Investigation on Different Filters and Different Frequency Bands for Brain Computer Interface with Right Hand and Left Hand Imaginations

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Abstract - For severely paralyzed people, Brain Computer Interface (BCI) is the only option to communicate. For BCI at least left hand and right hand imagination have to be identified. This paper investigates the region of frequency band and the filter type that provide significant separation between left hand and right hand imagination. For this analysis C3 and C4 channels of 59 channel system Electroencephalogram (EEG) are used. It is found that 5-10Hz band of C3 and C4 provides significant separation. Further, Chebychev type II filter emphasise the separation between left hand and right hand imagination and C4 have shown higher separation than C3.

Index terms - Brain Computer Interface (BCI), Electro-encephalogram (EEG), Event-Related Desynchronization (ERD), Event-Related Synchronization (ERS), Infinite Impulse Response (IIR), Discrete Fourier Transform (DFT), Amyotrophic lateral sclerosis (ALS)

I. Introduction

Some disease can really cause severely paralyzed condition called the locked-in syndrome[1], where the patient loses all voluntary muscle control. An example of such kind of disease is Amyotrophic Lateral Sclerosis (ALS)[1]. The ALS only affects the integral part of the motor pathways contain special neurons, the large alpha motor neurons[1]. In the beginning stage of ALS it only cause muscle weakness and atrophy. When it is developing further, the patient may lose the ability of voluntary actions, such as speaking, eating, moving and breathing, progressively. Despite, the patient can still see, hear, and understand what is occurring around them, because the disease does not attack cognitive and sensory functions[1].

Those who lost the motor pathway, any natural way of interaction (since they can understand what is happening around them) with the environment are lost as well. The only option for communication in such cases is BCI. BCI is a communication channel which does not rely on the brain's normal output pathways of peripheral nerves and muscles. So it gives an opportunity to supply paralyzed patients with a new approach to interact with the environment[1].

In order to do that, first the brain signals of a healthy subject are used to train and analyse, then to implement the system on paralyzed subjects. This will avoid delays related to train the paralysed subject.

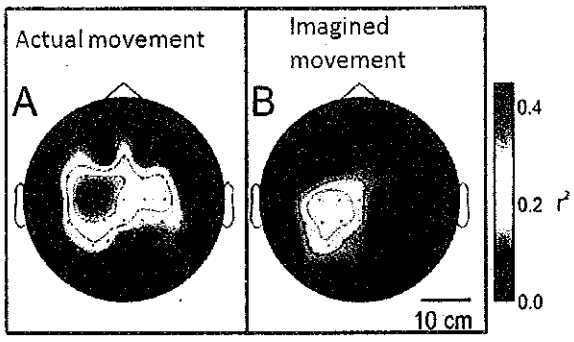
There are three main brain monitoring methods namely invasive, partially invasive and non-invasive. In non-invasive method, there are different neuron signal imagings or reading techniques such as Magneto encephalography, Magnetic resonance imaging, functional magnetic resonance imaging and electroencephalogram (EEG). Among those EEG is the main interest due to its advantages such as low cost, convenient operation and non-invasiveness.

Further monitoring the effects on the signal is related to what was attempted or what was thought by the subject. One possibility to open a communication channel for these patients is to use EEG signals to control an assistive device that allows, for example, the selection of letters on a screen of brain–computer interface (BCI) devise[2]. Towards the direction of using BCI to interact with the subject at least left hand and right hand imagination (motor imagery) have to be used in order to find what the subject is thinking. As shown in Fig .I the imagination of a limb (arm or leg of a person) movement can modify brain electrical activity similar to actual limb motion [3]. Depending on the type of motor imagery, different EEG patterns can be obtained. Activation of hand area neurons either by preparation for a real movement or by imagination of the movement is accompanied by a circumscribed event-related

desynchronization (ERD)[1]. Therefore these useful features should be extracted from EEG to develop a better classifier to perform the task without spending much time in training the patient in the real implementation (the training time can be reduced by better selection of frequency band and the best channel related to the task, thus better system).

More generally, evoked potentials (when neurons fire) can be considered to result partially from a reorganization of the phases of the ongoing EEG rhythms. From the viewpoint of psychophysiology, EEG signals are divided into five rhythms in different frequency bands: delta rhythm (0.1–3.5 Hz), theta rhythm (4–7.5 Hz), alpha rhythm (8–13 Hz), beta rhythm (14–30 Hz), and gamma rhythm (>30 Hz) [2] (page 137). There is another subpart in brain wave rhythm called sensory motor rhythm (SMR). It is an oscillatory idle rhythm of synchronized electromagnetic brain activity. It appears in recordings of EEG over the sensory motor cortex. For most individuals, the frequency of the SMR is in the range of 13 to 15 Hz. However alpha rhythm and beta rhythm are more related for cognitive activities (5-35Hz band).

Figure I: Topographical distribution on the scalp of the difference (measured as r^2 (the proportion of the single-trial variance that is due to the task)), calculated for actual (A) and imagined (B) right-hand movements vs. rest for a 3 Hz band centered at 12 Hz.



Thus this paper investigates which 5Hz bandwidth within 5-35Hz band contain significant information related to left hand and right hand imagination with respect to the rest state. That is, the previous systems use the whole 0-35Hz band and features are extracted from that band. However, if a narrow 5 Hz bandwidth within this whole band could be identified as carrying significant information then that would enable the feature extraction process to use only that 5 Hz bandwidth signal unlike in the previous case where the whole 0-35 Hz bands are used. Thus this analysis is focused to identify the most important band for efficient feature extraction. In one of the previous work [4] the band selection is studied but their objective is to increase the bands that can add information but our objective is to identify the band that has most significant information.

For this, different filters were used with different frequency bands of 5Hz bandwidth and checked for whether there is any difference between left hand and right hand imagination with respect to the rest state.

Furthermore in this study C3 and C4 channels among 59 channel system are checked, because those channels are highly related to left hand and right hand movements [1].

II. Database

Internationally recognized BCI competition IV dataset C ("BCICIV_calib _ds1c") is used to analyze the results. In that dataset BCICIV_calib_ds1_c, healthy subject has done left hand and right hand imagination with 59 channel system [5].

The dataset is extracted as Class1, Class2, Class10 and Class20. Where Class1 corresponds to right hand imagination and Class10 corresponds to rest state before right hand imagination. Likewise Class2 corresponds to Left hand imagination.

III. Method

filter selection analysis

The signal is fed through the band pass filters. For this purpose a low pass filter and high pass filter were made separately to make a band pass filter. The signal was filtered by low pass filter and then it was sent through the high pass filter to get the band pass response for different frequency bands.

From IIR filters Butterworth, Chebychev type I & Chebychev type II filters responses were checked in this paper to determine which performs well for this classification.

IV. Results

As mentioned in section 3, average energies for each case were calculated and plotted in Fig.III.

Fig.III shows channels C3 and C4 responses in columns of the figure, and the different filter responses as rows. In Fig.III, it is clearly visualized that 5-10Hz band pass filter responses give better response than other band pass filter bands.

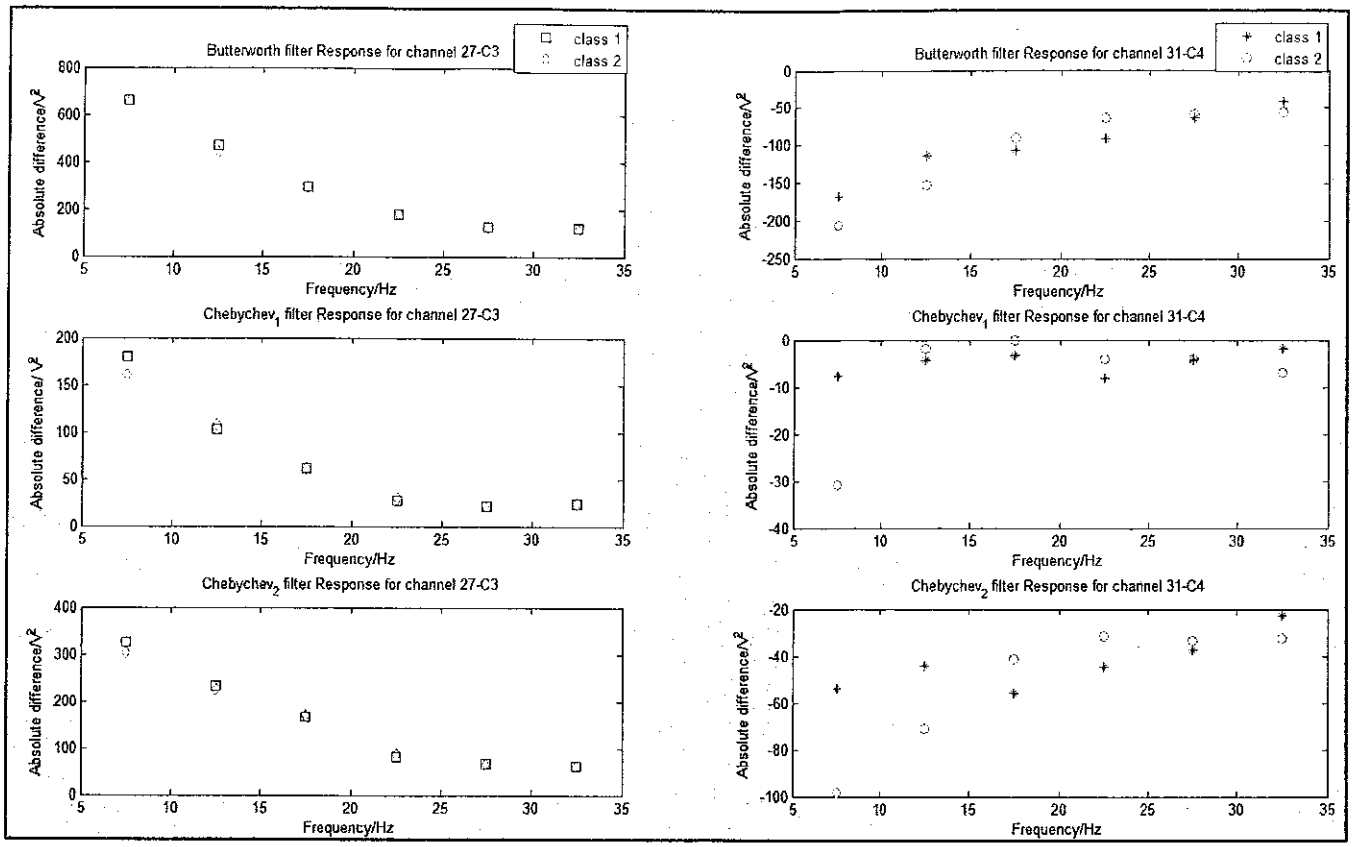


Figure III: Results of subject data corresponds for BCI competition IV dataset c for two classes of motor imagery such as right hand (Class-1), left hand (Class-2) imagery from Band pass filtering with two channels C3 & C4

Table.I: Difference between average energy of filtered Class1 $(A-E\ of\ class1_{F1C3_{abs}})$ and average energy of filtered Class2 $(A-E\ of\ class2_{F1C3_{abs}})$ across different IIR band pass (5-10Hz bandwidth) filters responses.

Filters	Channel C3 energy difference between filtered class1 & class2	Channel C4 energy difference between filtered calss1 & class2
Butterworth	10.8550	37.7356
Chebychev Type I	20.3574	23.2776
Chebychev Type II	20.4399	44.1898

Therefore 5-10Hz band is selected and then average energy difference between class1 and class2 is obtained and shown in Table. I.

In Table. I for instance take row as Butterworth filter and column as Channel C3 Energy difference between filtered Calss1 & Class2 /A-E, then the value 10.8550 is calculated as

$$(A-E\ of\ class1_{B1C3_{abs}}) - (A-E\ of\ class2_{B1C3_{abs}}) = 10.8550$$

Where

$(A-E\ of\ class1_{B1C3_{abs}})$ = Average energy difference between 5-10Hz Butterworth band pass filtered Class1 & Class10 with channel C3.

$(A - E\ of\ class2_{B1C3_{abs}})$ = Average energy difference between 5-10Hz Butterworth band pass filtered Class2 & Class20 with channel C3.

$(A - E\ of\ class1_{B1C3_{abs}})$, $(A - E\ of\ class2_{B1C3_{abs}})$ are calculated separately from equation (4).

Fig.III has shown overall 5-10Hz region performs well. For Channel selection channel C4 is better choice for separation of class Vs class2 compare to channel C3.

From the Table.I Chebychev type II filter performs well from the highest difference of 44.1898. It could be because of the steeper roll-off and flat pass band with no ripples response of Chebychevtype II filter.

V. Conclusion

Any natural way of interaction with the environment is lost for people who are severely paralyzed. Brain–computer interface (BCI) is the only option for communication in such case. It is found that Chebychev type II filter provide better separation. Further 5-10Hz band is found to contain more information related to left hand and right hand imagination respect to the rest.

In future, only the channel C4 data could be filtered with 5-10Hz band pass Chebychev type II filter for classification. This reduces the time for training the patient such as reducing the number of electrodes and the noise created by other unwanted thing.

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