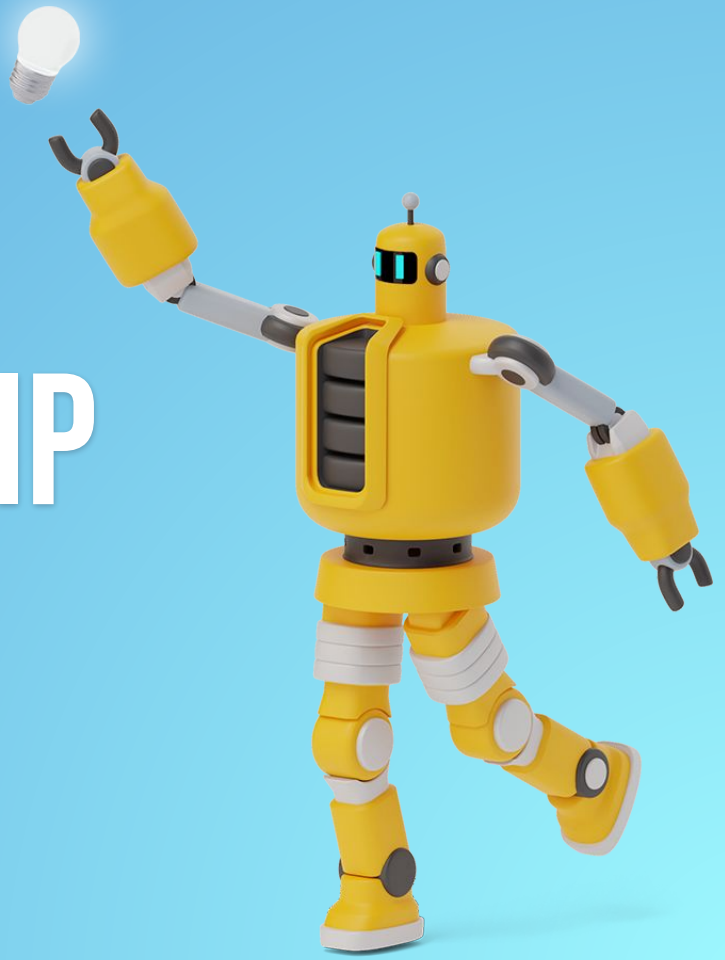
SUMMER INTERNSHIP

GROUP MEETING



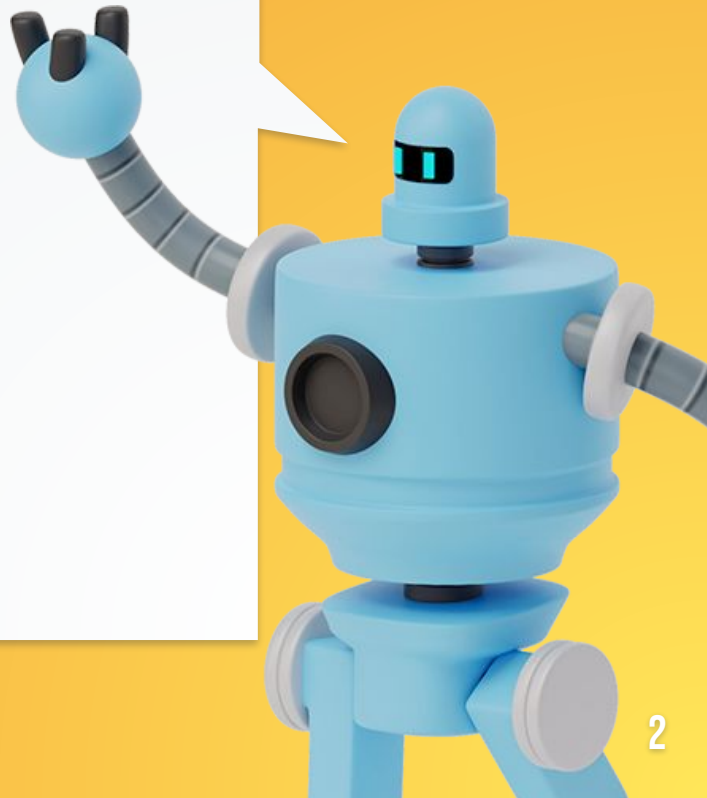
SUPERVISORS :

PROF. HOSSSEIN ROUHANI

DR. RICHA SHARMA

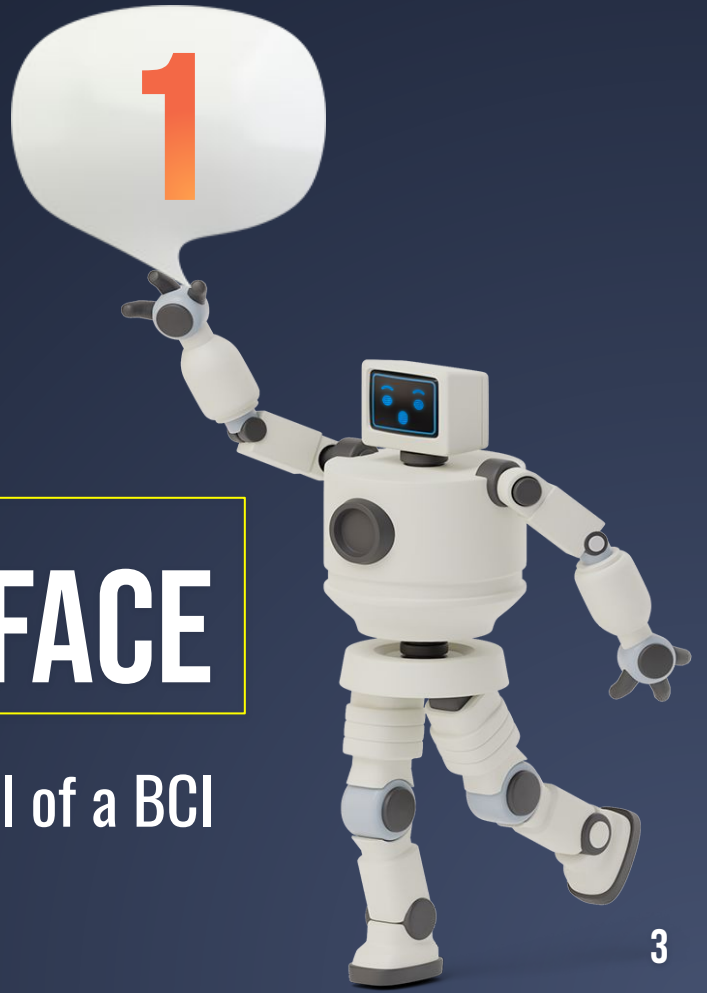
PROJECTS

- Brain Computer Interface
- Hand Glove Development



BRAIN COMPUTER INTERFACE

OBJECTIVE : To demonstrate the prototype model of a BCI system.



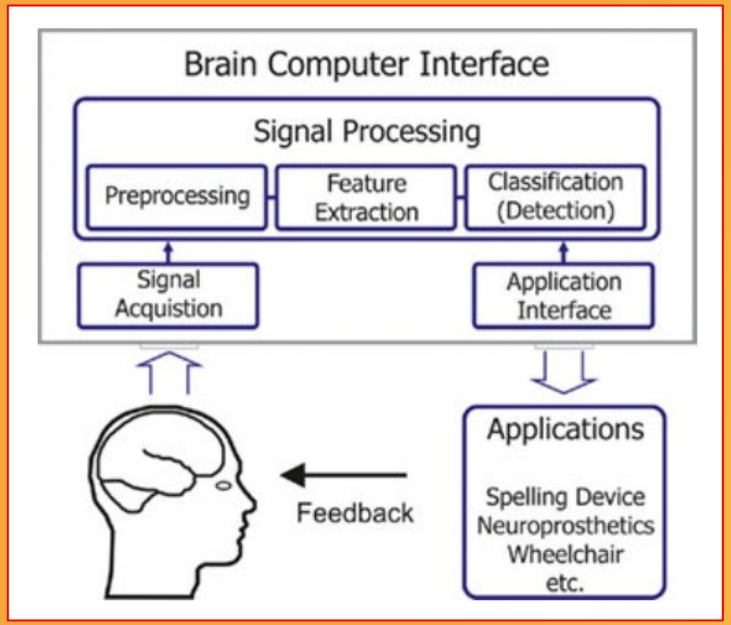
CONTENTS

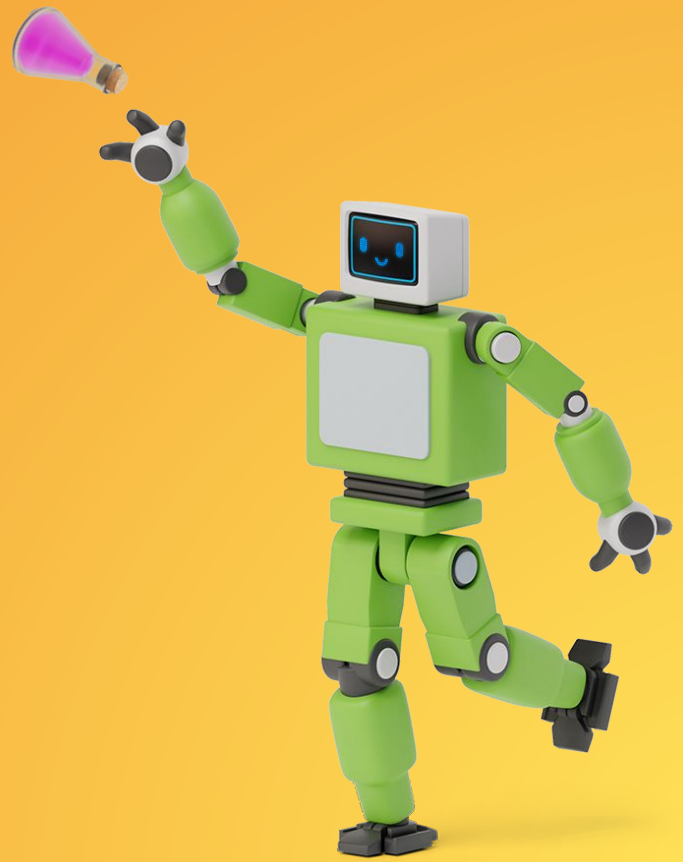
WHAT IS BRAIN COMPUTER INTERFACE ?

- Brain-computer interfaces (BCI) is to built a **direct information exchange** and control channel between the brain and computer or other electronic equipments.
- Via the BCI technology, people can use their own ideas directly to control an external device or express their ideas, but do not depend on peripheral nerves and muscles.
- These are systems mainly addressed to impaired people, who do not have an accurate control of their muscles, but often a clever mind.
- Pathologies such as **spinal muscular atrophy, spina bifida, amyotrophic lateral sclerosis or spinal cord injury** prevent from leading a normal life.

Image Source : medicinenet.com

BCI PIPELINE





STAGE 1 -:

Choose the action or activity to be classified.

Find the dataset containing the EEG signals corresponding to the action/activity chosen.

STAGE 2 -:

Data Preprocessing (using EEGLAB, MNE Python or BCI LAB)

Feature Extraction depending upon the classification task to be performed.
(Preferable with python using the MNE library)

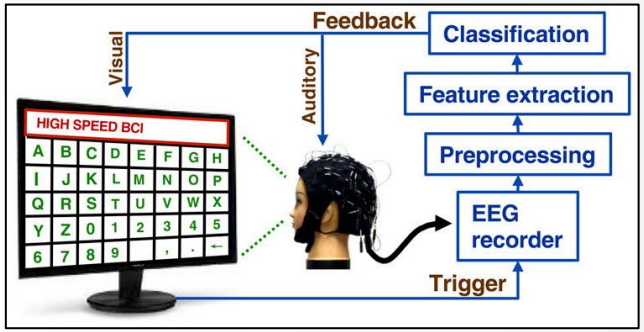
The data will be divided into three parts : training, testing and real time execution.

Training of the model using Deep Neural Network Technique
RNN or
LSTM(an application of RNN).

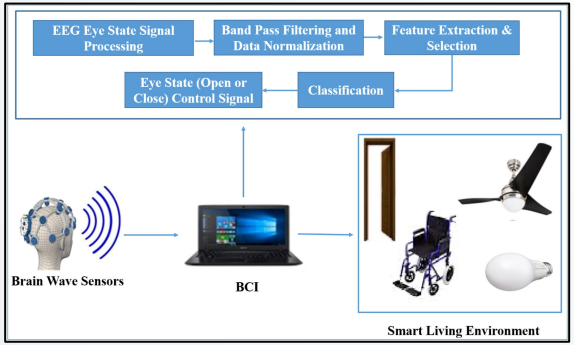
STAGE 3:

The prediction results can drive three major application areas.

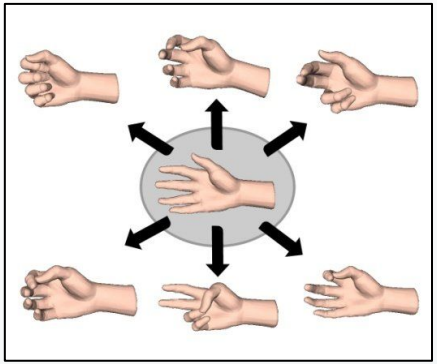
Speller Programs



Home Automation



Prosthetic Control



IMPLEMENTATION OF STAGE 1

➢ The dataset chosen was the :
EEG MOTOR MOVEMENT/IMAGERY DATASET

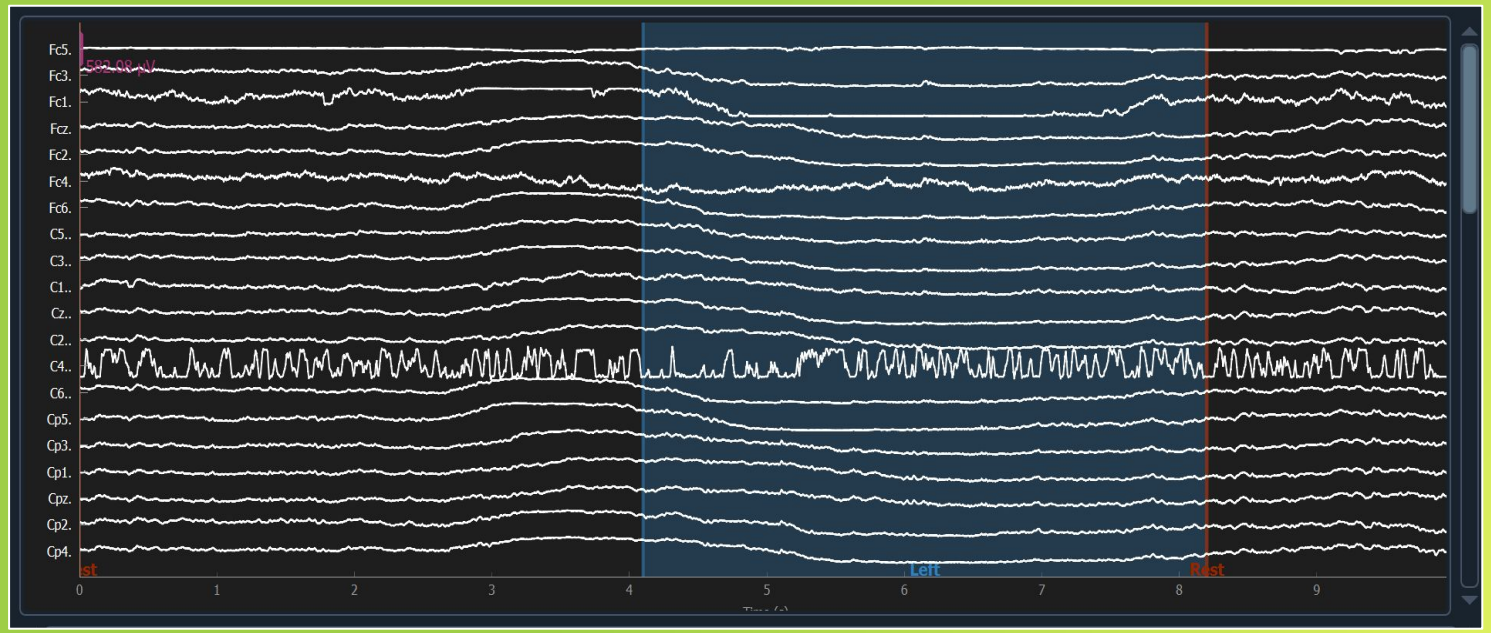
INFORMATION ABOUT THE DATASET :

- **Data collection is performed on 109 participants.** Each subject performed 14 experimental runs: two one-minute baseline runs (one with eyes open, one with eyes closed), and three two-minute runs of each of-:
    1. Opening and Closing of Right hand fist or Left hand Fist.
    2. Opening and Closing of both fist or feet.
    3. Imagine Opening and Closing Right Hand Fist or Left Hand Fist.
    4. Imagine Opening and Closing both fist or feet.
- Each of these experiments were repeated 15 times.
- The dataset had data from a 64 channel EEG system.

Note: In runs 1 and 3, left and right is decided on the basis of the visual stimulus provided to the participants. In runs 2 and 4, fist or feet is decided on the basis of the visual stimulus provided to the participant.

IMPLEMENTATION OF STAGE 2

- Importing Raw Data along with Event Markers

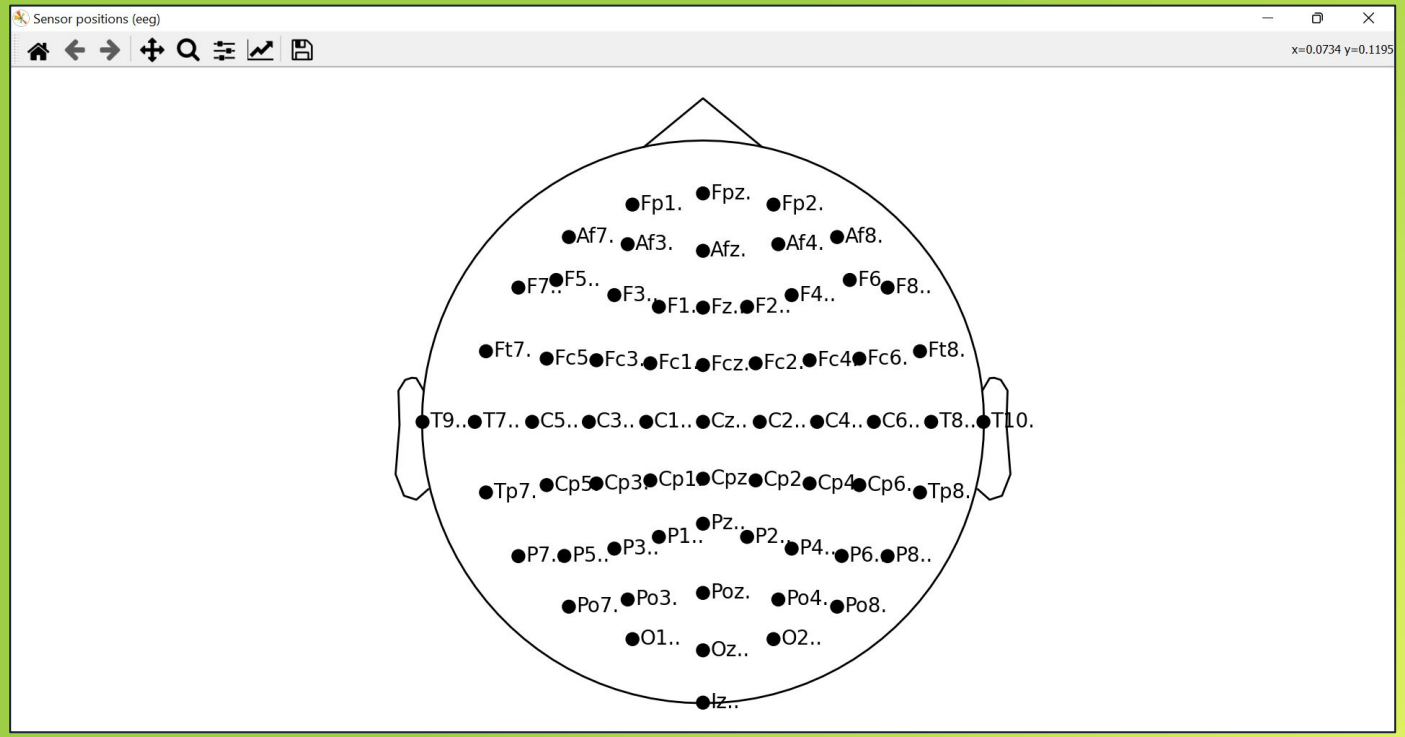


Plot for different channels [Voltage (in uV) Vs Time (in sec)]

IMPORTANT INFORMATION ABOUT THE RAW DATA

Measurement date	August 12, 2009 16:15:00 GMT
Experimenter	mne_anonymize
Participant	sub-109
Digitized points	0 points
Good channels	64 EEG
Bad channels	None
EOG channels	Not available
ECG channels	Not available
Sampling frequency	160.00 Hz
Highpass	0.00 Hz
Lowpass	80.00 Hz

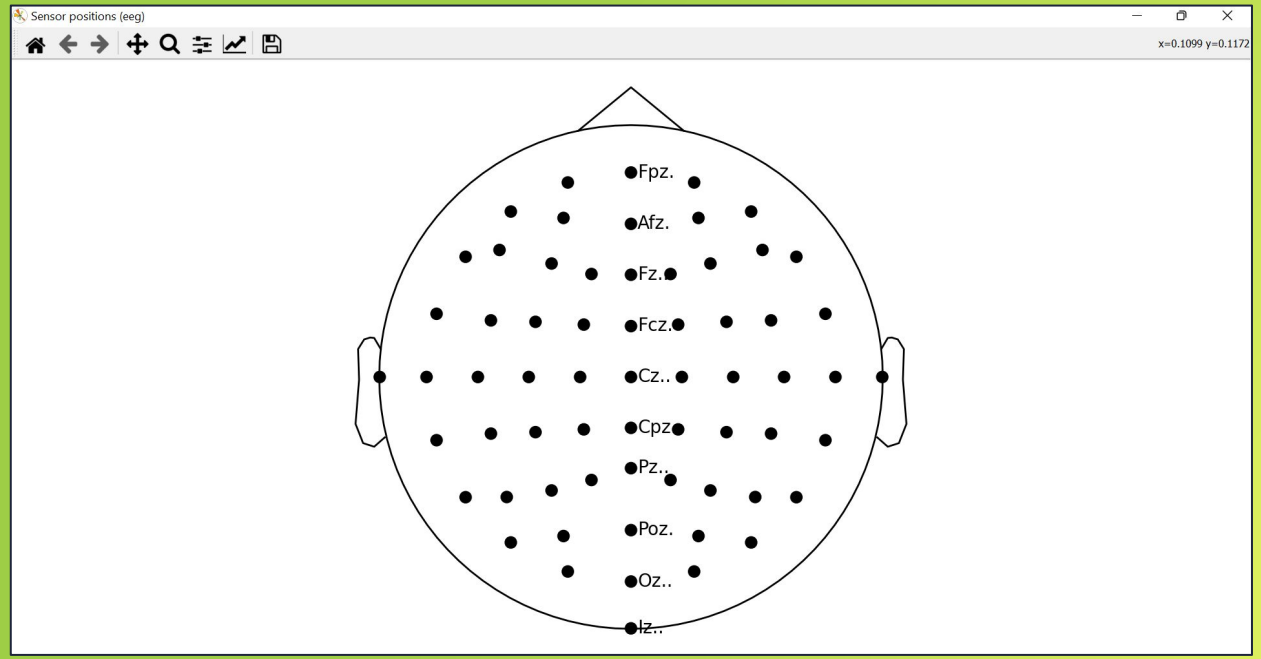
• Mapping of Sensor Names to Desired Locations to Visualise Various Plots



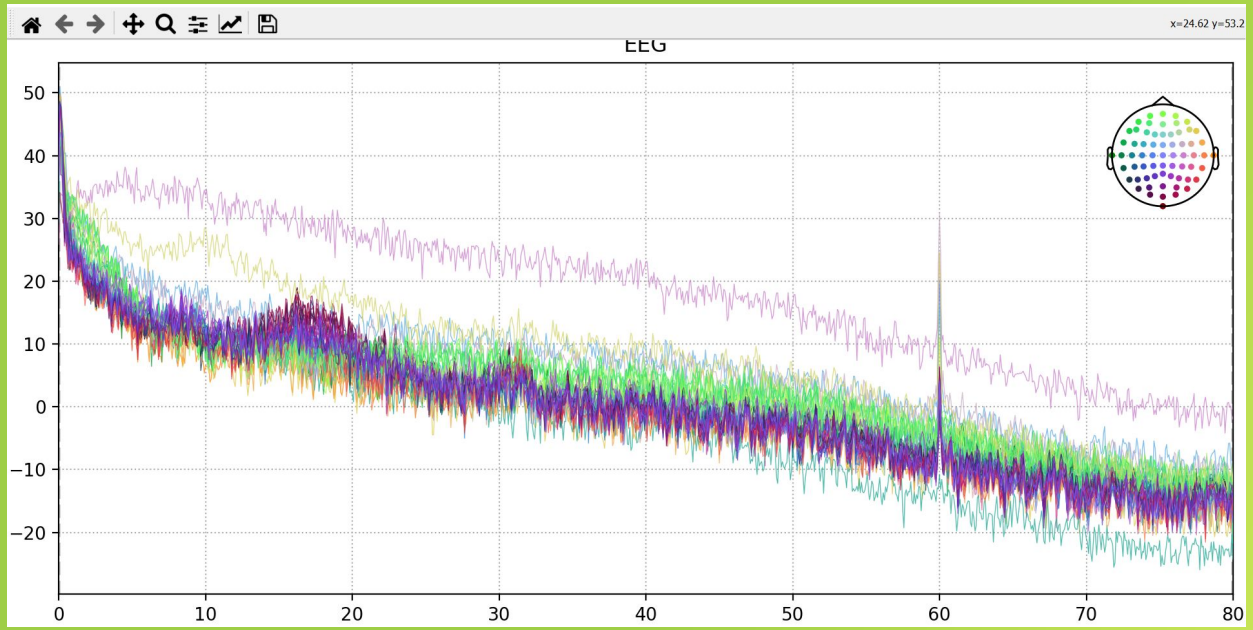
Sensor Plot according to the 10-10 International EEG System

- **Following channels were labelled as Noisy and Eliminated due to their non symmetric nature and Redundancy to the action to be characterised-:**

```
bipolar_referenced_data.info['bads']=['Fcz.', 'Cz..', 'Cpz.', 'Fpz.', 'Afz.', 'Fz..', 'Pz..', 'Poz.', 'Oz..', 'Iz..']
```



• Eliminate Power Line Noise



❖ Power Spectral Density Plot (Energy Vs Frequency)
(Before application of Notch Filter)

What is Power Line Noise ?

Powerline noise is characterized by a chronic sinusoidal 50/60 Hz element which can be observed in raw recordings of biomedical data. The sinusoidal component is usually a result of the use of devices that employ alternating current as a source of power.

Observation :

The effect of power line noise can be observed at **60Hz**. Hence these noise components needs to be filtered out !!

Methods to remove Power Line Noises for EEG Signals :

- Discrete Fourier Transform Filter
- CleanLine Filter
- Butterworth Notch Filter

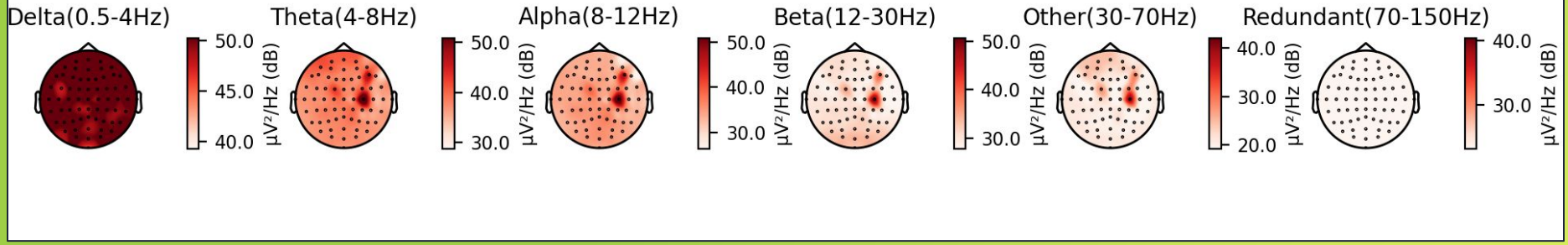
DFT Filter and CleanLine Filter :

- Due to **discretization** of signal performed in DFT filter, it fails to remove the highly fluctuating amplitude signals and CleanLine filter works by **estimating** the phase and amplitude for line noise frequencies hence fails to eliminate the highly fluctuating amplitude signals.

Butterworth Notch Filter :

- The Notch filter overcomes the issues faced by DFT and CleanLine filter as it is **capable of removing highly fluctuating amplitude** signals as well.
- The only issue with the Notch filter is that it comes with the **risk of potential severe signal distortions.**

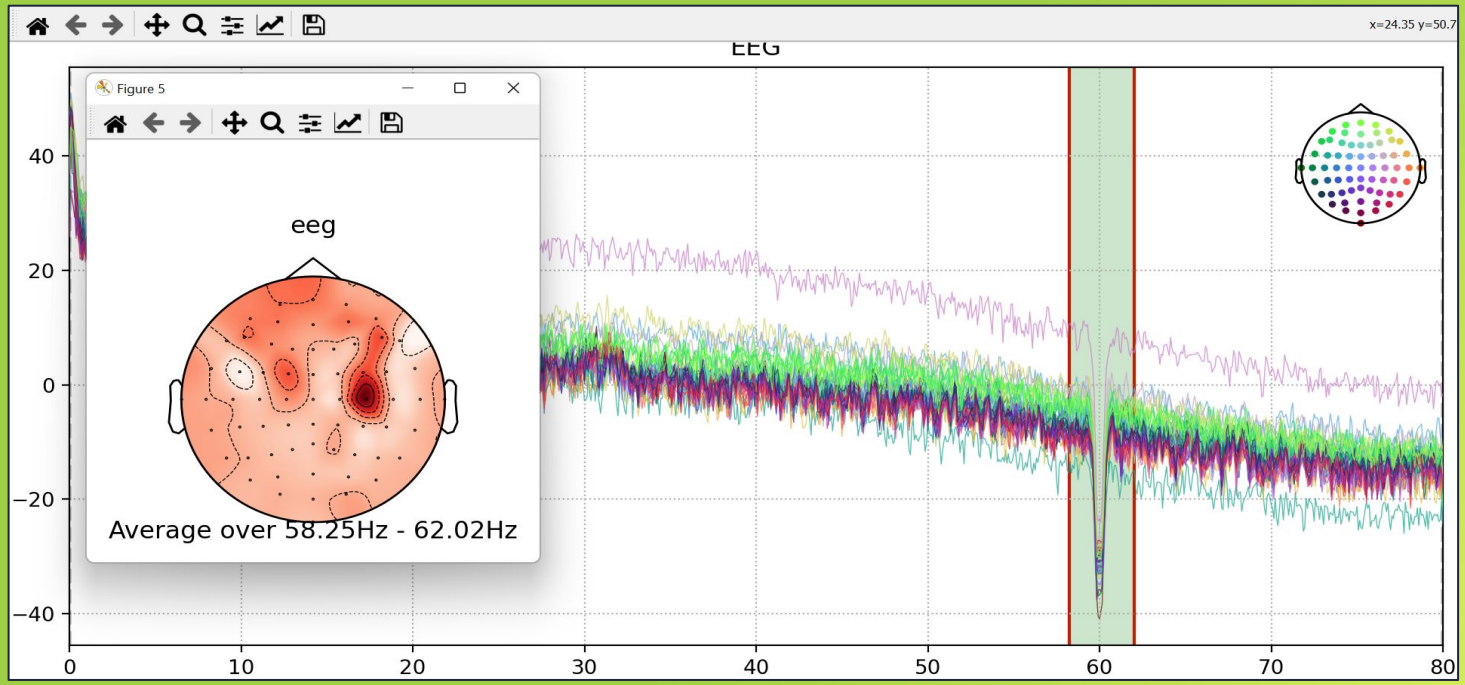
Topographical Map in Different Frequency Bands :



Inference :

- The topographical map clearly indicates that a majority of the activity takes place in the Delta frequency range and the least of activity takes place in frequency band named ‘Other’, hence application of a **Notch Filter** wouldn’t lead to a severe signal distortion because of the meagre amount of signal present in that frequency band.
- Moreover there is **no signal present above 70 Hz**, hence that region will also be filtered out due to the lack of any valuable information.

• Application of Notch Filter :



- ❖ Power Spectral Density Plot (Energy Vs Frequency) (After application of Notch Filter)
- ❖ Brain Mapped Plot Representing the signal concentration in the given frequency range

Inference :
The power line noise, effects specific electrodes depending on the impedance of the dry electrode and this brain map shows the **energy regions in solid line** indicating that these signal components will be removed as a result of the application of the notch filter.
(the same region was highlighted in the topo map of different frequency bands.)

- **Applying Band Pass Filter to Remove Redundant Frequencies :**

```
[9]: raw.info
```

[9]:

Measurement date	August 12, 2009 16:15:00 GMT
Experimenter	mne_anonymize
Participant	sub-109
Digitized points	0 points
Good channels	64 EEG
Bad channels	None
EOG channels	Not available
ECG channels	Not available
Sampling frequency	160.00 Hz
Highpass	0.50 Hz
Lowpass	70.00 Hz

The signal was processed through a **Band Pass Filter** with frequency range from **0.5Hz to 70 Hz**.

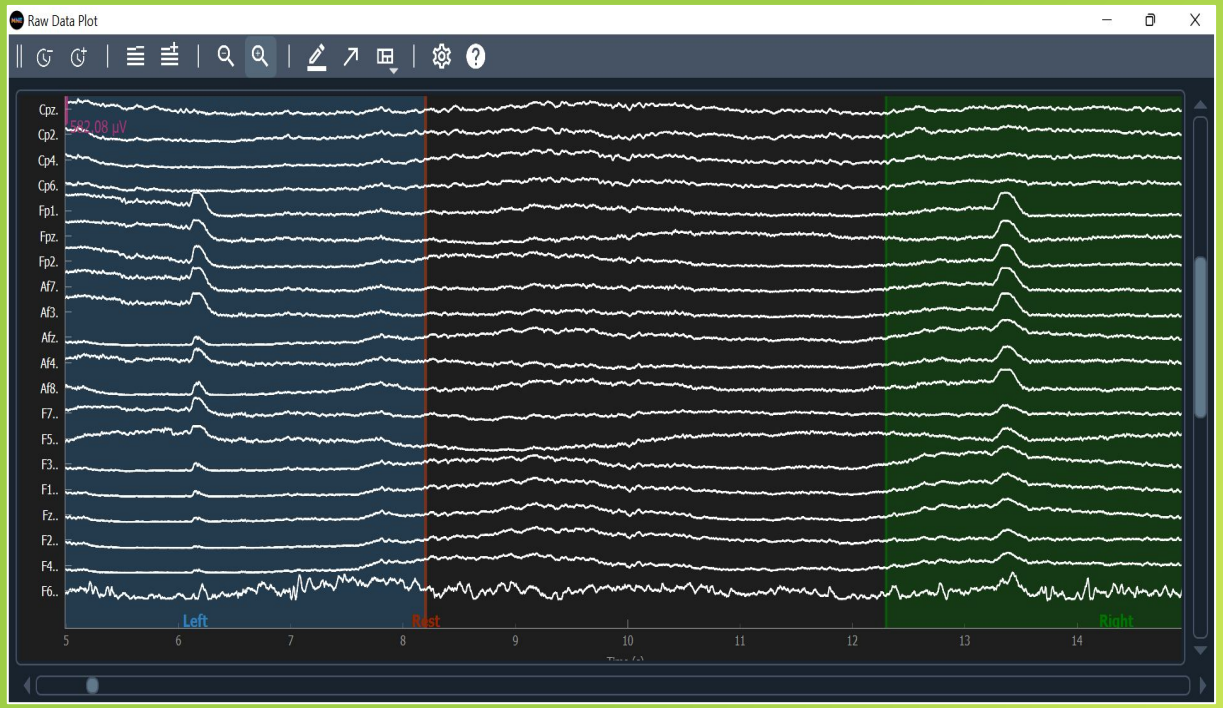
• Cleaning of Data

The two major artifacts observed in EEG data are -:

- **EOG (electrooculogram) :**It is a major noise source in electroencephalogram (EEG) recordings. One can assume that every EEG recording is contaminated with EOG artifacts, because eye movements are difficult to suppress over a sustained period of time. The operations performed in the given dataset are based on visual stimulus, hence eyes of the patients remain open, this further enhances the chances of observing the noise related to eye movements.
- **EMG (Electromyography) :**EMG is essentially electrical “noise” generated by facial muscle activity near the electrodes.Generally, the potentials generated in the muscles are of shorter duration than those generated in the brain and are identified easily on the basis of duration, morphology, and rate of firing (ie, frequency).

• EOG Removal

➢ **Observation of eye movement signals from Raw Data :**



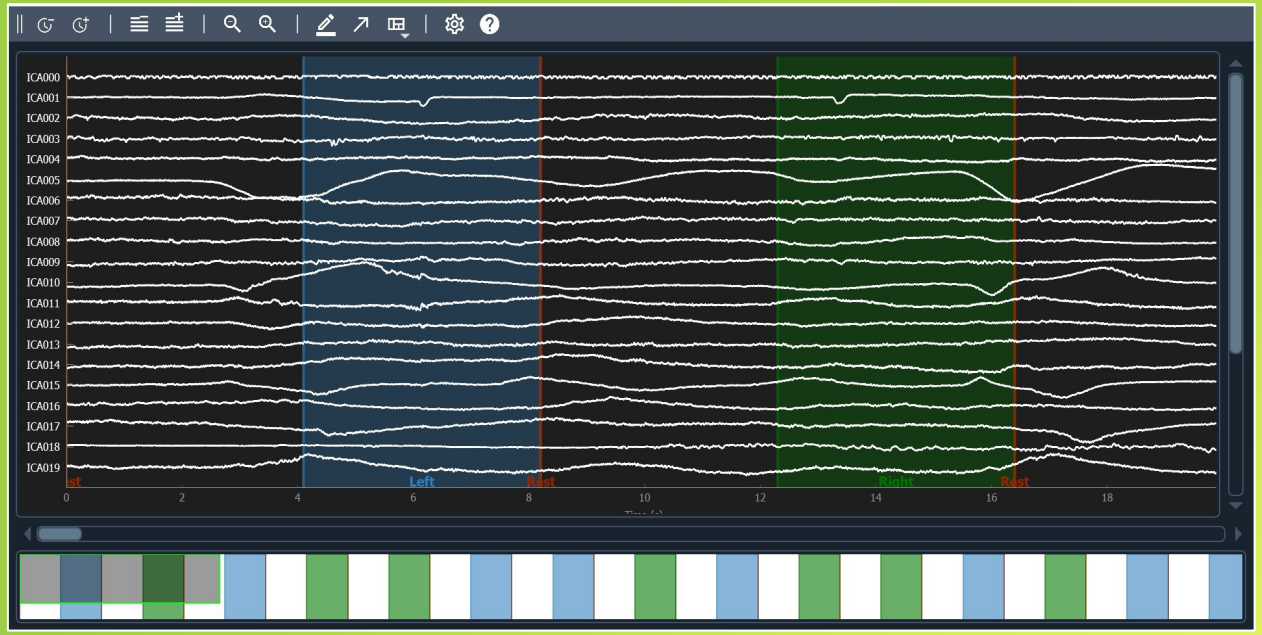
Raw Data Plot [Voltage(in uV) Vs Time(in secs)]

Inference:
The spikes observed in channels Fp1 to F4 as shown in the signal plot completely synchronise with the characteristics of the EOG signals, moreover these channels when visualised on the sensor plot appear to be the ones closest to the eyes. Hence these spikes are due to the EOG artifact and needs to be removed.

➢ Application of ICA (Independent Component Analysis)

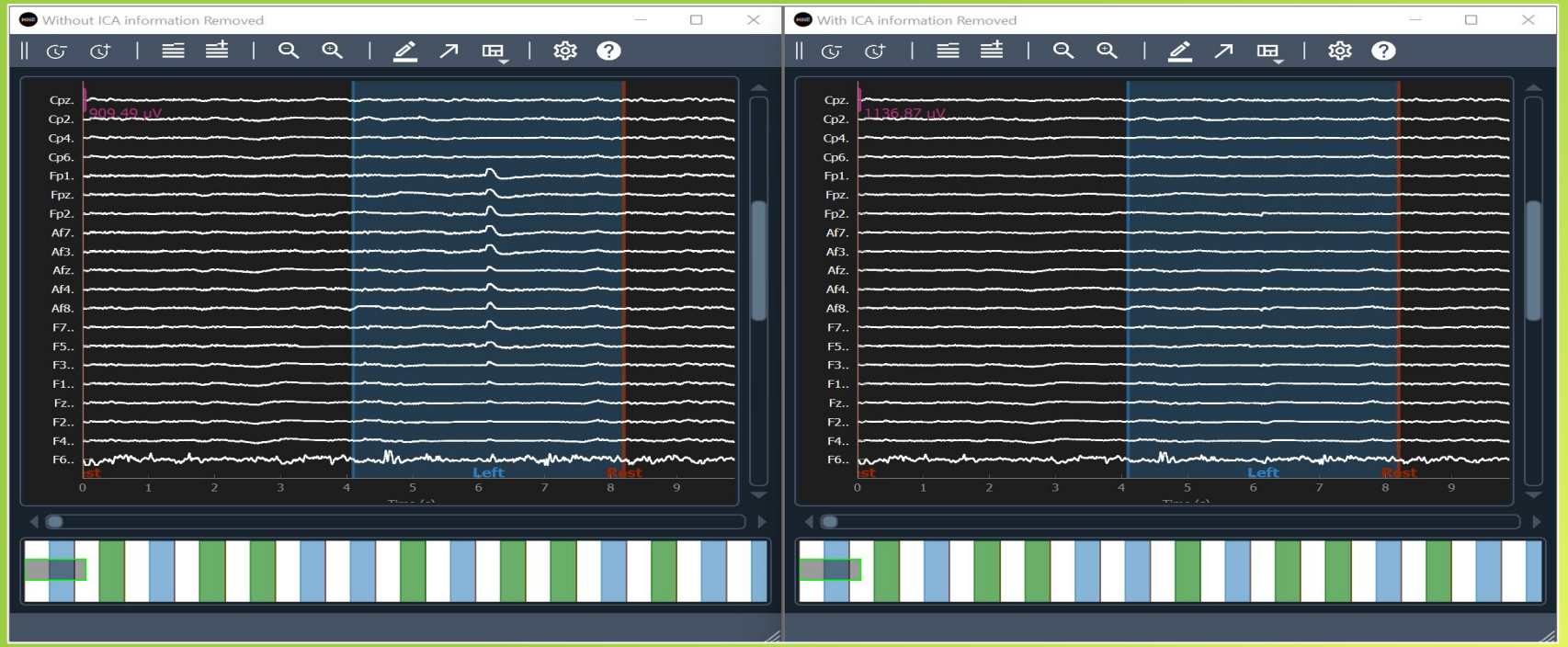
What is ICA ?

- Independent components analysis (ICA) is a technique for estimating independent source signals from a set of recordings in which the source signals were mixed together in unknown ratios.
- The standard problem used to describe ICA is the “Cocktail Party Problem” in which ICA will convert the two mixed audio recordings into two unmixed recordings of each individual speaker.



The Component ICA001 is observed to be the independent component representing the eye blink noise effect. No independent component was observed reflecting the EMG noise (as no high frequency component is observed).

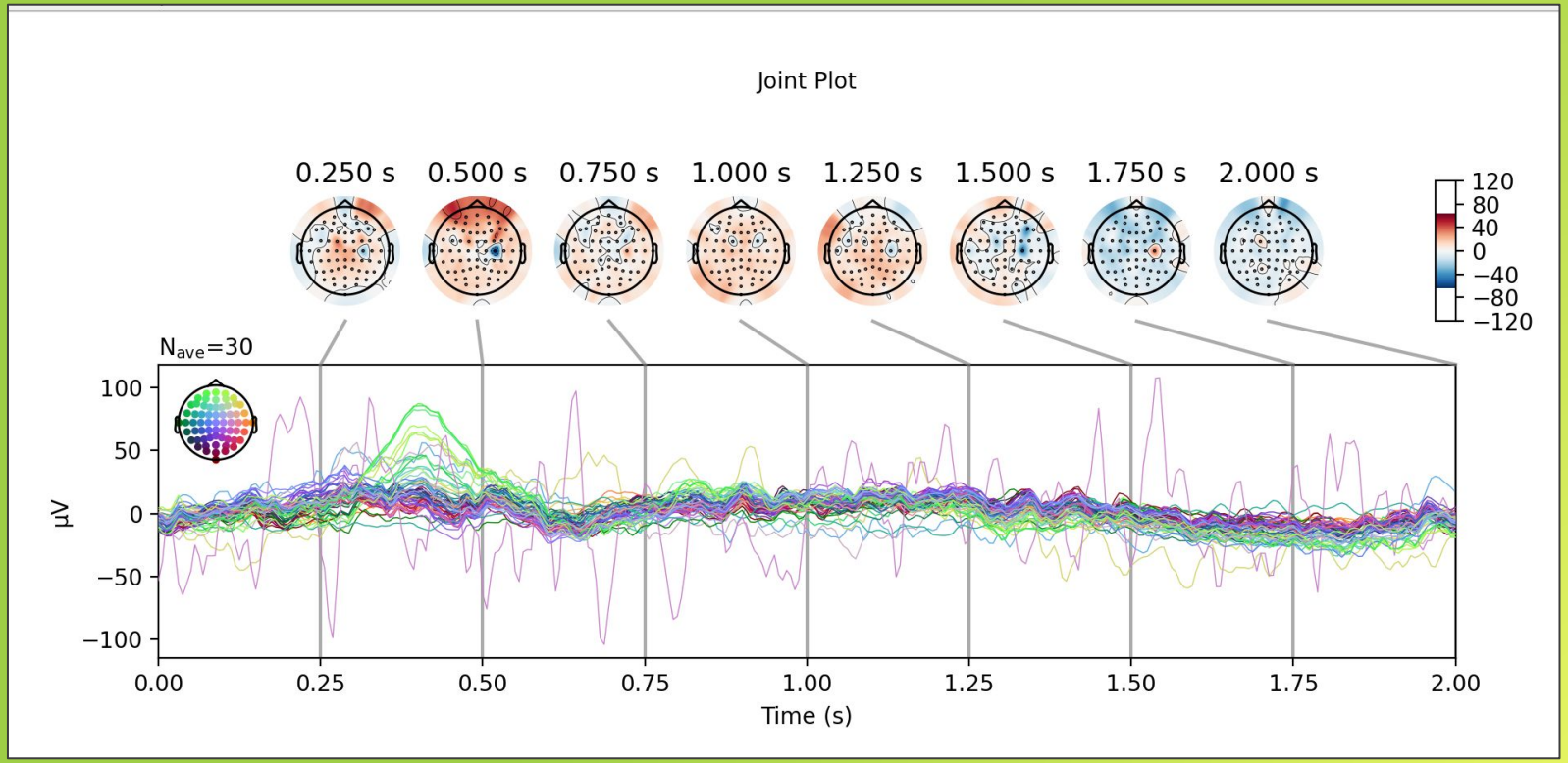
➢ Effect of ICA Application



Data Plot without ICA

Data Plot with ICA

- **Activity in the brain across different time stamps**



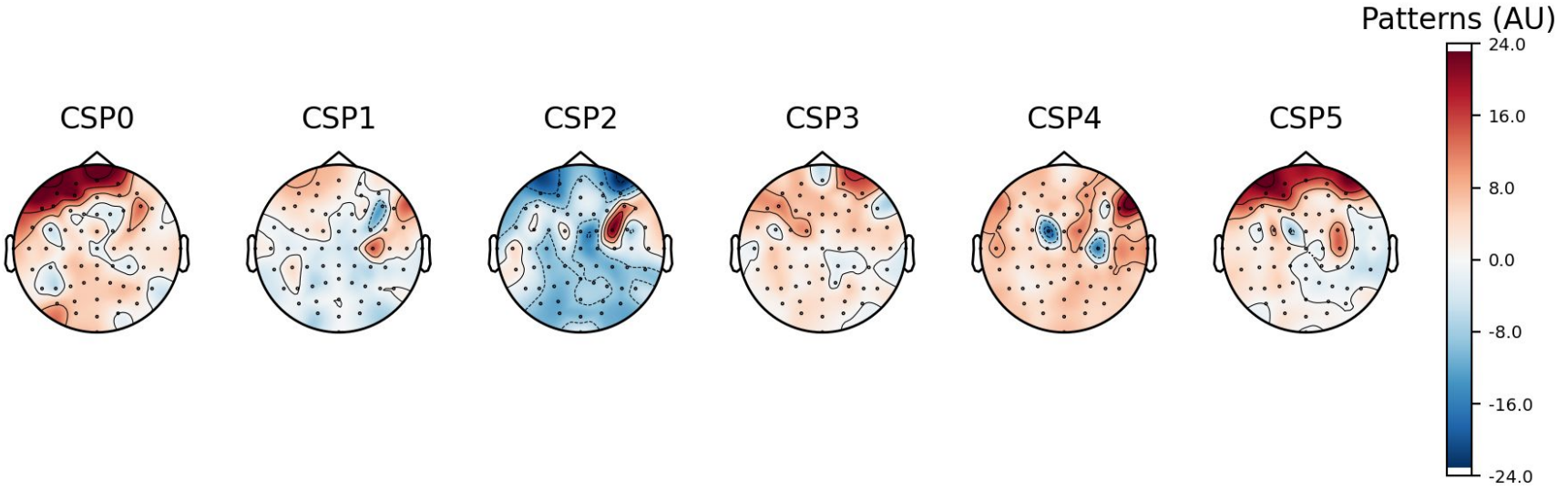
- **Feature Extraction**

➢ **Performed using Common Spatial Patterns Algorithm(CSP).**

➢ **What is CSP ?**

- The common spatial patterns (CSP) algorithm is a feature extraction method that uses spatial filters to maximize the discriminability of two classes.
- The main idea is to use a linear transformation to project the multichannel EEG data into low dimensional spatial subspace with a projection matrix of which each row consists of weights for each channels. Then these weights along with data from each trial is used to map this data to a particular pattern recognised.

- **Patterns Observed due to the application of CSP :**



- **Classification of Data :**

The deep learning models proposed for the task of classification of movement is :

- LSTM
- LSTM with Attention Mechanism
- CNN + LSTM

FUTURE WORK

- **Development of Hardware or Graphical User Interface for the implementation of stage 3**
  - A 3d printed Hand run using MG964R Servo motors and controlled using Arduino. After the classification is performed by the ML model, the desired output will be send to the arduino so that required action is performed.
  - An alternative to development of hardware can be development of a Graphical User Interface which shows the desired output from the ML model at the screen of the computer.

- **Automation of the BCI system and development of an Edge Computing based device, with the help of Raspberry Pi 4 and Google coral.**
  - A segment of data will be used for model training and testing.
  - The trained model will be uploaded on the Raspberry Pi 4 attached with google coral.
  - The real time data can then be wirelessly transmitted to the Raspi for prediction and on site implementation of the task.

HAND GLOVE DEVELOPMENT

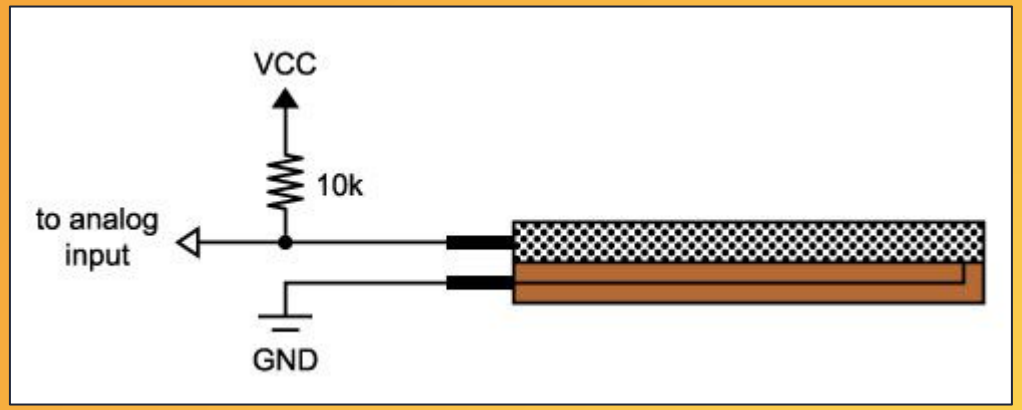
OBJECTIVE : Development of a Hardware Glove to collect data and classify the action in accordance to the American Sign Language convention.

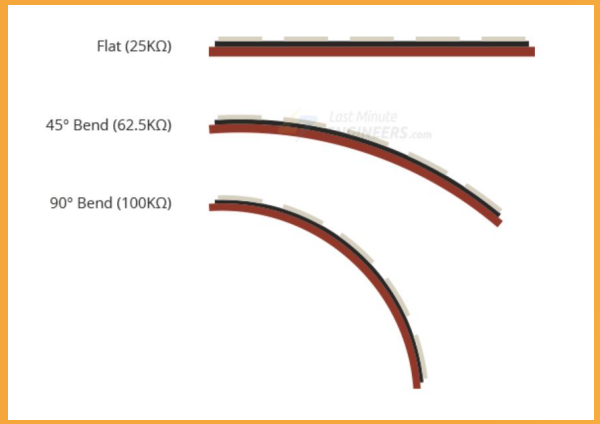
CONTENTS

- About Flex Sensors
- Sensor Placement
- Block Diagrams

About Flex Sensor -:

A flex sensor is a variable resistor that varies in resistance upon bending. Since the resistance is directly proportional to the amount of bending, it is often called a Flexible Potentiometer. It consists of a phenolic resin substrate with conductive ink deposited. A segmented conductor is placed on top to form a flexible potentiometer in which resistance changes upon deflection.





The conductive ink printed on the sensor acts as a resistor. When the sensor is straight, this resistance is about 25k.When the sensor is bent, conductive layer is stretched, resulting in reduced cross section (imagine stretching a rubber band). This reduced cross section results in an increased resistance. At 90° angle, this resistance is about 100KΩ. When the sensor is straightened again, the resistance returns to its original value.

Images Source : instructables_circuits.com

• Sensor Placement

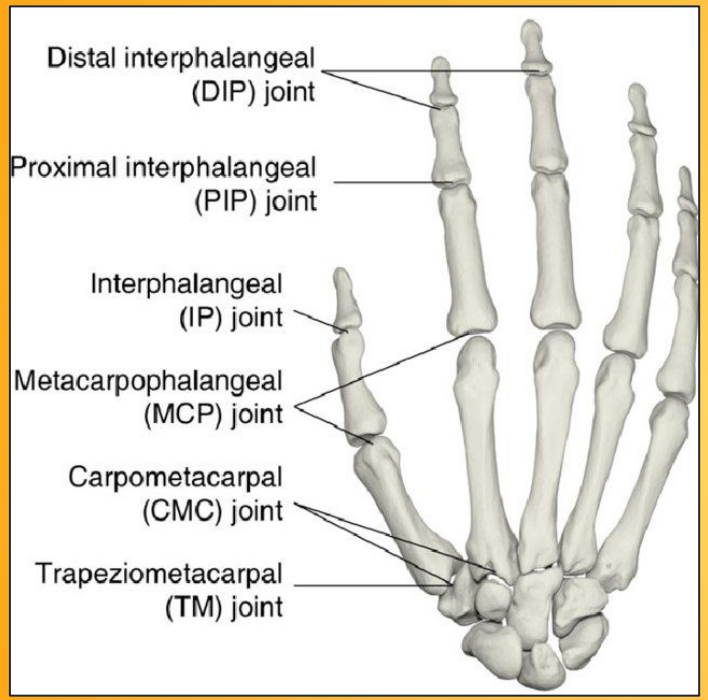
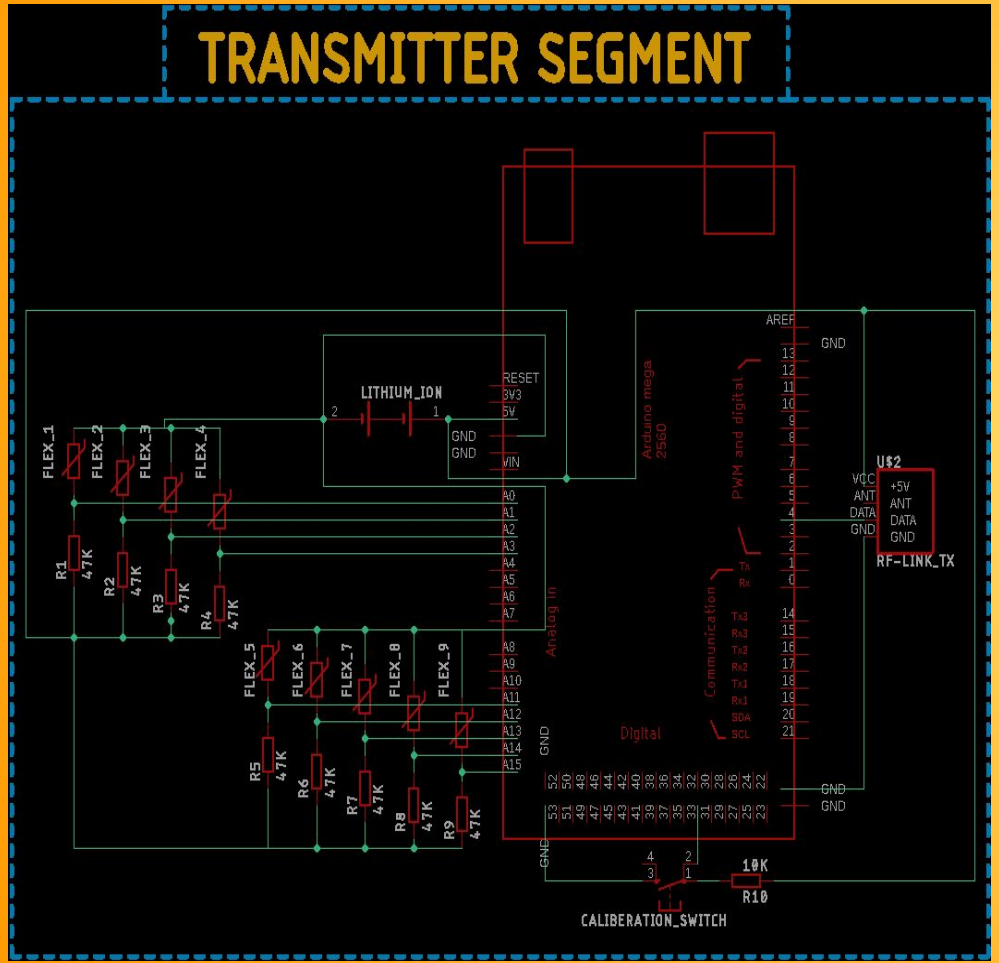
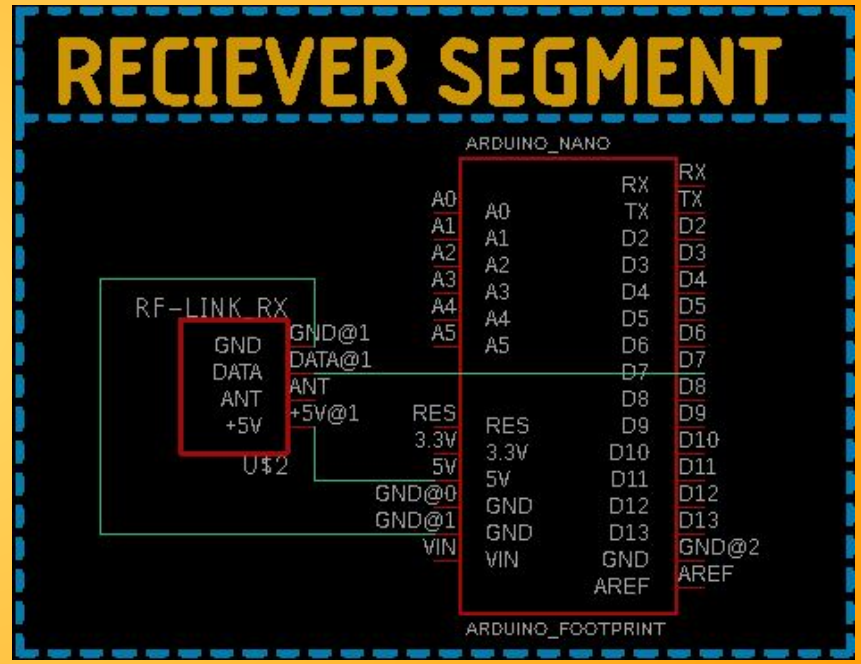


Image Source : reseacrhgate.net

The flex sensors have been placed to capture the movement information of the PIP and MCP joints of the four fingers, and the IP and CMC joints of the thumb.

BLOCK DIAGRAMS





References :

- ”Classification of Hand Movements From EEG Using a Deep Attention-Based LSTM Network”, Guangyi Zhang, Vandad Davoodnia, Yaoxue Zhang
- “Motor imagery classification in brain-machine interface with machine learning algorithms”, Biomedical Signal Processing and Control, Elsevier
- “A transfer learning-based CNN and LSTM hybrid deep learning model to classify motor imagery EEG signals”, Computers in Biology and Medicine, Elsevier
- “Optimal Combination of Channels Selection Based on Common Spatial Pattern Algorithm”, Mingai Li, Jianyong Ma and Songmin Jia
- “EEG-Based Emotion Recognition in Music Listening”,Yuan-Pin Lin, Chi-Hong Wang, Tzyy-Ping Jung
- “Power spectral density and coherence analysis of Alzheimer’s EEG Ruofan Wang”, Jiang Wang Haitao Yu, Xile Wei, Chen Yang, Bin Deng
- “Multiclass Common Spatial Patterns and Information Theoretic Feature Extraction”, Moritz Grosse-Wentrup, Martin Buss

Thank You