Motor Imagery Signal Classification Using CNN With Application For Brain Computer Interface

Sanjay Ganorkar, Bruhaspati Mane, Supriya Rajankar, Vrushali Raut

Abstract:A Brain Computer Interface gives a way to link human mind and the computer machine. EEG collecting Modulations corresponding to Motor Imagery are the input to brain computer Interface. The signal captured by non-invasive method like EEG is contaminated and thus is difficult to classify. In this paper matrix of seven statistical features is passed to Convolution neural network (CNN) for classification. Thus, it acts as input to three-layer CNN which consist of convolution, subsampling and fully connected layers. This method is adventitious as provides better accuracy and is manageable in less memory.

Index Terms:*Electroencephalography (EEG), Motor Imagery, Event Related De-synchronization (ERD), Brain Computer Interface (BCI), Convolution Neural Network (CNN), Discrete Wavelet Transform (DWT)*

1 INTRODUCTION

A brain computer interface (BCI), also termed as mind-machine interface (MMI), or direct neural interface (DNI) is an immediate pathway between an improved or wired person and an external contraption. This era is consistently gone for investigating, mapping, helping, broadening, or fixing human scholarly or substantial motor limits. Research on interfacing the brains started in 1970 under the permission of the National Science Establishment, and further contracted from DARPA. Hans Berger's captured the rhythmic activities of human brain activity by employing EEG in 1924 and observed alpha rhythm (8-13Hz) from EEG recordings. This research field is primarily focused on neural prosthetics applications for restoring hearing and sight loss advancement. Considering the amazing neocortical malleability of human brain, acquired brain signals, after alteration, be utilized to interact with outside world. The advances have been made during last decade does contributes to BCI field. Because of the remarkable growth of computing devices, and also, due to an upgraded knowledge of human brain activities became the prime motivation for most researchers. The detected signals can be utilized to handle an artificial limb, or a wheelchair, or a word processor, by catering the person with interaction channels which was cut-off by the disease or accident. This It also be used for handling a moving the cursor on screen, or a spelling device, controlling the neuroprosthetics and other similar devices by thinking only.

2 LITERATURE SURVEY

Leuthardt et al. [1] focused on retrieving the brain signals using Electrocorticographic (ECoG) methodology. It was observed that signals recorded using EEG has lower spatial resolution and those recorded using ECoG methodology gives more resolution of spatial aspect and increased amplitude.

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They developed a BCI that controlled the movement of one-dimensional computer screen cursor by executing the motor imagery actions. The electrode grids were implanted for 3-8 days over the sensorimotor cortex. The frequency bands related to different actions were identified and it was observed that the accuracy of control was increased to 74-100% after the users were given a training of 3-24 minutes. A brain actuated wheelchair using P300 brain signal with automated navigation was developed by Iturrate Iaki, et al. [2]. When in use, the user is provided with the real time reconstruction of scenario in front of the eyes on a display. Then person points his attention on the location where he wants his wheelchair to be driven which elicits the P300 signal and with the help of signal processing the target location is identified and passed to the automatic navigation system and then wheelchair is guided to desired location. Laser scanner is also used to detect any obstacles in the path thus avoiding path collisions. Once location has been determined, the user then can relax by not involving himself in any exhausting mental process. An alternative to EEG based BCI due to low SNR was proposed by Lal Thomas Navin, et al. [3]. The proposed system is BCI based on electrocorticography (ECoG). In this study they took three epileptic patients and signals were recorded by placing the electrode grids on the motor cortical region of human brain. For experimentation, the patients were told to imagine finger or tongue movements and results were recorded. For classification a Support Vector Machine (SVM) is used along with Recursive Channel Elimination (RCE). An effective study to develop BCI which relied on event related de-synchronization or synchronization (ERD/ERS) was proposed by Huang Dandan, et al. [4]. ERD/ERS is studied with the help of EEG which corresponds to motor execution/motor imagery movements of left/right hand. Synchronous activity of neurons lead to low SNR which has reduced the accuracy of BCI built using EEG. This encouraged the research groups to find more reliable features that helped to understand the thoughts of the subject more accurately. The ERD that suppress or attenuates the EEG signal power in the corresponding part of the brain when engaged in either actual physical task or just the imagery action. This result helps in understanding of which particular region of the brain is activated at a particular point of time. Rebsamen Brice, et al. [5] designed a mind-controlled wheelchair using P300 signal. Electrodes are attached to a cap which in turn is connected to a computer system that is responsible for amplifying, digitizing and filtering the recorded signal from the scalp. The user is provided with two types of stimuli, the first one is a desired stimulus and the second signal is a non-desired stimulus. The system uses virtual oddball paradigm. Using P300, extensive training is not necessary for the subject. Stimuli are randomly flashed on the screen and the subject has to concentrate on the desired input eliciting the P300 signal. Once detected it is sent to the computer where it is amplified and cleaned using desired filtering techniques. Curran Eleanor A. and Maria J. Stokes [6] have conducted research on the cognitive tasks and other activities to observe the changes in the EEG of the subject. They found that till now motor imagery is the best task that helps in driving the BCI. In one study a group of five healthy subjects was taken and they performed different motor imagery tasks. The task is to imagine the movement of right and left middle finger for 10 seconds and to perform these actions in real for 10 seconds each. The setup involved 26 surface electrodes, arranged according to 10-20 international system. With this experiment it was concluded that 6-9 electrodes when placed on fronto-centro-parietal region of the brain which is enough to determine the cognitive states of imagined movements.

3 SYSTEM IMPLEMENTATION

The working of implemented system is described using following figure 1. Input: The captured EEG is signal is the input for the system. Pre-processing: At this stage signal is cleaned thus removing the artifacts and sliced into frames having only Motor Imagery Information. For removing noise low pass and notch filter algorithms are used. Wavelet Decomposition: The processed signal is decomposed into sub-bands of frequencies to extract the µ-band and β-band The signal is decomposed upto three levels using Daubechies mother wavelet. Feature extraction: Sub-band coefficients of the decomposed signals are used for calculating the statistical and higher order statistical features. Mean and standard deviation kurtosis and skewness acts as the features covering dynamic of the signal. Classification: Minimum distance algorithm and CNN are the algorithms used for classification. Predicted class: This class depends on movement of cursor control i.e. direction of cursor in left, right, up, down direction. Application Interface: According to the predicted class we can use it to trigger an action like mouse control, hand movement etc.

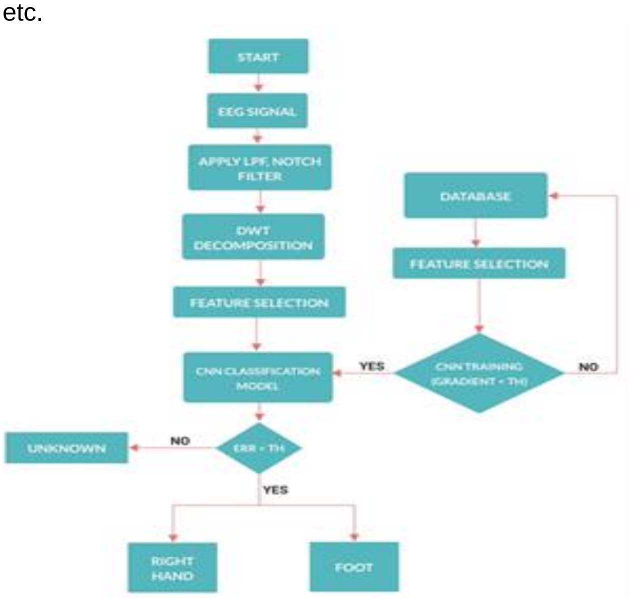

***Fig. 1**. System Implementation*

4 RESULTS

The following Filtered signal is observed after applying FIR Low Pass and Notch Filter.

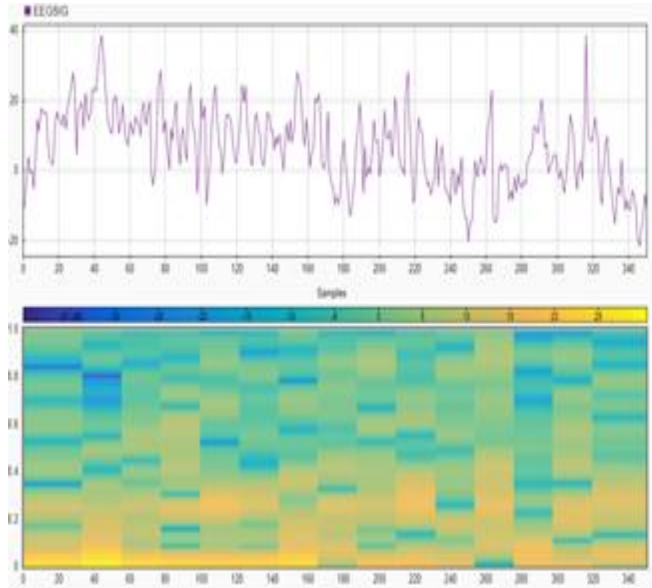

***Fig. 2**. Original Signal*

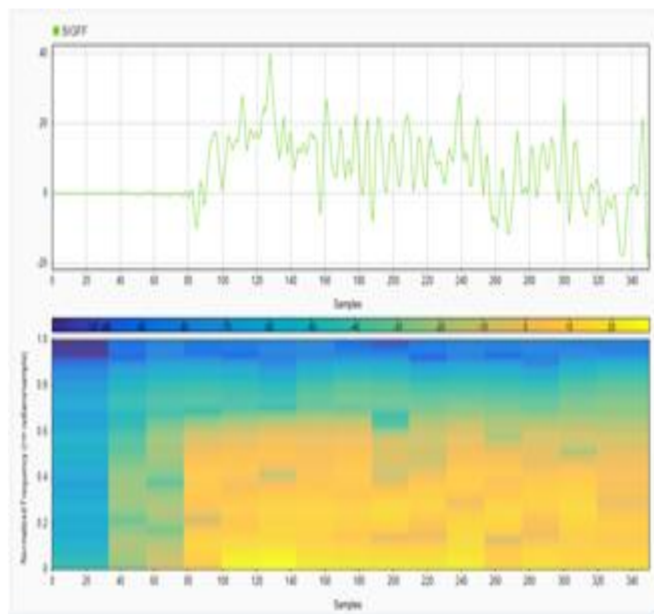

***Fig. 3.** Filtered Signal*

The filtered signal is then decomposed using Daubechies (dB02) Wavelet shown in figure 4.

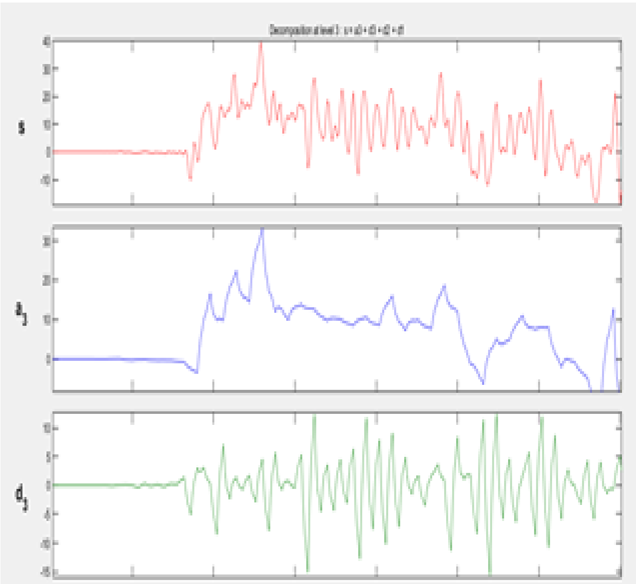

Fig. 4. *Three Level DWT Decomposition of EEG Signal*

Figure 5 shows, on of the sample signal used for the testing of the model, which predicts intended movement based the past inputs provided during training phase. Figure 6 shows time-frequency graph of the predicted sample signa

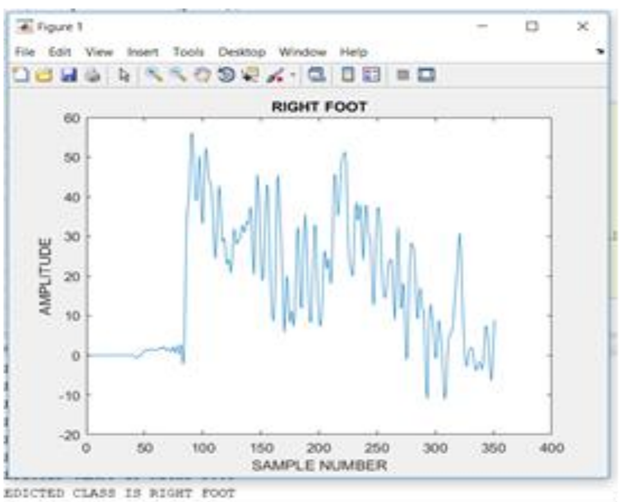

Fig. 5. *Right Foot Classification*

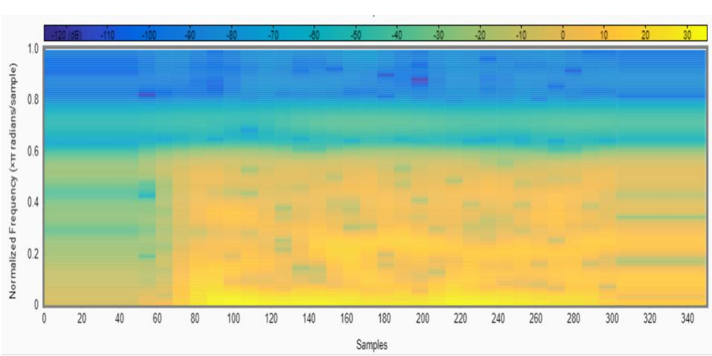

Fig. 6. *Right Foot Spectrogram*

Table 1 compares the accuracy of previously implemented systems with proposed method.

TABLE 1

COMPARATIVE ANALYSIS OF PROPOSED SYSTEM

Methods	Accuracy
CNN (Proposed)	83.15%
Gaussian SVM (BCI-Competition-III)	78.57%
Polynomial SVM (BCI- Competition-III)	80.35%
KNN (BCI Competition-III)	80%

5 CONCLUSION

The BCI is used to provide the intercommunication between the computer systems i.e. smart system and the human brain. This can serve to person with critical motor impairments as a fully capable BCI works without any muscle activity. Artificial Neural Network approach called as CNN used for classification in this work. Features passed to classifier are the higher order statistical features obtained using wavelet decomposed signal. The proposed model achieved the maximum accuracy of 83.14% and average accuracy of 79.85%. Processing of signals and model training is done on MATLAB to predict the right hand and foot imagery movement. The BCI Competition III - dataset IVa is used for this study, one of the major contributors in BCI research domain.

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