IT478 : Internet Of Things

Controlling Wheelchair using Brainwaves

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Problem Statement

Wheelchair is the most relevant equipment for elderly people and those with walking impairments. It can be used by them to carry out daily routines and tasks with minimal issue. Therefore, researchers have proposed many tools which can be used to control the movement of wheelchair e.g. joystick or keyboard. But these tools are useful for healthy people only. The existent problems faced by the disabled people with traditional wheelchair gives a motivation to build a technology for wheelchair which will facilitate the disabled people.

Proposed Solution

The basic solution which one can think of is to detect the thinking process of the person. Brain computer interface is an effective way for controlling wheelchair, as it allows them to control one by just thinking in a particular direction. For controlling wheelchair we only need 5 type of signals which are left, right, forward, backward and stop. We use machine learning algorithms to classify the thinking of a person. After collecting the brain signals of a particular person we can match them with the already classified data and make the wheelchair move in a particular direction.

The project implementation can be divided into 4 main parts:

Constructing the EEG circuit (Hardware Design)

A. Hardware parts required to construct the EEG circuit:
    a. Arduino Mega 2560
    b. SparkFun Single Lead Heart Monitor AD8232
    c. Adafruit ADS1115 16 bit ADC 4-channel chip
    d. 2x TL074
    e. 3x Electrodes
    f. 5x LEDs
    g. Resistors, Capacitors, Breadboard, jumper wires
B. Compiling the Hardware together to form EEG circuit

EEG (Electroencephalography) data is collected through three EEG electrodes (positive, negative and ground) which are directly in contact with the human head. The electrodes are placed using International 10-20 system. Based on this system, two electrodes are worn on both the corners of forehead and third one is worn on the bone behind the ear.

The range of EEG signal in adults is about 10 uV to 100 uV in amplitude when measured from scalp. Hence, in order to be able to view the EEG signal and further work on it, amplifier circuit is required. The signal is amplified using ECG sensor - SparkFun Single Lead Heart Monitor AD8232.

Twin-T notch filter has been added after the amplifier to filter the noise present at 50 Hz. This filter is needed because otherwise it would result in signal with amplitudes greater than supported by ADC, thus distorting the signal.

Op-Amp used here is TL074 low noise JFET - input operational amplifier. It works as band pass filter because of its low power consumption, low noise and its main usage in medical applications.

The signal must be transformed from analog to digital in order to be processed by the computer. Therefore, Adafruit ADS1115 16 bit ADC 4-channel chip is used. It also includes a programmable 16x amplifier. Arduino Mega 2560 is used as it is compatible with MATLAB. It captures the data and feeds it to MATLAB via serial communication.

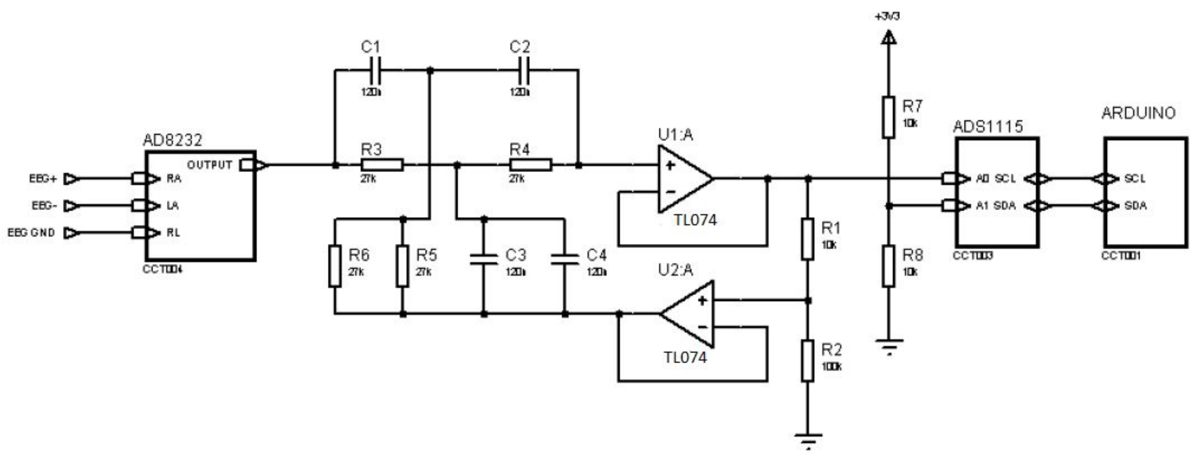


Fig.1 - Hardware Circuit

Collecting the EEG Data

After constructing the EEG circuit, we collected data through arduino and MATLAB. Baud rate of arduino is set to 115200 and conversion rate of programmable ADS1115 is set to 475 samples per second. Sampling frequency is set to 475 Hz to match the conversion rate of ADS1115. This is collected for 4.2 seconds such that we can collect almost 2000 samples (475*4.2). Differential value of ADS1115 is read in arduino.

Data collected by arduino is transferred to MATLAB via serial communication. This data is saved in a vector. We have collected almost 250 such datasets of different directions. 50 of each direction of one subject is taken into consideration.

Subject was asked to think and visually imagine that he is moving the pin in a particular direction. Left, right, forward and backward are collected using this technique. Eye blink has some special characteristic in EEG signal so we used continuous 4-5 blinks for stop functionality. Taking 2000 samples takes 20 seconds of time.

Preprocessing in MATLAB

Preprocessing part is applying filters to reduce the noise. Noise of the hardware components used and line noise need to be removed. Also we only need frequency band of 1-30 Hz as alpha is of range 8-12 Hz, beta is 12-30 Hz, delta is 0-4 Hz and theta is 4-8 Hz. So we have applied low pass filter of 30Hz on the dataset and then High pass filter of 1Hz. Low pass filter is built to filter the frequencies which are above alpha/beta/theta/delta. If we do not apply this low pass filter output will be full of noise, which will result in undesired output. High pass with cutoff frequency of 1 Hz is there to get rid of unwanted noise of low frequencies and to remove the DC offset.

Moreover, Pre-processing the signal by converting EEG data from time domain to frequency domain is done using periodogram. Periodogram will calculate the Fast Fourier Transform (FFT) and normalize the output to find the Power Spectral Density (PSD).

After computing the PSD,.frequencies of different bands (i.e alpha, beta, delta, theta) are separated using band filters and the values are stored in a text (comma separated) file.

Applying Machine Learning Algorithm

The alpha,beta,delta,theta values collected earlier are used to train and classify the data. The data is divided into two sets - Training data set (80% of total data set) and Testing data set (20% of total data set). The training dataset is used to train the algorithm. Using this data set, the structure of that algorithm is constructed. Once it has been designed, the testing data set is used to test if the constructed algorithm works correctly and gives the desired result or not. This is analyzed by checking the accuracy.

Machine learning is applied to classify the data into 5 major categories: Left, Right, Forward, Backward and Stop. Matlab has this functionality 'Classification Learner' which trains the model according to training data provided. We have labeled each class with value 1-5 where 1 = Left , 2 = Right, 3 = Forward, 4 = Backward, 5 = Stop. The labels 1-5 are used as responses - a parameter used in classifier.

Results

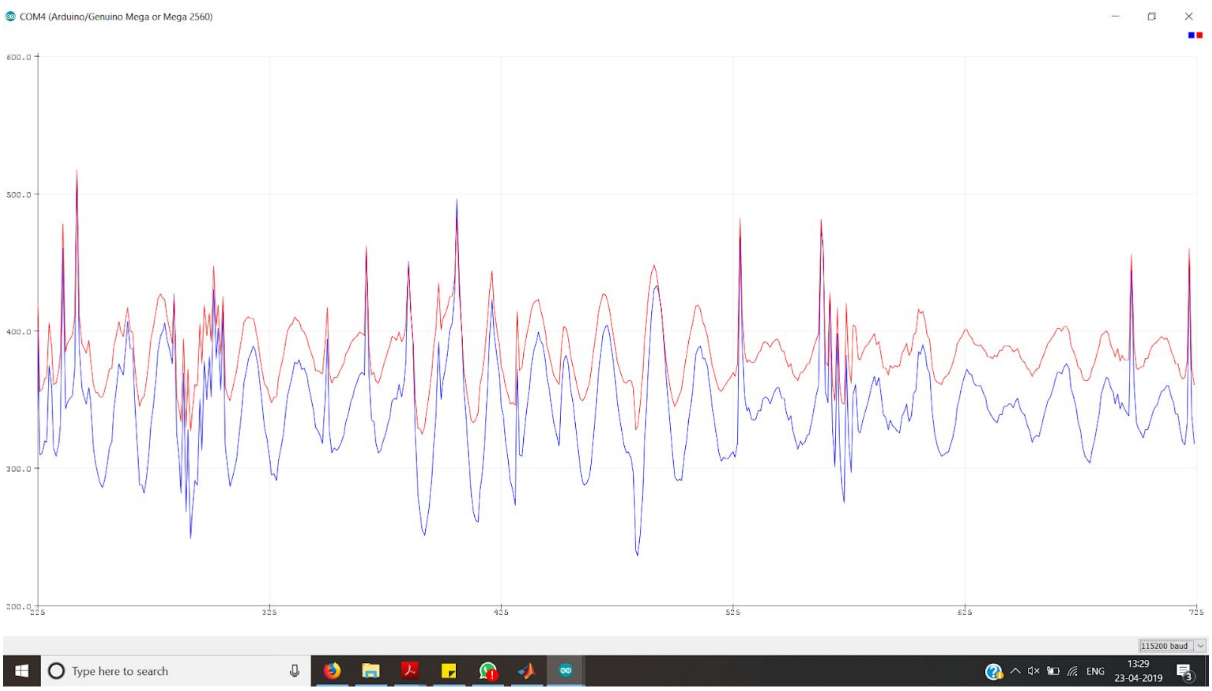


Fig. 1 - Raw EEG Data

Blue Line - Input Signal | Red Line - Output Signal

This graph is of EEG Signal after applying hardware filter. We can see in the above diagram that the SNR has increased because noise has been reduced in the signal. Consecutive Multiple peaks in the diagram represents multiple blinks of the subject.

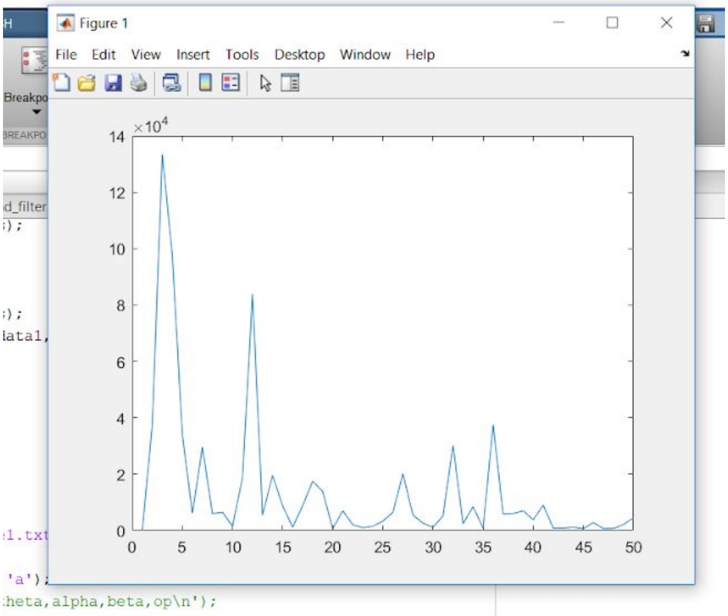


Fig.3 PSD of EEG signal

Figure above shows the power spectral density (Power → Frequency) graph. As it can be seen from the above graph, brain signals lie between 0-40 Hz frequency. We further classify the signals into alpha, beta, delta, theta bands based on the frequency range.

```
delta,theta,alpha,beta,op
-0.380,-0.780,-0.650,-0.715,1
-0.060,-1.054,-1.625,-1.773,1
-0.099,-0.942,-1.241,-1.490,1
-0.218,-0.749,-0.846,-1.129,1
-0.200,-0.820,-0.846,-1.123,2
-0.111,-0.755,-1.495,-1.752,2
-0.373,-1.169,-0.968,-0.397,5
-0.217,-1.424,-0.839,-0.677,5
-0.089,-1.255,-1.425,-1.037,5
-0.182,-1.449,-1.259,-0.600,5
-0.382,-0.989,-0.847,-0.469,5
-0.101,-1.222,-1.546,-0.923,5
-0.144,-1.210,-1.257,-0.784,5
-0.064,-1.388,-1.290,-1.346,1
-0.099,-0.880,-1.289,-1.692,2
-0.156,-0.926,-1.054,-1.024,1
-0.021,-1.555,-2.047,-1.957,3
-0.022,-1.797,-1.739,-1.801,3
-0.017,-1.654,-1.969,-2.220,3
-0.072,-1.010,-1.554,-1.572,3
-0.032,-1.690,-1.593,-1.617,3
-0.064,-1.248,-1.385,-1.399,3
-0.118,-0.960,-1.080,-1.349,4
-0.015,-1.590,-2.414,-2.299,4
-0.296,-0.953,-0.673,-0.770,4
```

Fig. 4 Data set after preprocessing

Alpha, Beta, Delta, Theta values are stored in text file after preprocessing step. Op has been provided by the subject itself based on what he/she was thinking. We provide this text file to train the model and some of these data to test the model. 1- left, 2-right, 3-forward, 4-backward, 5-Stop.

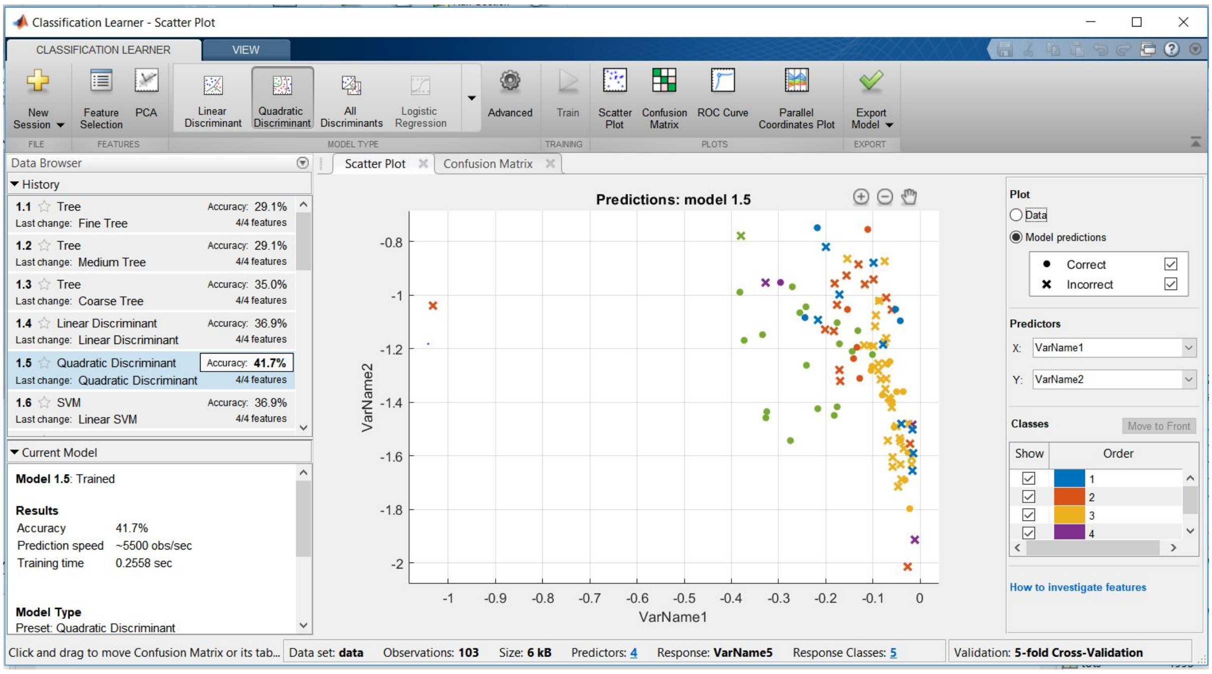


Fig. 6 Predictions of the model

Above figure shows the predictions of the trained model. We provided this text file to the classification learner and after trying all the classification techniques (e.g. SVM, LDA, KNN, etc) we got highest accuracy in **Quadratic Discriminant Analysis (QDA) (41.7%)**. That is why the trained model is created using QDA.

Now we can test the model with any data collected. Matlab saves the test data as a text file which is input for the trained model. QDA trained model returns the predicted value of the unknown data provided. It labels the data between 1-5. This is used to move the wheelchair.

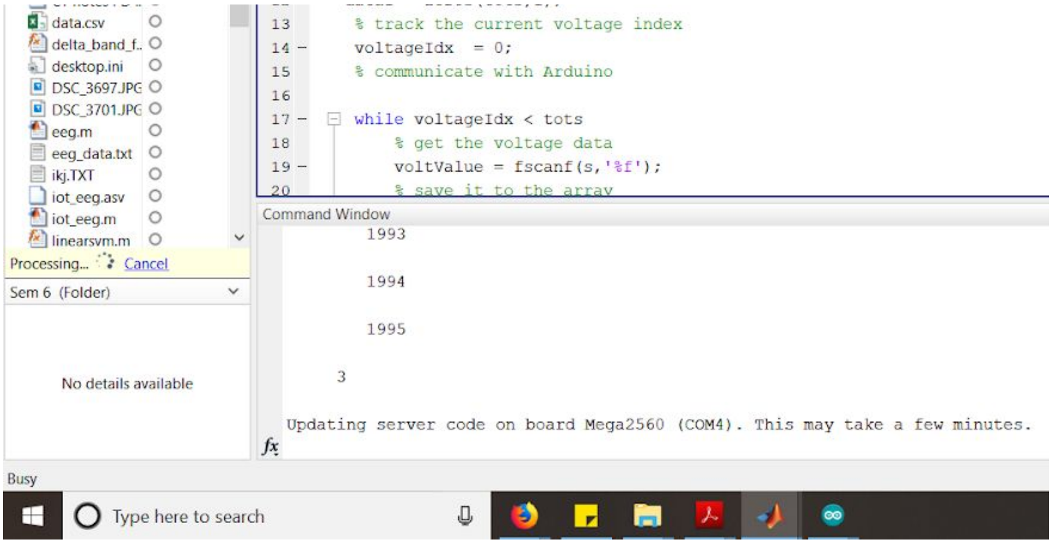
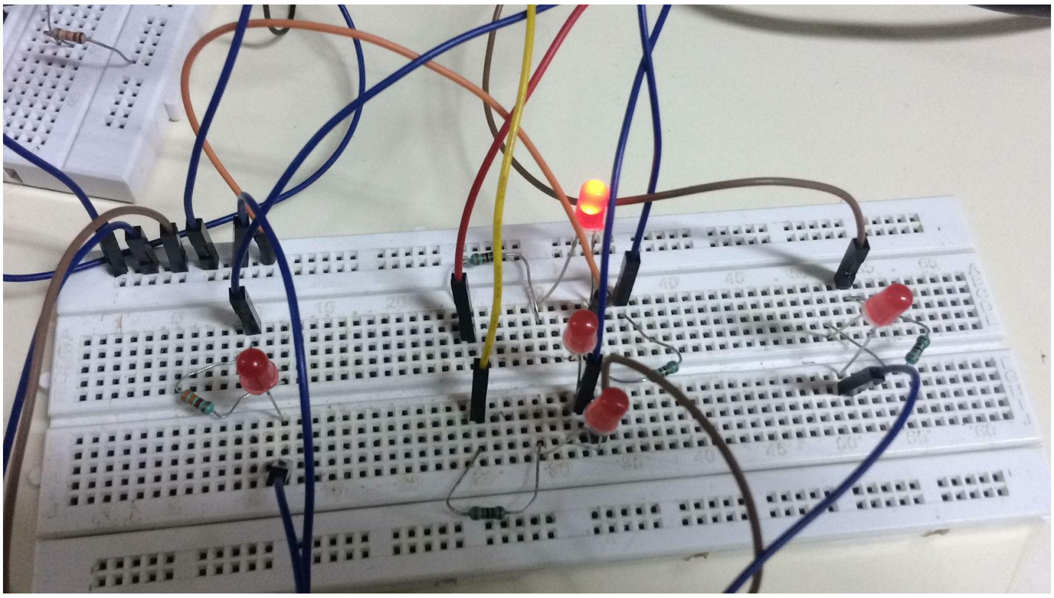


Fig. 7 - Testing

As we can see, the subject was asked to think in forward direction (Hence 3). The result was predicted accurately. The LED corresponding to forward direction lights up.



Limitations

- **Time Delay :** Whole system should be real time in case we need to use in real life. We were facing time delay issue because of several reasons.
  - Using Electrodes instead of wireless headband.
    - We need to filter the raw data using matlab and hardware circuit while headband comes with TGAM chip which does everything and wirelessly transfer the data to arduino.
  - Data collection of 2000 samples via matlab is delaying the system.
  - Serial port connection establishment for transferring data from MATLAB to Arduino takes time which leads to time delay in whole circuit.
- It takes time for subject to learn how to think for collecting the data. Thus the system needs enough number of datasets to train the model accurately.
- Due to time constraints, we were not able to build motor driven car. We have instead used five LEDs to show in which way the vehicle will be directed.

References

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