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Classification of EEG Signals in BCI

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Abstract—A Brain Computer Interface or BCI is an emerging technology that targets to directly convey intentions of people to the outside world from their thoughts. This works as a promising tool for normal people to improve the way of communication with machines or computer systems and it can also be used for helping those people who are physically disabled. BCI has introduced not only the dimensions in machine controlling terminologies but also it has shown a bright way to researcher around the world to explore the possibilities to use this new growing technology in real life applications. It has driven anticipation to researcher that an alternative to communication can be provided for those people who are physically disabled. In this paper we are going to present a brief idea about classification of EEG signals used in BCI and the accuracy of the method of classification implemented. The methods which are used for pre-processing of the raw EEG signals will also be discussed as it can enhance the quality of input data for classification so that we can get more accurate results.

Keywords- BCI, EEG signals, Pre-processing, Classification, Independent Component Analysis, Support Vector Machine.

I. INTRODUCTION

A brain computer interface serves as an efficient technology which provides new dimensions in the field of human computer interaction. It avails new capabilities to the physically challenged people in terms of controlling computers and machines. It provides new communication channels to such people to make their life comfortable in spite of being paralyzed. A BCI system makes use of some neuro imaging techniques to capture the neural activities of brain corresponding to the thoughts generated in one's mind. Electroencephalography (EEG) is one of those widely used invasive neuro imaging techniques. EEG measures the electrical activity of the neurons along the scalp corresponding to the mental state (thoughts) of a person at that moment. The electrode placement is shown by following figure [1].

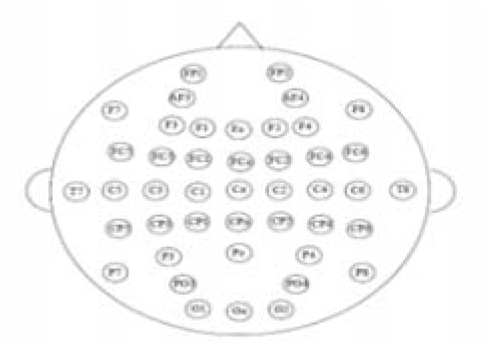

Figure 1:Electrode placement [1]

A BCI system works as a sequence of following four steps acquisition of brain signals in the form of EEGis the very first activity taking place in such a BCI system. The acquired signals are filtered by using some pre-processing techniques to remove odd noisy artifacts from the original data. The pre-processed signals are subjected to the classification activities. Classification refers to mapping of pre-processed EEG data to the corresponding mental task.

The computer interaction step can make use of such classified data to perform its intended functionalities. The following figure shows the basic steps [2].

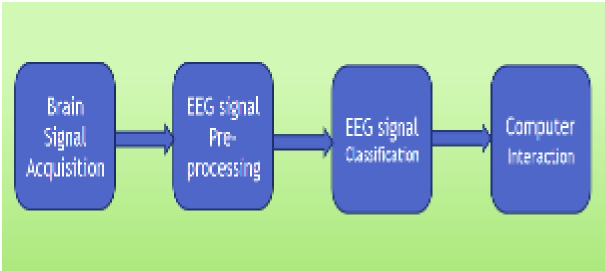

Figure 2: BCI common structures [2]

The paper aims at pre-processing and the classification of acquired EEG signals by using ICA for pre-processing and SVM for classification purpose and to evaluate the performance of final classified signals in terms of classification accuracy.

We have used the data set available on BCI competition II provided by university of Tuebingen for classification purpose [3]. They have provided a two class date set. The data set was taken from a healthy subject. The cortical potentials of the subject were recorded when the subject was asked to move a cursor up and down on a computer screen. Cortical positivity and negativity corresponds to downward and upward movement of the cursor respectively. Data set contains training data of 268 trials in the form of two files each trial labeled with its class. The test data consist of 293 trials with the class labels provided in separate file.

II. PRE PROCESSING

The EEG data thus acquired contains several noisy patterns and other signals also .Hence the data needs to be pre-processed in order to use it for further steps of a BCI system. A better pre-processed data promises better result in classification. For the pre-processing purpose we use the

Independent Component Analysis (ICA) [4].

Independent Component Analysis decomposes the mixture signal into independent components with the assumption that the mixture signal is a linear combination of several Independent components and both measured and independent signals are equal in number. If x is the mixture signal pattern, A is mixing matrix and s is the original source. Then

$$x=As$$

If we can calculate the inverse of A the s can be estimated from the following equation

$$s=A-1x$$

We have used EEGLAB toolbox of MATLAB for implementing ICA on the data. EEGLAB toolbox provides a better user friendly Graphical User Interface (GUI) [5] which avails many facilities to the user allowing the user to process their high-density EEG data and other non-static brain data with better flexibility and interactivity. The toolbox contains in-built function runica() for the ICA algorithm. The EEGLAB toolbox provides the facilities to export the weight matrix as well as the pre-processed data in the specified file format.

To pre-process the whole training data in one run of ICA we have merged both the files of training data obtained from BCI competition II [3] making a single file of 268 trails and have saved the class labels in a separate file. The file now represents a matrix of 268*5376 dimension that is used as matrix x. x is used in the EEGLAB toolbox to run ICA algorithm on it by providing the basic parameter of the data. Thus form x and A the EEGLAB toolbox provides an estimation of s which is the original source signal with reduced noise.

Before running ICA algorithm the Scroll Channel Activities of the raw data are as shown by the following plot

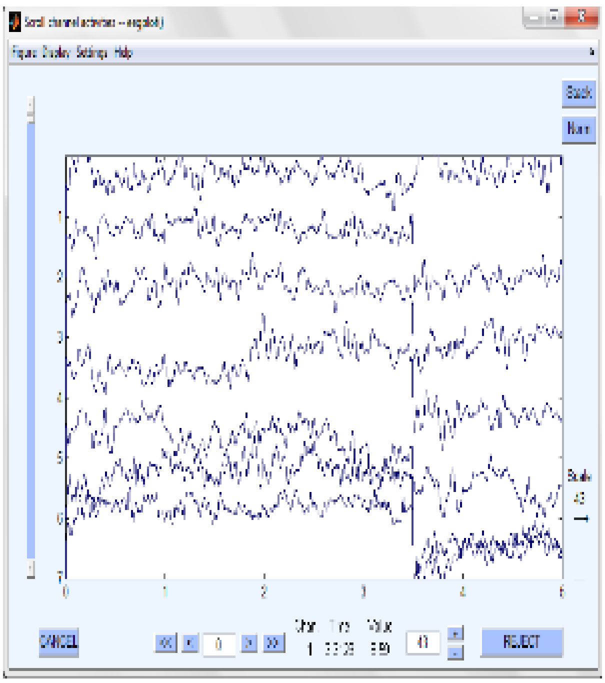

Figure 3: Scroll channel activities of the training data (Norm)

After running ICA algorithm the Scroll Channel Activities of the raw data are as shown by the following plot

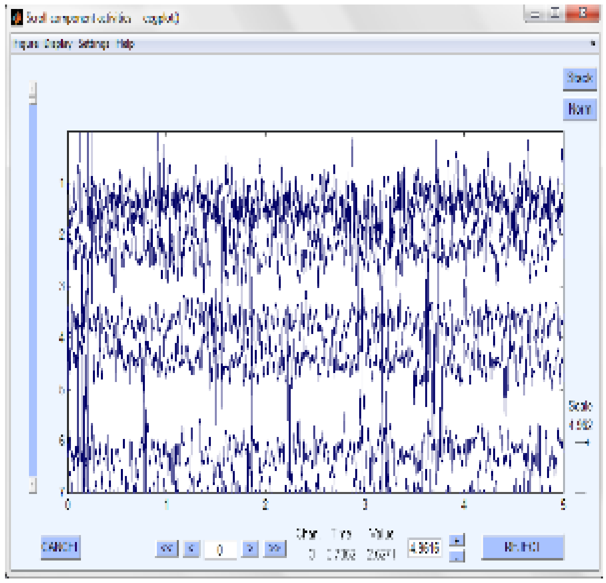

Figure4: Component activation plots of pre-processed training data (Norm)

In this way the raw data is pre-processed and the noise is eliminated from the data after applying the ICA on input data.

III. CLASSIFICATION

To use BCI in real time application the key issue is the classification accuracy. Classification refers to the mapping of the EEG signals to the corresponding mental tasks .This mapping is a difficult learning task because of the noisy nature of EEG data (Lee et al. 2005; Thulasidas, Guan, and Wu 2006))and the varying attention of the subject resulting in dynamic mental states even in a very short period of time.

For the classification purpose we have used Support Vector Machine algorithm. Support Vector Machine (SVM) can be used when the data has exactly two classes. SVM finds a separating best hyper-plane to classify the data in two classes. A best hyper-plane refers to a hyper-plane with the maximum margin.

The support vectors are the data points that are closest to the separating hyper-plane, these points are on the boundary of the slab[6].

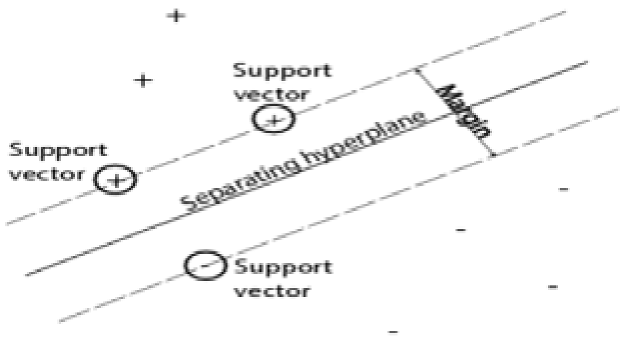

Figure 5: Support vectors and the separating hyper-plane [6]

We have used Bioinformatics Toolbox of MATLAB to implement SVM on the pre-processed data. The Bioinformatics Toolbox comes with two inbuilt function that aresvmtrain() and svmclassify() used for learning and classification respectively. The svmtrain() function constructs a structure i.e. struct from the pre-processed training data with provided class labels of the training data. svmclassify() uses that struct to classify the test data. The

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test data is in the form of a text file with 293 trails hence forming a matrix of 293*5376 dimensions. We run ICA on the testing data with the same as done with the training data. Thus pre-processed data is used for the classification purpose in svmclassify() method. The svmclassify() predicts the labels of the pre-processed testing data with the help of model struct obtained in the learning step with training data.

The whole process of classification takes place as shown in the following figure [7]

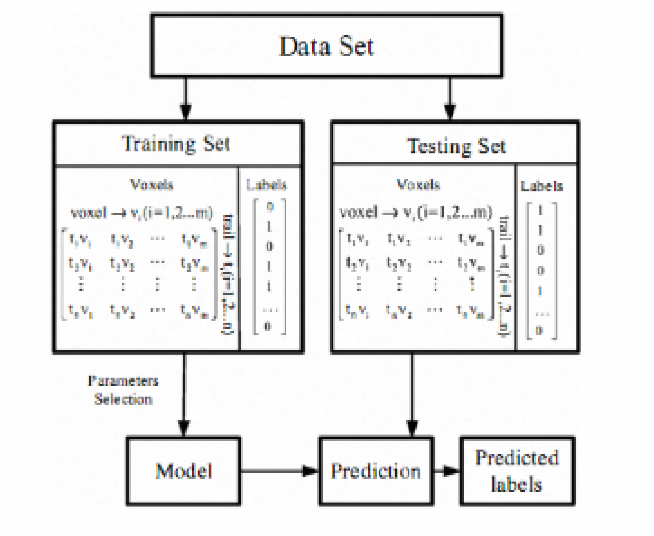

Figure 6: The complete classification process [7]

IV. RESULT

We have applied ICA on provided training data and testing data for pre-processing purpose after that we have used SVM for classification on both. As result of training a structure is constructed that is used for the classification of test data of 293 trails. After classification we get result accuracy about 85% on test data as for 293 trials, the class of 249 trials matched as per given results. So,

$$\text{Accuracy} = \frac{249}{293} * 100$$

$$\text{Or Accuracy} = 84.98\ \%$$

$$\text{Therefore, Error} = 15.01\ \%$$

V. CONCLUSION

Thus ICA for pre-processing and SVM as classification algorithm serves as a better combination for efficiently classifying the given EEG data. This paper deals with two class data set. In the same way better classification results can be obtained in case of multiclass data set also using appropriate algorithms of pre-processing and classification which can be further facilitate several real time BCI based applications.

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