentral gyrus, and handles signals coming from the thalamus. These signals are transmitted from the gyro to the brain stem and spinal cord via corresponding nerves.

Hence, by considering all these important features of the brain and its activities the placement of the electrodes are decided to acquire the brain signals.

4.2 <u>THE 10-20 SYSTEM</u>

The **10–20 system or International 10–20 system** is an internationally recognized method to describe and apply the location of scalp electrodes in the context of an EEG test or experiment. This method was developed to ensure standardized reproducibility so that a subject's studies could be compared over time and subjects could be compared to each other. This system is based on the relationship between the location of an electrode and the underlying area of cerebral cortex. The "10" and "20" refer to the fact that the actual distances between adjacent electrodes are either 10% or 20% of the total front–back or right–left distance of the skull.

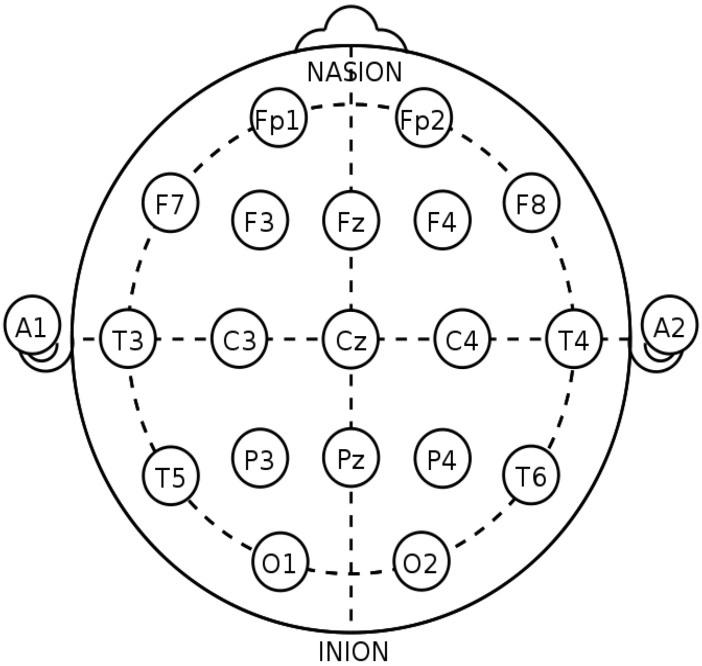


Fig. 7 – *Electrodes placement in a 10-20 system*

Each site has a letter to identify the lobe and a number to identify the hemisphere location. The letters F, T, C, P and O stand for frontal, temporal, central, parietal, and occipital lobes, respectively. (There exists no central lobe; the "C" letter is used only for identification purposes.) Even numbers (2,4,6,8) refer to electrode positions on the right hemisphere, whereas odd numbers (1,3,5,7) refer to those on the left hemisphere. A "z" (zero) refers to an electrode placed on the midline. In addition to these combinations, the letter codes A, Pg and Fp identify the earlobes, nasopharyngeal and frontal polar sites respectively.

Two anatomical landmarks are used for the essential positioning of the EEG electrodes: first, the nasion which is the distinctly depressed area between the eyes, just above the bridge of the nose; second, and the inion, which is the lowest point of the skull from the back of the head and is normally indicated by a prominent bump.

4.4 <u>AVAILABLITY OF ELECTRODES</u>

EEG systems use electrodes attached to the scalp to pick up electric potentials generated by the brain. Of course, you could just attach wires to the skin - however, this would create a very unstable electrical connection. Rather, opt for wet EEG electrodes. These are metal disks or pellets that connect with the skin via conductive gel, paste or cream, typically based on saline. The right combination of electrode metal and conductive paste is important as some metals corrode rather fast, resulting in poor data.

Under optimal conditions, the skin, the electrode and the electrode gel function as capacitor and attenuate the transmission of low frequencies. The most common wet electrode type is made of silver (Ag) with a thin layer of silver chloride (AgCl).

Alternatively, dry EEG electrodes can be used. These make direct contact with the skin without requiring electrode gel. Typically, dry electrodes are much faster to apply, at the same time are more prone to motion artifacts compared to wet sensors.

Fig.8 – ***Cap type EEG Electrode Set***

Fig.8A – ***EEG Electrode Headset***

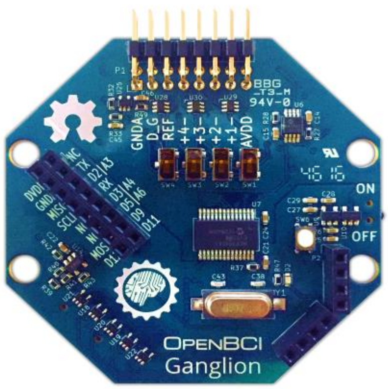


Fig.9 – ***OpenBCI-Ganglion Electrode***

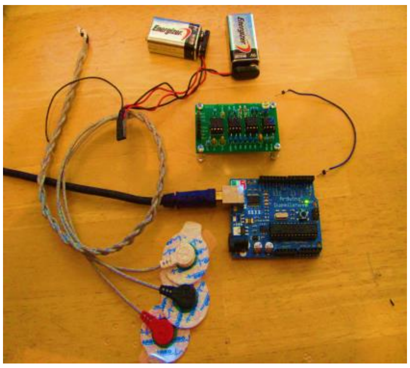


Fig.10 - ***A Simple EEG Electrode Set***

4.5 EMOTIV

Emotiv Systems is an Australian electronics innovation company developing technologies to evolve human computer interaction incorporating non-conscious cues into the human-computer dialog to emulate human to human interaction. Developing brain–computer interfaces based on electroencephalography (EEG) technology, Emotiv Systems produced the EPOC near headset, a peripheral targeting the gaming market for Windows, OS X and Linux platforms. The EPOC has 16 electrodes and was originally designed to work as a brain-computer interface (BCI) input device. The company was founded in Australia in 2003 by technology entrepreneurs Tan Le, Nam Do, Allan Snyder, and Neil Weste.

Fig.11 – ***EMOTIV Epoc Headset***

4.5.1. HEADSET

The figure below shows all the necessary kits/components that is required to activate or initialise the headset in order to acquire the brain signals of the user. The kit consists of:

a) EMOTIV EPOC Headset
b) Sensors
b) USB Receiver
c) Saline Solution

Fig.12 – ***EMOTIV EPOC Headset***

4.5.1.1 <u>EMOTIV EPOC HEADSET SETUP</u>

<u>Step 1</u> - Initial charging of headset.

Make sure the small switch on the rear underside of the headset is set to the "Off" position before starting. Plug the mini USB cable attached to the supplied battery charger into the slot at the top of the headset and to the USB port on your PC or the power cord into a 50 or 60 Hz 100-250 V electrical outlet.

The Lithium battery can be recharged to 100% capacity in approximately 4 hours depending on the initial state of charge. Charging for 30 minutes usually yields about a 10% increase in charge.

The EPOC Headset contains two status LEDs located at the rear and next to the power switch at the back of the headband. When the power switch is set to the "on" position, the rear LED will illuminate and appear blue if there is sufficient charge for correct operation, unless charging is in progress.

The charging LED will appear red during battery charging; when the battery is fully- charged, the charging LED will display green.

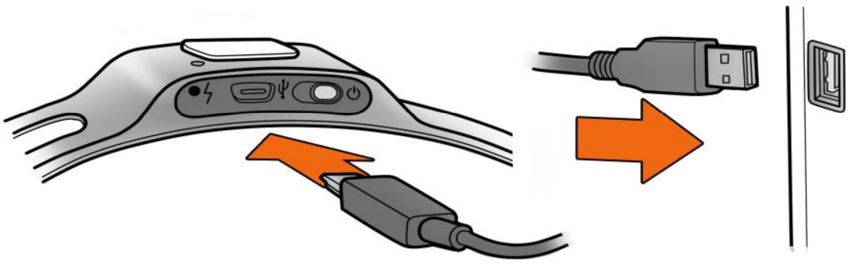


Fig.13 – *Charging of the Headset*

<u>Step 2</u> - Hydrating the Sensors

The saline solution is used to saturate the large white hydrator pad attached to the top cover of the hydrator. This is used to maintain the moisture of the felt pads when they are not in use. Hydration of the sensors are done in order to achieve a good quality contact with the user's brain in to obtain the EEG signals. The hydrated sensors are then put upon the Emotiv Headset.

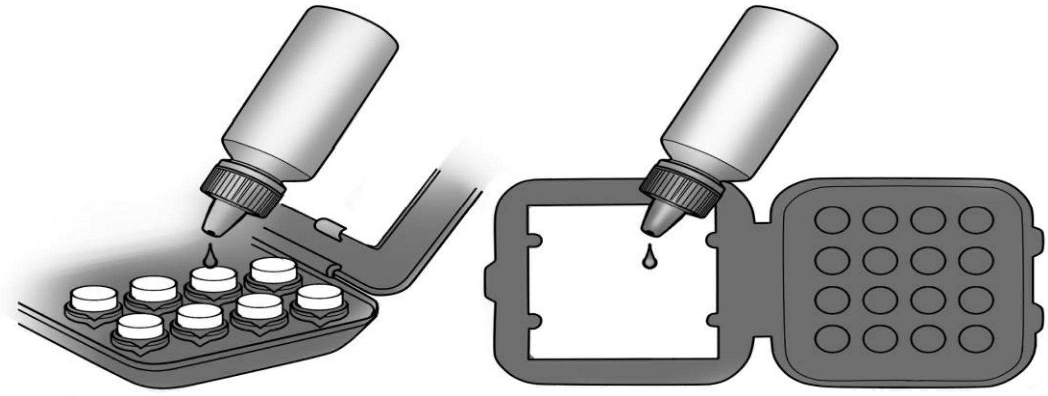


Fig.14 – ***Hydration of Sensors***

Step 3 - Sensor Assembly

After the wetting the sensors using the saline solution the sensor units are inserted into the into the black plastic headset arms, turning each one clockwise direction thus hearing a “click or a locking sound” which indicates that the sensors are inserted perfectly into the headset arm.

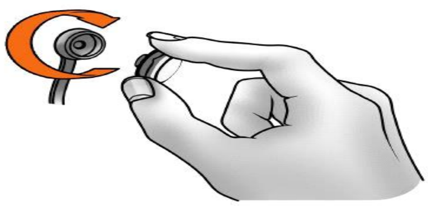


Fig.15 – ***Inserting sensors to headset arm***

Step 4 - Pairing the Neuroheadset

Insert the USB Transceiver Dongle into the computer's USB slots. Use a USB extension cable and position the Transceiver in a prominent location away from the monitor and PC to improve poor reception. The headset is turned on using the switch at the bottom end of the headset, holding it close to the Transceiver.

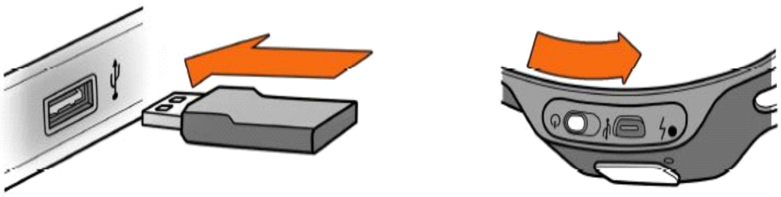


Fig.16 – ***Pairing of Headset***

<u>Step 5</u> - Headset Placement

Once the headset is in position, press and hold the 2 reference sensors (located just above and behind the ears) for about 5-10 seconds. Good contact of reference sensors is the key for a good signal. Hence, the lights corresponding to these 2 reference sensors turn from red to green in the EPOC Control Panel Headset Setup screen.

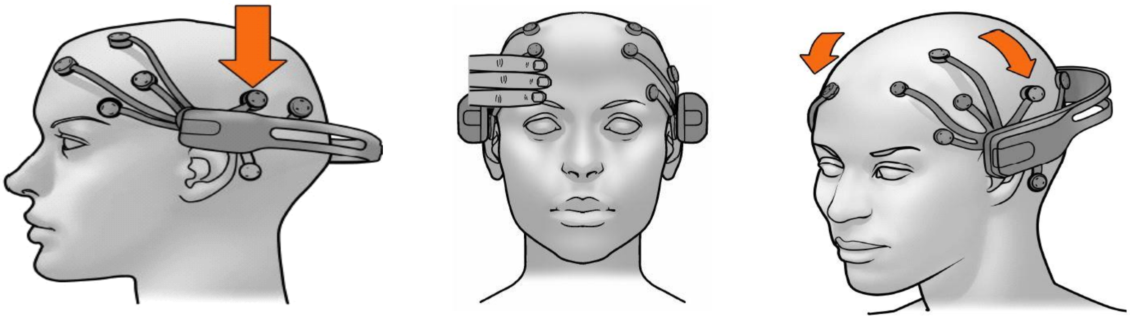


Fig.13 – *Placement of the Headset*

4.5.2 <u>XAVIER CONTROL PANEL</u>

The Xavier Control Panel is an open source SDK developed by the EMOTIV Inc. which helps to give an interactive environment for the user, controlled by the EMOTIV EPOC headset. The control panel is connected to the headset through the USB transceiver. The following features are included in the interface:

- The contact quality of the electrodes with the scalp can be determined once the USB transceiver is connected to the headset.

Fig. 14 – *Good Contact Quality of Electrodes*

- The above figure shows contact quality of 14 electrodes to capture EEG data and 2 electrodes as reference electrodes. The EEG data is captured by the electrodes only after reference electrodes are in proper contact with the scalp.

- The contact quality is indicated by colours as follows:

Fig. 15 – ***Contact Quality Indicator***

4.5.2.1 <u>MENTAL COMMANDS</u>

The Xavier Control helps to train and detect mental commands and help to test the same using an interactive environment.

The list of actions that can be trained are: 1. PUSH
2.PULL
3.LEFT
4.RIGHT
5.ROTATE CLOCKWISE
6.ROTATE ANTI-CLOCKWISE
7.LIFT&DROP
8.NEUTRAL

I. Training

The mental command NEUTRAL has to be trained in beginning to unlock all the other actions .Each of the action can be trained for 8 seconds. The responsiveness of the mental commands depends on the skill rating. The Skill rating increases every time the action is trained, that is, each time the action is trained, the accuracy of the action being retrieved increases.

II. Action

Once the mental commands are trained, the SDK can be put in ACTION mode and the block starts to move in the direction the user thinks in, that is, when the user thinks to push the block, the block gets pushed inward.

4.5.2.2 FACIAL COMMANDS

The Xavier control panel also helps to detect the facial commands of the person wearing the headset.

The facial commands that can be detected are: 1.BLINK
2.LEFT WINK
3.RIGHT WINK
4.SMILE
5.RAISED EYEBROWS
6.FROWN
7.LAUGH

4.5.3 POWER VALUES OF FACIAL & MENTAL COMMANDS

The EMOTIV EPOC provides an API (Application Program Interface) which gives a library of functions which can be used to determine the facial, mental commands along with the intensity of the thought which is defined as ***Power*** which is in the range of 0 and 1.

The power values for the mental commands gives the information about how intense the thought is being made by the user , that is, a power value tending to 1 determines that the person is thinking about the trained thought intensively and vice-versa. The power values of the facial commands determine the degree of movements for the facial expressions. An example is the turning of head towards left or right that is the power will tend close to 1 if the user turns the head to the extreme position in either direction and becomes 0 when the user looks straight.

The facial commands can be divided as: **Upper face action**: Surprise, Frown
Eye related action: Blink, wink right/left
Lower face action: Smile, Clench, Laugh

The EMOTIV EPOC headset determines the facial command and is send across to the USB transceiver as an ASCII character. The list of various ASCII characters for various facial commands are:

FACIAL EXPRESSION	ASCII CHARACTER
1. BLINK	B
2. WINK LEFT	I
3. WINK RIGHT	r
4. SURPRISE	b
5. FROWN	F
6. SMILE	S
7. CLENCH	G

The facial expression BLINK, WINK LEFT and WINK RIGHT will always have a power value of 1 during their respective events as it can be defined by only a single degree of movement. The below graph shows the **number of blinks** the user has made in a period of time and it also indicates that it has taken amplitude values of either 0 or 1.

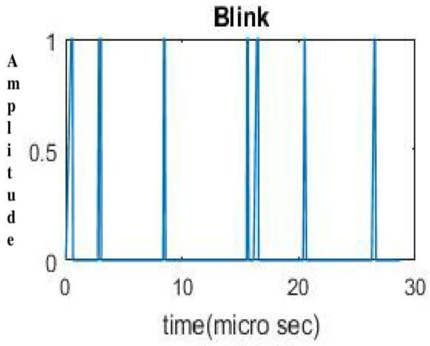


Fig. 18

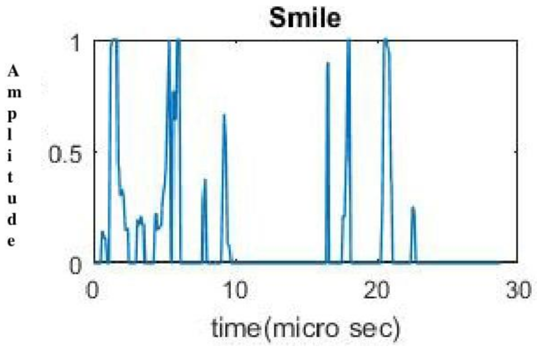


Fig. 19

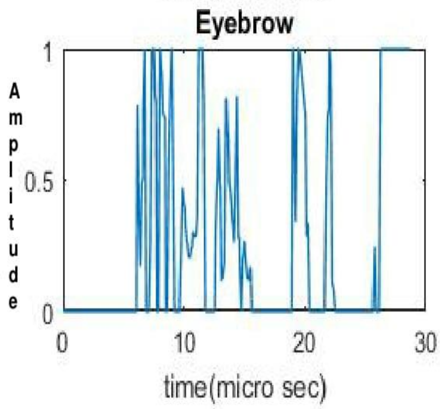


Fig. 20

The facial commands that are sent from the head set will have the ASCII character determining the facial expression and the power values. **S50** is an example of data that is sent from the head set and it defines that the facial expression of the user is smile and has a power value of 0.5.

The mental command specific events are declared and can be trained until the desired skill rating is obtained. The trained commands can be stored in the user profile that is created by the user .The headset makes the trained data as a reference and return the command user thinks in real time. The snippet below shows real time thought of commands PUSH and NEUTRAL that were initially trained by the user.

Fig. 21

4.5.4 ACCESSING MENTAL COMMANDS

4.5.4.1 EMOTIV API

The EMOTIV API is an ASCI C type interface which defines functions that lets user to extract mental commands. The functions are defines within 3 header file namely:

1.iedk.h
2.iEmoStateDLL.h
3.iedkErrorCode.h

The EmoEngine is the abstraction of various functionalities that are provided by the EMOTIV. The API functions that control the EmoEngine settings are:

EmoEngine Events	Description
IEE_UserAdded	New user is registered with EmoEngine
IEE_UserRemoved	User is removed from EmoEngine
IEE_EmoStateUpdated	Detects any updation in EmoEngine
IEE_ProfileEvent	Gives profile of the user
IEE_MentalCommandEvent	Detects a new mental command type
IEE_FacialExpressionEvent	Detects a new facial event type
IEE_InternalStateChanged	Used by Emotiv Control Panel during a modification made to EmoEngine through API
IEE_EmulateError	Internal error to EmoEngine

The mental command detection requires a training process. The recognition of mental command depends on the training of commands by the user. A user can train up to 4 mental commands at a time.

The **IEE_MentalCommandSetTrainingAction(MentalCommand)** will set the training action for the 'MentalCommand' that has to be trained. The training of the mental command starts with calling the **IEE_MentalCommandGetTrainingAction().** Once the training starts, the user should imagine the corresponding command until the training is over,which last for 8 seconds.

The training result can be either accepted or rejected by the user using the commands: **IEE_MentalCommandSetTrainingControl(MC_ACCEPT)** or **IEE_MentalCommandSetTrainingControl(MC_REJECT).**

Once the training process is completed, the user can update the EmoState such that it starts giving the mental command and power. The current EmoState is returned using the **IS_MentalCommandGetCurrentAction()** and the corresponding power is given by **IS_MentalCommandGetCurrentActionPower().**

4.5.4.2 EXTRACTING MENTAL COMMANDS

The mental commands can be extracted using the following steps:

Step1: The mental commands that are to be extracted should be transferred to a microcontroller such that the commands can be used to control the prototype.

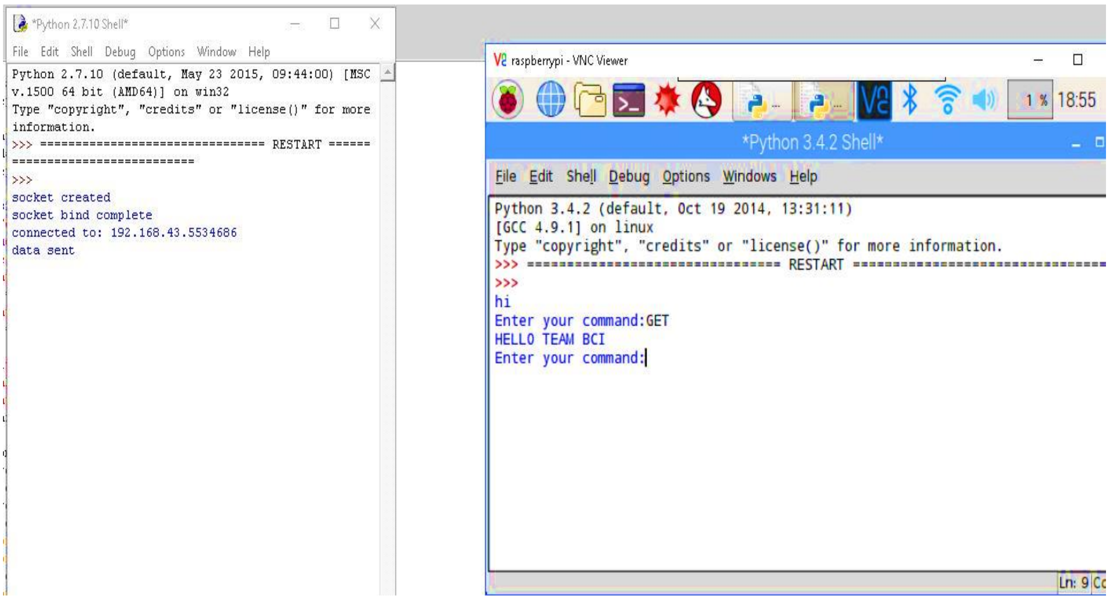


Fig. 22 - ***Socket connection between Windows PC and Raspberry pi***

Hence, the two devices (Computer & Raspberry Pi) which are connected to the same Wi-Fi can share the data using the socket transfer.

Step 2: Once the communication is established between the Raspberry pi and Personal computer, the user should connect the EMOTIV head set to the USB transceiver connected to the PC. The user can connect to the EMOTIV head set using the **IEE_EngineConnect("EmotivID")** function which returns a value 0 when connected.

Step 3: As mentioned above, the extraction process include the training phase that the user has to undergo. The training data can be stored in the profile that has to be created by the user. Once the profile is created, the user can use the **EC_Login(userName**, p**assword)** to login to the profile. If the function call returns a 0, the user is successfully logged in.

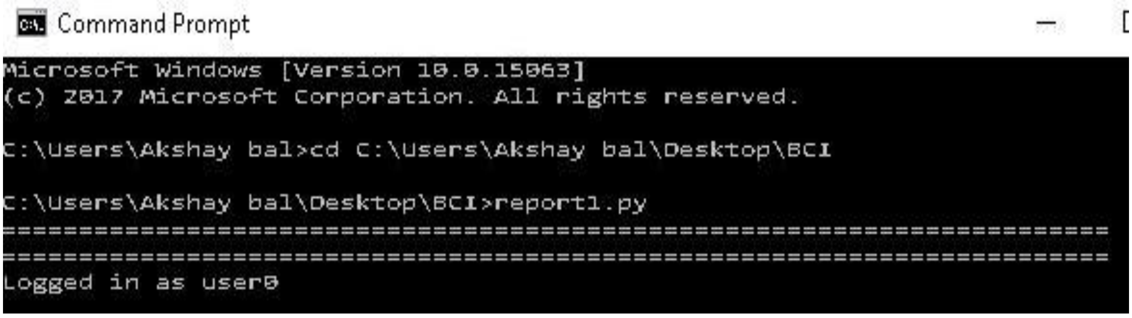


Fig. 23

Step 4: When the user is logged in to the cloud profile, the user can set or initialize the actions that has to be trained. Only those mental commands that are defined by the EMOTIV can be trained. The **IEE_MentalCommandSetActiveActions()** can initialize the mental commands ,which are given as a parameter in the function

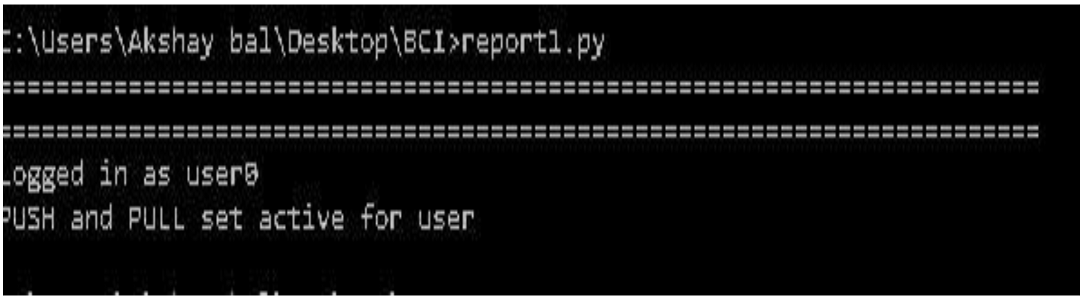


Fig. 24

Step 5: The training of commands require the initialising of the action that has to be trained. The training action is set using the **IEE_MentalCommandSetTrainingAction()** function which takes the command to be trained as it's parameter. Once the training action is set, the training can be started using the **IEE_MentalCommandGetTrainingAction()** function.

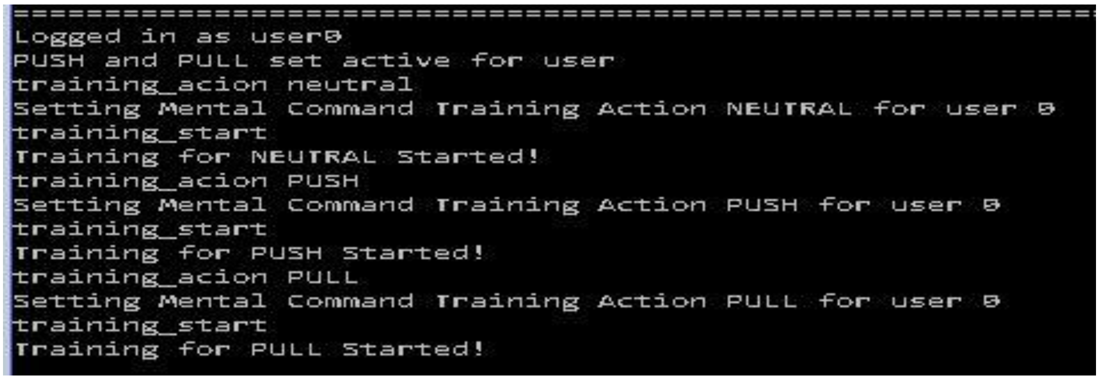


Fig. 25

Step 6: Once the commands are trained, the user can analyse the real time thoughts by calling the **IS_MentalCommandGetCurrentAction().** The data that are trained will match with thoughts of the user once the user starts imagining the trained commands.

The intensity level of the thought can be extracted using the **IS_MentalCommandGetCurrentActionPower()** function. The power will always be a value between 0 &1.

The mental command will be transferred to the raspberry pi module over the Wi-Fi were the controller act as the client and the host PC which receives the mental command from the head set act as the Server.

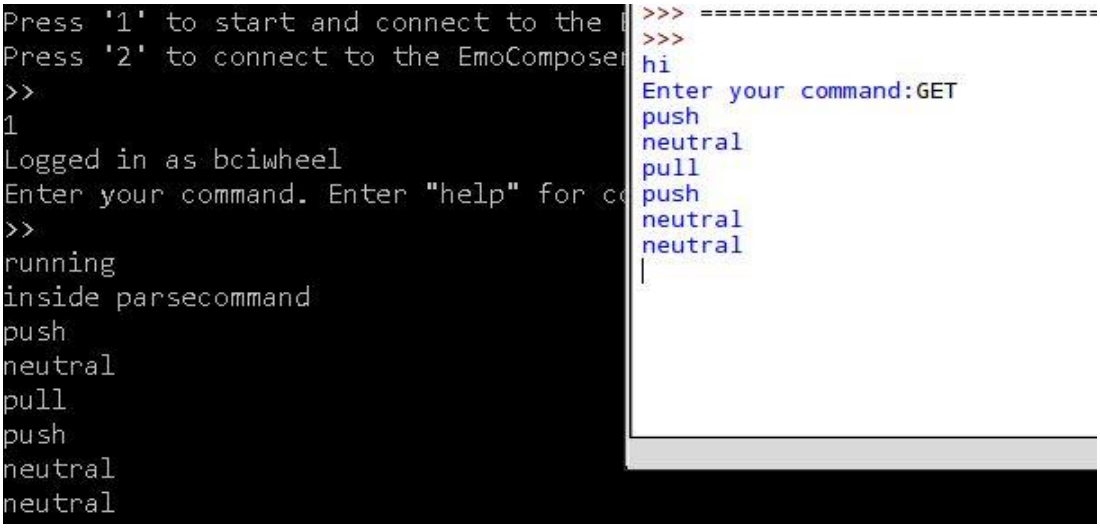


Fig. 26 - ***Transfer of Mental commands from Server to Client***

Chapter 5

MICROCONTROLLER UNIT

A controller is basically a miniature computer on a chip or a system-on-chip. It acts as a medium to send data between two devices or even take some data as input, process it and store it for future use.

The architecture of a controller consists of one or more central processing units (CPUs), input/output peripherals that can be programmed and memory.

Controllers are widely used in different embedded system applications. It can be programmed to give a desired output and these outputs can be viewed using the components interfaced to the controller. In the controller's input state, it is best suited to read various signals from devices and in the output state it can pass signals to devices interfaced to it such as LED, LCD display, motors, etc).Use of Controllers are usually preferred over the use of processors because processors have only a CPU on them. Memory such as RAM or ROM has to be externally interfaced to it by the user if needed and it is also limited to specific tasks. The controller's system-on-chip design makes it more suitable for use in different complex applications.

The different controllers that we come across are listed below:

I. Atmel ATMega169
II. Nios 16-bit
III. MCS-51 8051
IV. ARM CortexM3
V. Aurdino
VI. Raspberry Pi

5.1 RASPBERRY PI 3B

5.1.1 INTRODUCTION TO RASPBERRY PI 3B

Raspberry Pi, a card sized controller, was developed by Eben Upton and developed by Raspberry Pi foundation. The word 'Raspberry' was based on companies whose names were based on fruits like Apple, Apricot computers etc. While 'Pi' was used since this controller was like a small computer based on the programming language Python. The low cost of the Pi and its easy accessibility makes it much more popular. It allows the user to handle both hardware and software. It consists of a processor, RAM and hardware ports. In general the Pi consists of a Broadcom system-on-chip, an ARM compatible CPU and a Video core IV on-chip graphics processing unit. SD cards are used to store pi's operating system (OS). It also consists of GPIO pins, an audio jack (3.5 mm) and USB ports.

Thus, all the above mentioned features of the Raspberry Pi, makes it the best suitable controller in our project.

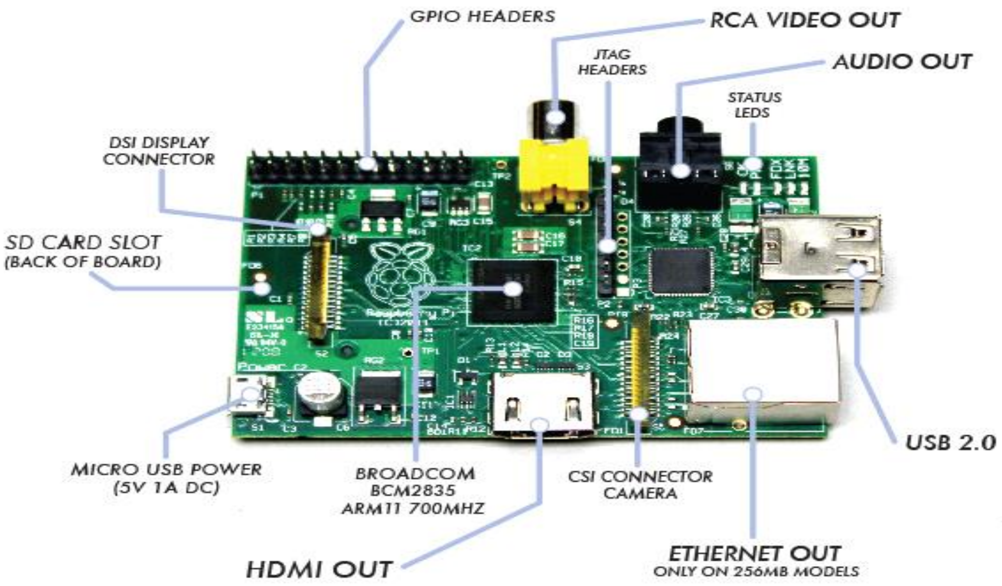


Fig. 27 - ***Labelled diagram of the Raspberry pi module***

5.1.2 <u>RASPBERRY PI 3B MODULE</u>

For our project, we are using the Raspberry Pi 3B module. It consists of 64-bit quad core ARM Cortex A53 with a clock frequency of 1.2 GHz. This version of the Pi has an inbuilt 802.11N wi-fi and Bluetooth 4.0. wi-fi making it the best choice of Raspberry Pi version required for us, since our project deals with a lot of wireless communication and wireless data transfer. Also, the Pi3 is 50 percent faster than the previous model. The Pi (be it any module) comes with a pi cam as well, which helps to capture videos and pictures.

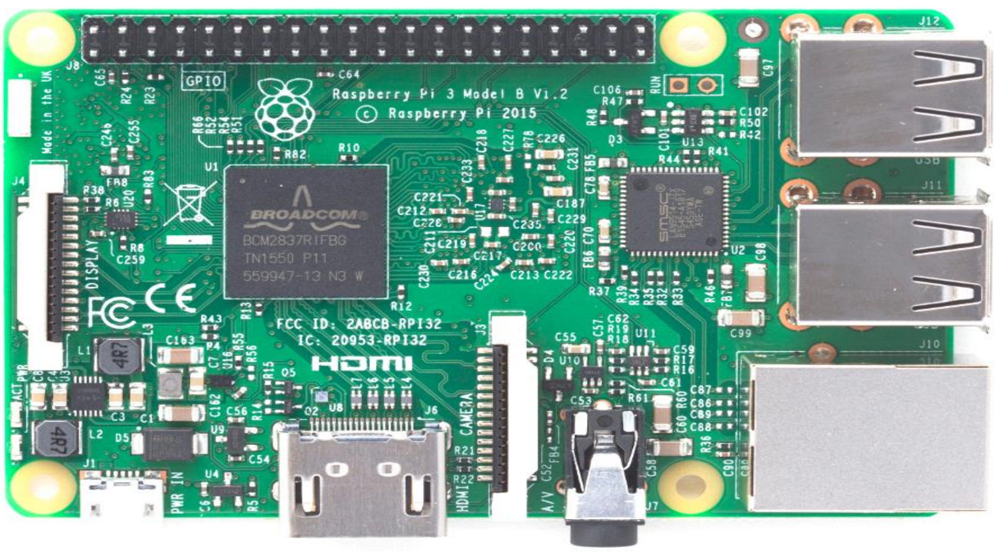


Fig. 28 – ***Raspberry Pi 3B Module***

5.1.3 SPECIFICATIONS OF RASPBERRY PI 3B MODULE

The table below shows some of the specifications of the Raspberry Pi 3B module.

FEATURES OF RASPBERRY PI 3B	DESCRIPTION
PROCESSOR SPECIFICATION	It consists of a Broadcom (BCM2837) processor. The BCM2837 is a full HD encode/decode DualCore VideoCoreIV multimedia co-processor
CPU CORE	The CPU core used in this module is Quadcore ARM cortex 64 bit.
CLOCK SPEED	1.2 GHz (50 percent faster than Raspberry Pi 2)
RANDOM ACCESS MEMORY(RAM)	This module consists of 1 GB RAM.
GPU	400 MHz Videocore is a low power mobile multimedia processor. It has a two-dimensional DSP architecture making it efficient enough to decode and encode many multimedia codecs in software.
NETWORK CONNECTIVITY	1x10/100 ethernet (RJ45) port
WIRELESS CONNECTIVITY	It consists of an 802.11n wireless LAN (Wi-Fi) and Bluetooth 4.1.
USB PORTS	It has 4 USB 2.0 ports.
GPIO HEADER PINS	There are a total of 40 general purpose input/output pins that can be configured according to the use by referring to its data sheet.
CAMERA INTERFACE	It has a 15 pin MIPI
DISPLAY INTERFACE	DSI 15 pin/ HDMI out/ Composite RCA
CURRENT CAPACITY	It can hold a current capacity of maximum 2.5 Amperes.

5.1.4 SETTING UP THE RASPBERRY PI 3B MODULE

1) First power up the pi by using an adapter or by plugging into the USB port of the PC.

2) Load the Raspbian OS (Jessie) into the SD card and insert the SD card into the SD card slot of the Pi.

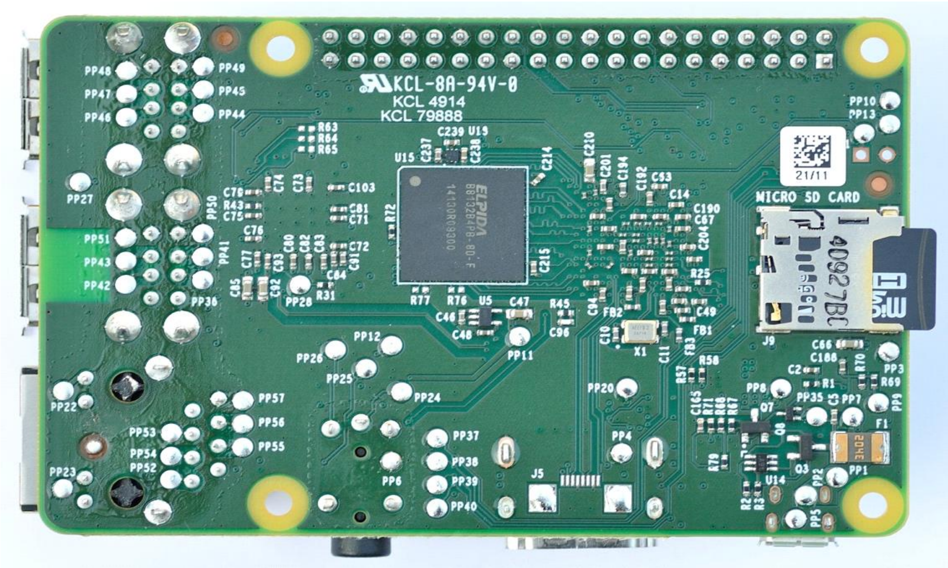


Fig. 29 – ***Shows the SD card inserted into the SD Card slot of the Pi***

3) The raspberry Pi can be connected to the desktop or laptop using an HDMI cable.

4) Other system users can also connect to the same pi by using software such as VNC viewer or Xming server if desired to work at the same time.

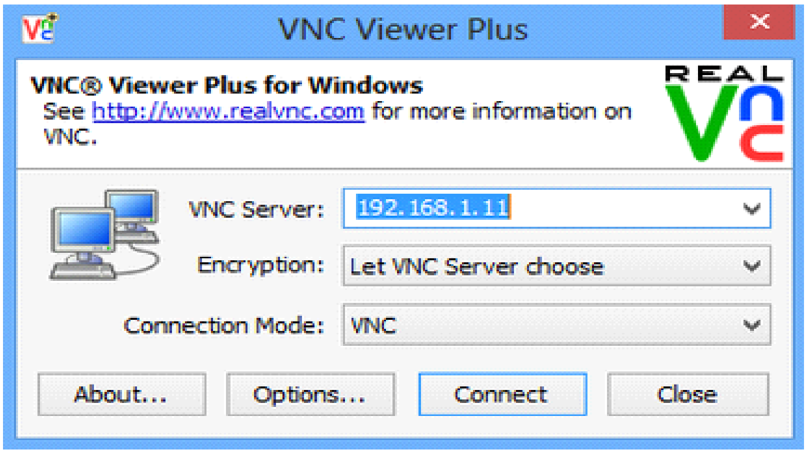


Fig. 30 - ***VNC Viewer***

5) When the Pi boots up, ***raspi-config*** will be shown on the screen.

6) To open the configuration tool, we need to type the command:
sudo raspi-config - Here *sudo* is used because, many changes will be made to the files by the pi user.

7) The default **username** will be *pi* and **password** will be *raspberry.*

8) After doing the above steps, the user can finally see the raspberry pi screen.

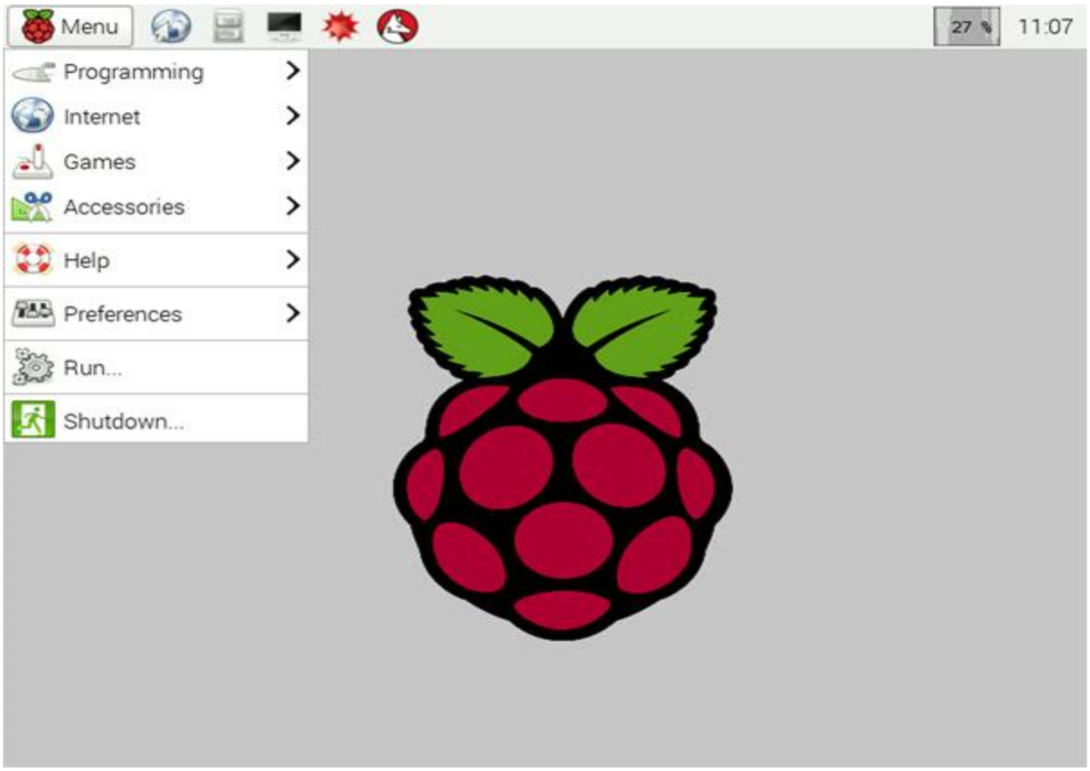


Fig. 31 - ***Pi screen that appears after the Pi boots up***

5.2 SOCKET COMMUNICATION

Sockets allow communication between two processes on the same or different machines. It uses the standard UNIX file descriptors. Sockets are mainly used in client-server platforms. The client usually requests the server for some task to be performed. The different types of sockets are:

a) Stream Sockets
b) Datagram Sockets
c) Sequenced Packet Sockets
d) Raw Sockets

IP address or internet protocol address is a 32 bit address represented as four 8 bit numbers. It is used to identify the hosts connected to the internet and plays an integral part in socket communication.

Without the address, the server and client cannot be connected together. Also, we have to provide access to a free and established port of our PC during socket communication.

In this project, the Raspberry Pi acts as the **client** and the Emotiv Epoc Headset acts as the **server**. When the Emotiv headset is connected, a socket is created. Once the Emotiv(server) starts giving the mental commands the raspberry Pi(client) requests the Emotiv headset for those mental commands which can be accessed on the pi screen by typing a certain command according to program.

The server program has been explained under the Emotiv headset. In this section the client portion of the socket communication will be explained.

Given below is the process / steps to make a client:

Step 1: A socket is created with the help of socket() system call.

Step 2: The socket is the connected to the address of the server using connect() system call.

Step 3: Data is read and written using read() and write() system calls.

The IPv4 address (AF_INET family) of the host is defined in the client program which creates a socket using socket.socket(socket.AF_INET,socket.SOCK_STREAM) which forms a socket for communication.Socket creation is succeeded by socket connection using the s.connect((host,port)). Here:

a.” s” is the socket that is initialized.

b.” host” carries the IP address of the host.

b. ”port” defines the port 5560 which helps to establish TCP connection.

The host is made available for any of the client in the same network to connect to it.

s.bind() and data.receive() function helps to connect to the client and receive the commands which is further decoded. Real-time data could then be transferred from the host to the client which could further be extended to send the mental commands data between the Emotiv headset and Raspberry Pi.

5.2.1 FLOW CHART OF SOCKET COMMUNICATION

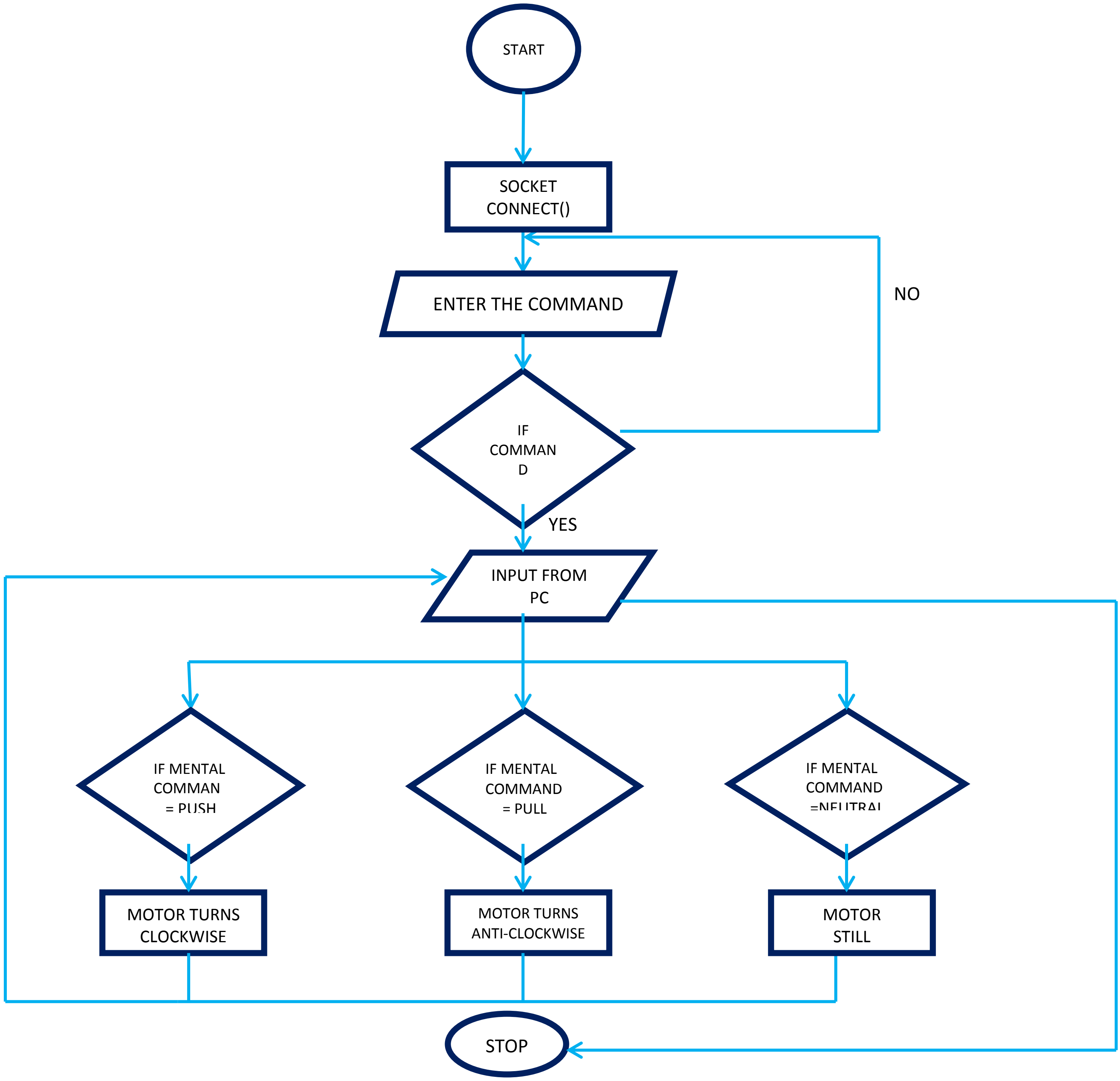


Fig. 32

Chapter 6

PROTOTYPE DESCRIPTION

6.1 L293D MOTOR DRIVER

The L293D motor driver is a device that is commonly used for Embedded Application and interfacing. The L293D is a Dual Full Bridge driver that can drive up to 1Amp per bridge with supply voltage up to 24V. It can drive two DC motors, relays, solenoids, etc. The device is TTL compatible and has Two H Bridges that can be connected in parallel to increase its current capacity to 2 Amp.

The motor driver L-293D is a 16 pin IC which can supply a maximum current of 600mA and drive motors up to 36v and control two motors simultaneously. It works on the principle of H-bridge which is fabricated with 4 switches. The direction of the voltage can be determined by the orientation of connection between the switches.

6.1.1 L293D IC

The driver IC L293D is quad push-pull drivers capable of delivering output currents to 1A per channel respectively. Each the channel is controlled by a TTL-compatible logic input. The L-293D IC consist of 2 H-bridges, one for each motor. A connection between switch S1 and S4 makes the motor to run in clockwise direction and a connection between S2 and S3 makes the motor to run in the counter clockwise direction.

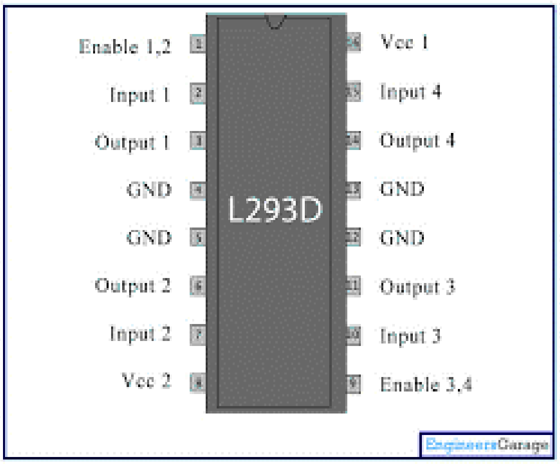


Fig. 33 – ***Pin Configuration of L293D***

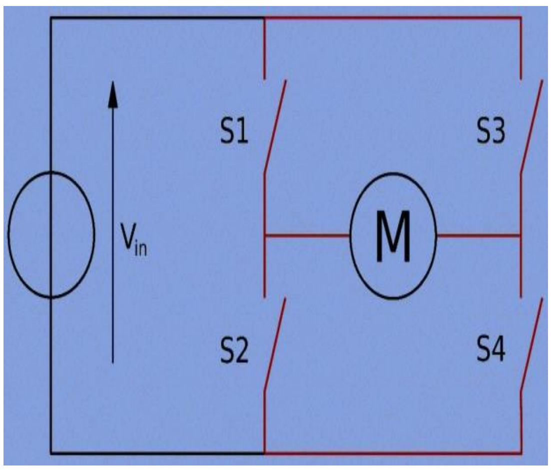


Fig. 34 – ***H Bridge Diagram***

6.1.2 DESIGNED L293D MOTOR DRIVER

The figure below shows the designed motor driver using L293D IC that is fabricated on a Printed Circuit Board (PCB). This motor driver is interfaced to the Raspberry Pi where the DC motor control program is initiated to run the motors in both clockwise and counter-clockwise direction.

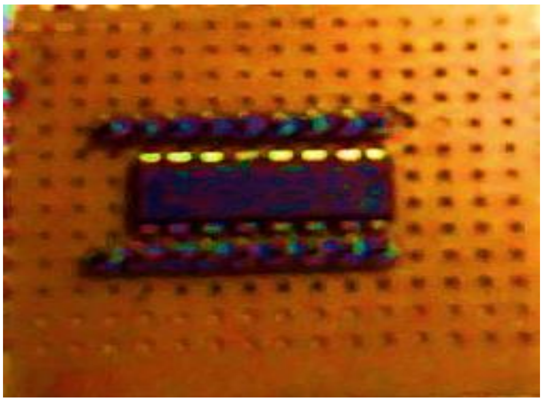


Fig. 35 – *Designed L293D DC Motor Controller*

6.1.3 CONNECTION METHODS

The diagram below shows the method in which the connections from the L293D motor controller are made as per our requirement for the control of the prototype.

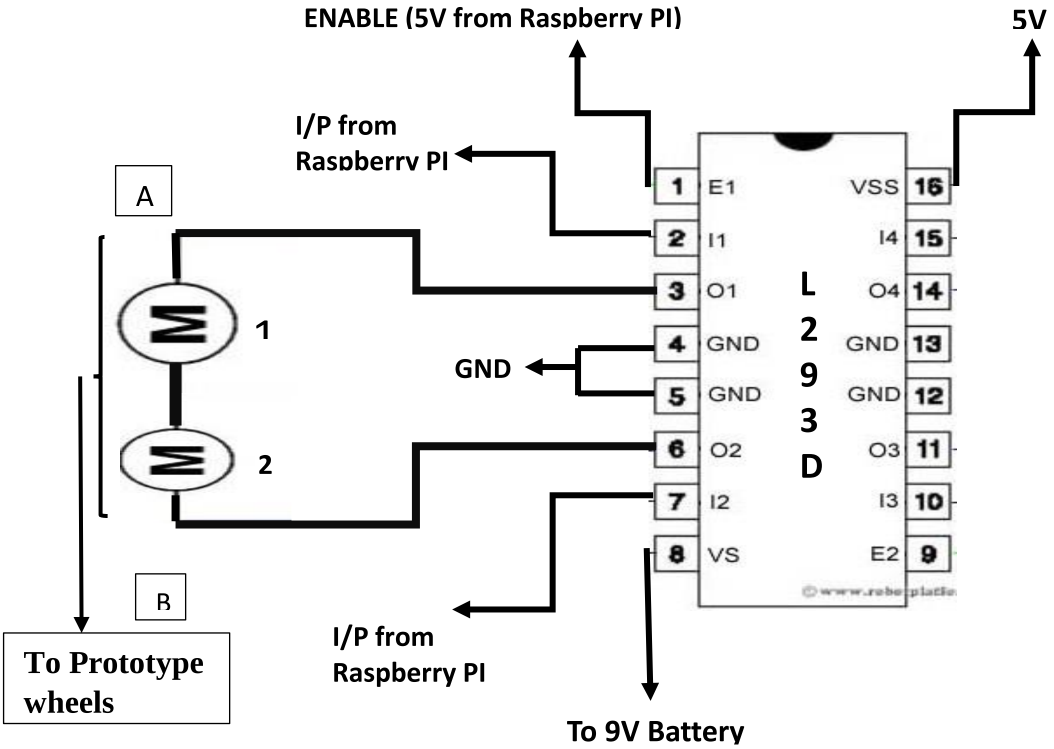


Fig. 36 – Construction of Motor Driver

6.1.4 WORKING

Initially, motor controller's ENABLE pin E1 is given with logic 1 (high) which is powered from the Raspberry Pi which gives a maximum output voltage of 5 volts.

Further, pin 2 and pin 7 are used to receive input 1 and input 2 respectively from the Raspberry Pi GPIO pins wherein the DC Motor Control program is fed to the motor controller to run the DC motor connected to the prototype. The program is used to control the prototype in such a way that two different actions namely "push" and "pull" takes place when the user thinks upon.

Pin 4 and Pin 5 is shorted appropriately in order to achieve necessary grounding for the circuit. The "ground pin" from the motor controller is connected to the Raspberry Pi's grounding terminal.

Pin 8 (VS Pin) is used to power up the motor controller. The motor controller can be powered up by using an external 9V battery. A VSS of maximum 5V is also provided by the Raspberry Pi to Pin 16 of the motor controller. This is done to enable all the pins of the motor controller.

Here, the two motors M1 and M2 are connected in series to Pin 3 and Pin 6 (output 1 and output 2 respectively) such that the power generated by the motor controller is supplied conveniently to the DC motors for their functioning. Hence, equal power is supplied to both the DC Motors and thus achieving equal RPM (Rotations per Minute).

Finally, the DC Motors are connected for the functioning of the prototype.

6.2 DC MOTOR

A DC motor is electromechanical device that converts electrical energy into mechanical energy that can be used to do many useful works. It can produce mechanical movement and has specific ratings ranging from 6V to 12V. When the DC motor is connected with power supply the shaft rotates in both clockwise and counter-clockwise direction depending upon the polarity of input power supply.

Referring to the above diagram, the positions A and B defines the placement of the wheels where active high and low signals are given as follows:

MENTAL COMMANDS	A	B
CLOCKWISE (PUSH)	HIGH	LOW
ANTI-CLOCKWISE (PULL)	LOW	HIGH
STOP (NEUTRAL)	LOW	LOW

Chapter 7

RESULTS

The output results so obtained are satisfying the above objectives of this project and they are follows:

1) Extraction of EEG signals using electrodes.

Fig. 37

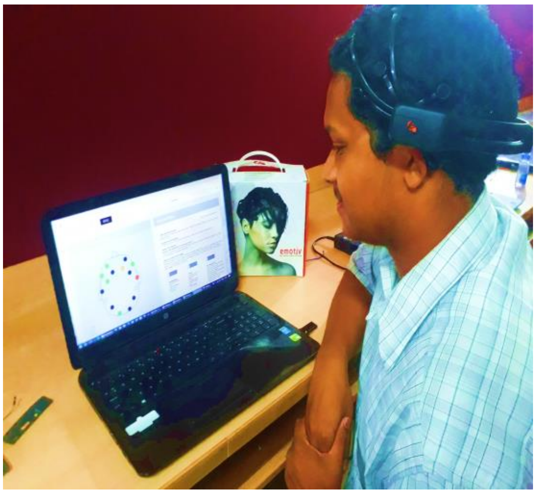
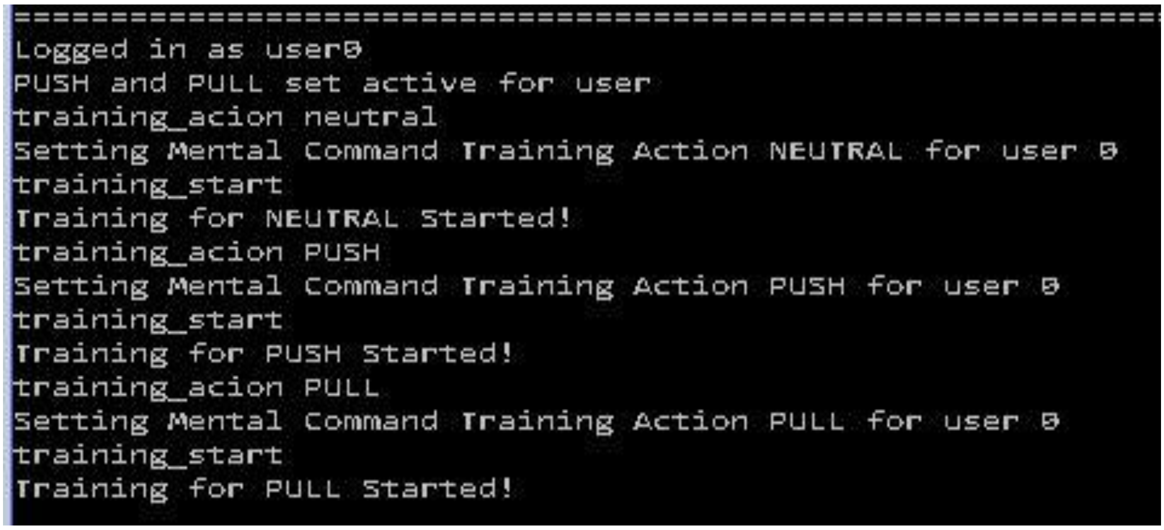


Fig.38

2) Using the Emotiv libraries to get meaning full data from EEG signals.



```
==============================================================
Logged in as user0
PUSH and PULL set active for user
training_acion neutral
Setting Mental Command Training Action NEUTRAL for user 0
training_start
Training for NEUTRAL Started!
training_acion PUSH
Setting Mental Command Training Action PUSH for user 0
training_start
Training for PUSH Started!
training_acion PULL
Setting Mental Command Training Action PULL for user 0
training_start
Training for PULL Started!
```

Fig. 39

3) Transferring the data to microcontroller over internet.

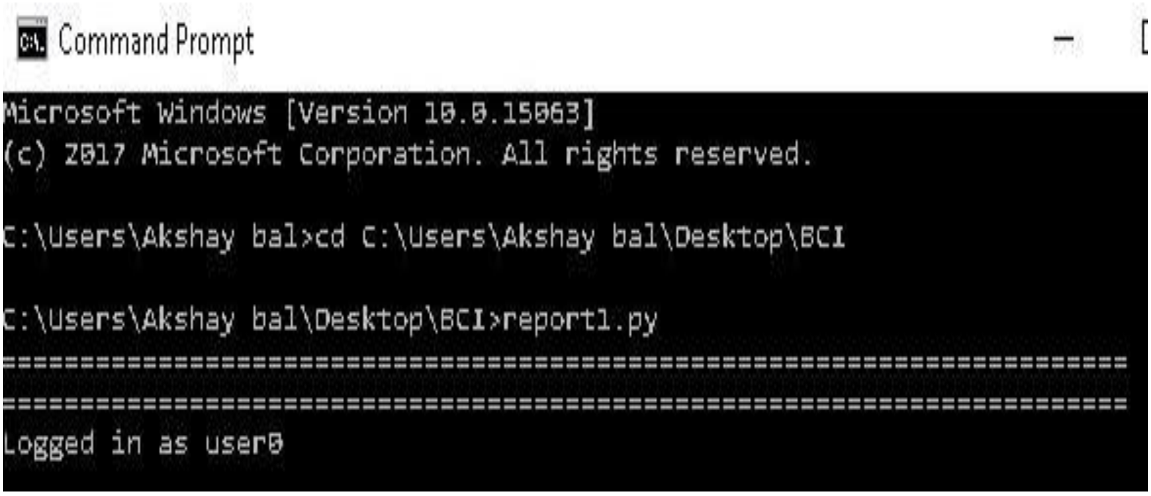


Fig. 40

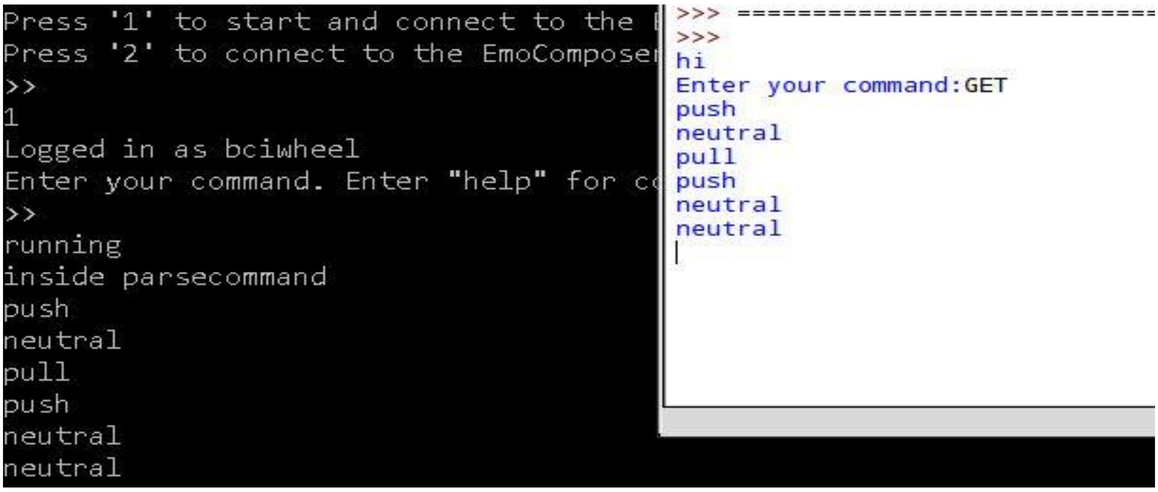


Fig. 41 – ***Raspberry Pi output window***

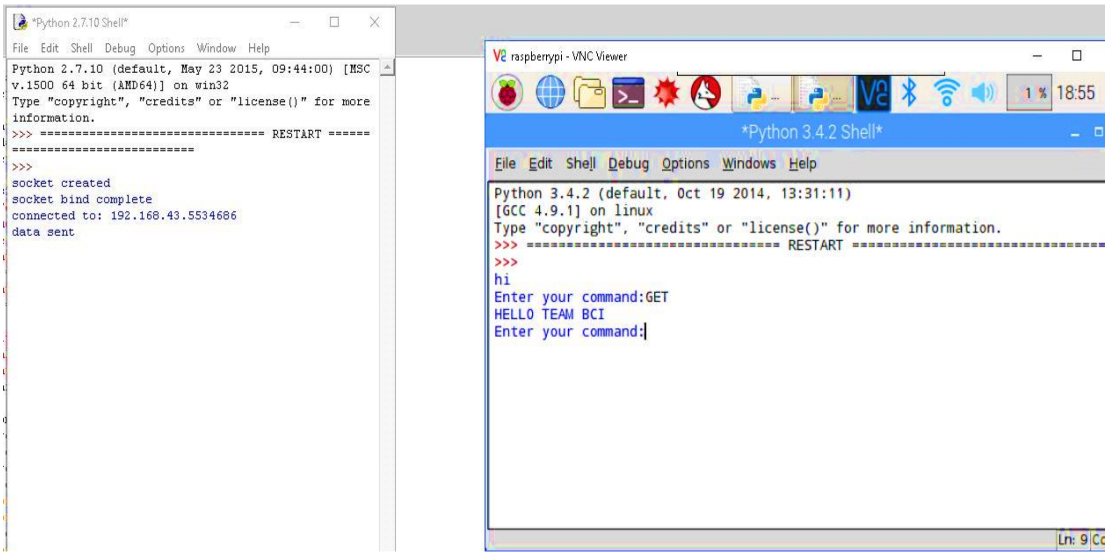


Fig. 42 – ***Raspberry Pi output window***

4) Controlling the prototype using the microcontroller unit.

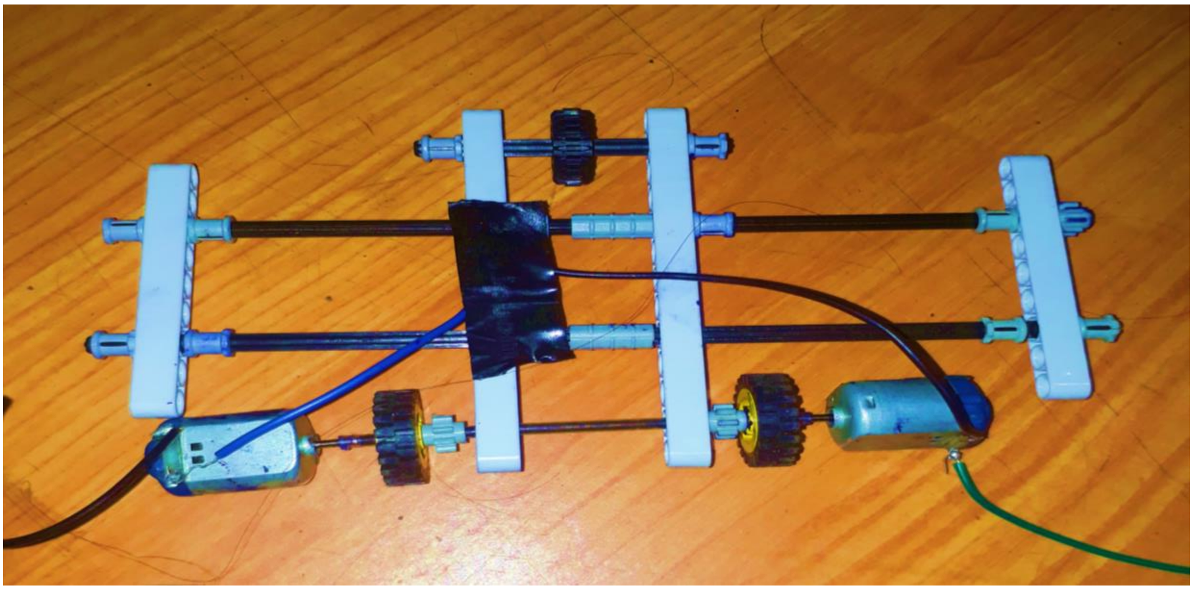


Fig. 43

THE FINAL PROTOTYPE

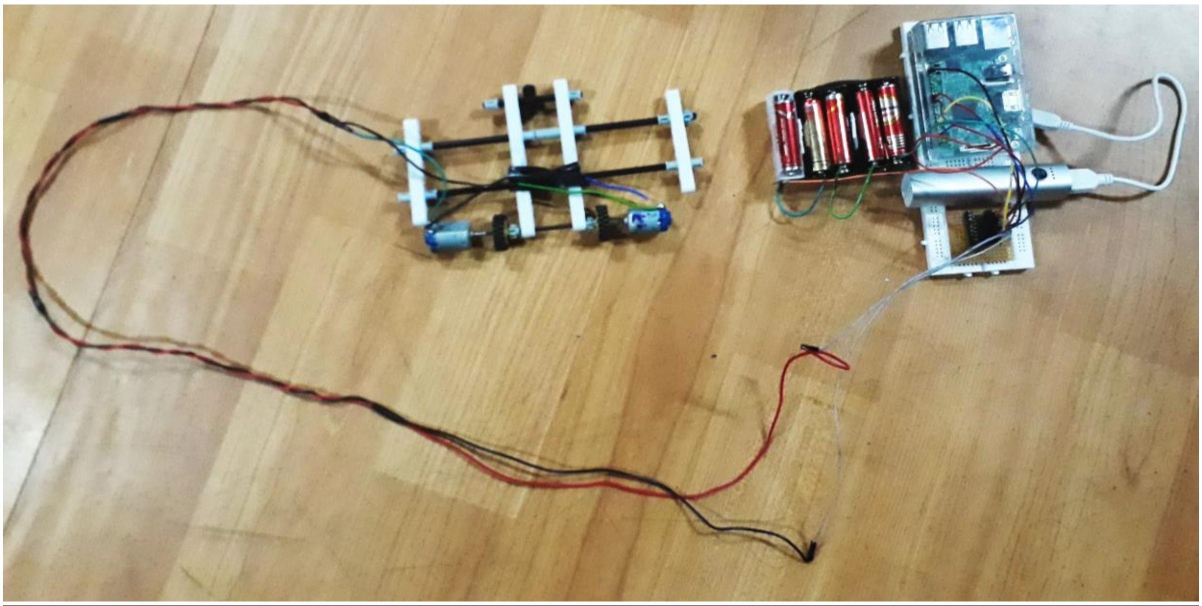


Fig. 44

Chapter 8

FUTURE WORKS

1. To design and construct our own EEG device to obtain the raw EEG data or finding the better cost effective and efficient device that can give raw EEG data.
2. To design and perform pattern matching algorithms and machine learning that are very efficient on the raw EEG signals. Here in Emotiv device the pattern matching algorithm is in-built.
3. To implement the Brain computer interface on larger and helpful applications. In our project it is BCI with wheelchair.
4. The wheelchair can be used in multiple ways based on the problem faced by the patient (i.e. voice commands, gesture controlled and BCI).
5. To make the wheelchair smarter such that it can scan and detect the obstacles on its way to the destination.
6. To make the wheelchair user interactive by giving back warnings or suggestions about the unseen obstacles that is not in the view of the user.
7. To prepare a GUI that has a map of a particular campus for the user to select the path of travel based on convenience.
8. To make the algorithms and the entire system open source and in a cost effective manner.