POST STROKE REHABILITATION USING BRAIN-COMPUTER INTERFACE AND MOTOR IMAGERY

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Abstract—Brain-Computer Interface (BCI) is a mechanism that helps in the control/communication of one’s environment through the brain signals obtained directly from the brain via an EEG signal acquisition unit. A BCI incorporating Motor Imagery for post-stroke rehabilitation of upper limbs and knee in fully disabled patients is designed. It helps in restoring some of the activities of the daily living. It aids post-stroke sufferers to carry out functionalities like movement of right and left hands, right and left knee, grabbing things, etc. Till now, the post-stroke rehabilitation is possible in partially impaired patients. The therapy was given to the damaged cortical area in the brain directly by the therapist moving the hand of the patient. This is not suitable as it requires the presence of therapist, can be done only in a hospital leading to high cost, muscle fatigue, slow recovery of the damaged area. In this paper, a survey of various BCIs is done and an optimum design is devised. Also the overall accuracy of the system is calculated to be approximately 91%.

Keywords—Brain Computer Interface, Motor Imagery, Support Vector Machines.

1. INTRODUCTION

In today’s world, it is possible for the paralyzed people to interact with the environment as a normal person. They are able to carry out some of their activities of daily living on their own. The advance of technology has brought this into a reality: Humans can use the electrical signals from brain activity to interact with, influence, or change their environments. This technology commonly known as the Brain-Computer Interface is an emerging field where new applications are being developed. The available methodologies for the design of BCI are many and it is the designer's decision and knowledge in this area that leads to the most comprehended design which takes care of all the existing short-comings and improve the working and the use of the BCI.

2. EXISTING METHODS

The Brain-Computer Interface (BCI) includes acquisition of brain signals, band-passing the acquired signals to obtain the significant frequency band, extracting the feature vectors corresponding to the concerned activity and using these to classify the incoming brain signals. This can be given as a command signal to an assistive device like a wheel chair, computer keyboard, mouse, robotic hands or sensor attached shoes to carry out the action. In the present scenario, either the therapist gives the simulated signal corresponding to an action or the brain waves of the patients when they move their eyelids in a trained way is used to carry out the action. Yet in some BCIs, the partially impaired patient is asked to do the action with healthy hand and the corresponding signal is processed to carry out the action for the other hand. Usually Electroencephalography (EEG) is used to acquire signals from brain due to its reliability when compared to other signal acquisition methods. This is band-passed using any of the available filters like Butterworth band-pass filter, Chebyshev filter or using window functions like Hamming window, Hanning window etc to get the concerned frequency band where the brain activity is maximum during an activity. The features are obtained by taking either power spectral density or log-variance or any method that distinguish the variation in the brain rhythm during the concerned activity. The various feature extraction methods available include Principal Component Analysis (PCA), Linear Discriminant Analysis (LDA), Fisher’s Discriminant Analysis (FDA) etc. Classification algorithms used in BCI designs include linear classifiers like Support Vector Machine (SVM), neural network classifiers, non-linear Bayesian classifiers etc. Thus there are many methods available at each step of BCI design and choosing the best methodology to get better classification accuracy is a difficult task. Till now; the post-stroke rehabilitation is possible only in partially impaired patients. Most of the existing designs focus on the rehabilitation of upper limbs and classify feature vectors between any two movements. The therapy is given to the damaged cortical area in the brain by moving the hand of the patient. This is not suitable as it requires the presence of therapist and can be done only in a hospital leading to high cost, muscle fatigue, slow recovery of the damaged area etc. This also leads to patients discontinuing the rehabilitation programme and only partial recovery is attained in post-stroke patients. At present, the
striking achievements of BCI research and development remain confined almost entirely to the laboratory, and the bulk of work to date comprises data gathered from able-bodied humans or animals. Studies in the ultimate target population of people with severe disabilities have been largely confined to a few limited trials closely overseen by research personnel. The translation of the exciting laboratory progress to clinical use, to BCI systems that actually improve the daily lives of people with disabilities, has barely begun. This essential task is perhaps even more demanding than the laboratory research that produces a BCI system. It must show that a specific BCI system can be implemented in a form suitable for long-term independent home use, define the appropriate user population and establish that they can use the BCI, demonstrate that their home environments can support their use of the BCI and that they do use it, and establish that the BCI improves their lives. This work requires dedicated, well-supported, multidisciplinary research teams that have expertise in the full range of relevant disciplines, including engineering, computer science, basic and clinical neuroscience. Brain-Computer Interfaces may eventually be used routinely to replace or restore useful function for people severely disabled by neuromuscular.

3. METHODOLOGY

The methodology followed in this paper combines the advantages of frequency sub-bands and channel selection using common spatial pattern algorithm. In the proposed method, the movement is evoked by the zero-mobility patient directly by imagining the movement. Motor imagery corresponds to a set of EEG signals generated in the sensory motor cortex area of the brain when the person is imagining a movement. This set of EEG signals usually lies in the mu-beta range (8-30 Hz). These EEG signals corresponding to the upper limbs and knee movements are used in this work. The datasets are first divided into trial and test datasets. The trial datasets are used to design the BCI by assuming that the classes are known beforehand. The trial datasets are first passed through a band pass filter bank to separate it to a sub-band of 4 Hz each in the frequency range 4-40 Hz. Here a filter bank of Gabor band pass filter is used which has a centre frequency of 4 Hz and the range is from 4-40 Hz. Thus 9 sub-bands are obtained at the end of this stage. Each sub-band is then passed through Common Spatial Pattern algorithm (CSP) to select the optimal subset of channels where relevant information is found. This is done by sorting out the CSP coefficients. Out of 118 channels used in this case, 2 channels were selected based on the condition that the coefficients should have maximum variance ratio among the classes.

The design is verified for 100 datasets each of left hand, right hand, right knee and left knee imagined movements. This can be further used to drive the assistive devices like wheelchairs, mouse etc. Thus, communication of paralyzed people with the external world is made possible. This type of classification is known as supervised classification. After training, a SVM model is created. SVM model uses a hyperplane to classify the feature vectors. The feature vectors above the hyperplane are classified as one class and the feature vectors below the hyperplane is classified as the other class. This model is used to classify the test datasets, i.e; the test dataset is first passed through the filter bank, optimal subset of channels are selected by passing through the CSP, feature vectors computed, dimensionally reduced and finally classified. Using this design, the recovery of damaged area of brain is faster as the patient himself is carrying out the therapy. This method is further extended to knee movement. Thus a four class implementation of the motor imagery classification is made – the designed BCI is capable of distinguishing the left hand, right hand, left knee and right knee imagined movements.

4. RESULTS

The design is verified for 100 datasets each of left hand, right hand, left knee and right knee imagined movements. Further the accuracy of the whole system is measured in terms of the movement achieved versus the desired movement. The accuracy of the design obtained while distinguishing left hand imagined movement from the rest was 90%, right hand imagined movement from the rest was 93.33%, left knee imagined movement from the rest was 92% and right knee imagined movement from the rest was 88.89%. The overall accuracy of the designed BCI was 91.11%.
Using this design, zero-mobility patients can be rehabilitated at home. This reduces muscle fatigue as the patient is doing the task and necessary breaks, as and when required, can be taken. Also there is no need of a therapist or heavy hospital equipments to give simulated signals. The cost of rehabilitation is reduced and more movements are included in the rehabilitation programme. Since the rehabilitation programme can be continued at home with simple equipments, there is more chance for the patient to complete the programme and complete recovery of the patient can be ensured. Further, this work can be extended to include visually evoked potentials along with MI signals. Here the patient is trained to blink once or twice when imagining a particular movement and the signals corresponding to both the activities can be used to classify the activities to one of the concerned actions. By doing so, it is assumed that the classification will be a lot easier and the chances of error is minimized but at the cost of more intermediate processing steps.

In this paper, the datasets obtained from BCI competition IV were used. There were 400 datasets comprising right hand, left hand, right knee and left knee motor imageries. The datasets were divided into trail and test sets.

**REFERENCES**


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