Classification of EEG Signals based on Neural Network to Discriminate Five Mental States

Vijay Khare, Jayashree Santhosh and Sneh Anand

Abstract-- **This Paper demonstrates the comparison of performances by five artificial neural network (ANN) training methods for classifications of five mental states. Wavelet packet transform (WPT) was used for feature extraction of the relevant frequency bands from electroencephalogram (EEG) signals. The five ANN methods used were (a) Gradient Descent Back Propagation (b) Levenberg-Marquardt (c) Resilient Back Propagation (d) Conjugate Learning Gradient Back Propagation and (e) Quasi Newton Method.**

Index Terms--**Electroencephalogram (EEG), Wavelet Packet Transform (WPT), Artificial Neural Network (ANN), Levenberg-Marquardt, Resilient Back Propagation, Conjugate Learning Gradient Back Propagation, Gradient descent BP.**

I. INTRODUCTION

BRAIN computer interface (BCI) designs are very useful for individuals to communicate with their external surroundings. This is specially true for the paralyzed. Brain signals extracted through EEG carry information needed for the design and development of Brain Computer Interface (BCI) systems. It is well documented that proper feature extraction and classification methods are the key features deciding the accuracy and speed of BCI systems. ANN has been more widely accepted as one of the best classification method to distinguish various mental states from relevant EEG signals [1-5].

In this study a feature vector representing the unique EEG characteristics to differentiate the five mental tasks. The coefficients of wavelet packet transform (WPT) were used as the best fitting input vector[6-8]. Five various artificial neural networks (ANN) training methods were used to compare the performance in classifying the five mental tasks.

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II. METHODS AND MATERIALS

A. EEG Recording

EEG data used in this study were collected by Keirn and Aunon using the following procedure shown in figure1. The subjects were seated in a sound controlled booth with dim lighting and noiseless fans for ventilation. An Electro-Cap elastic electrode cap was used to record from positions C3, C4, P3, P4, O1, and O2, defined by the 10-20 system of electrode placement. The electrodes were connected through a bank of Grass 7P511 amplifiers and band pass filtered from 0.1–100 Hz. Data was and recorded at a sampling rate of 250 Hz with a Lab Master 12 bit A/D converter mounted in an IBM-AT computer. Eye blinks were detected by means of a separate channel of data recorded from two electrodes placed above and below the subject's left eye[9].

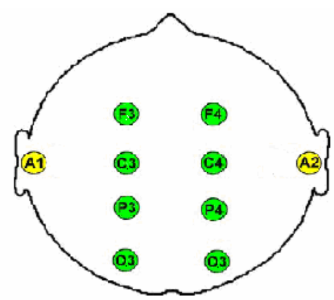

Fig. 1. Montage showing electrode placement.

For this paper, the data from four subjects performing five mental tasks was analyzed. These mental tasks were as follows

Relaxed: - The subject was asked to relax with their eyes closed. No mental or physical task to be performed at this stage.

Arithmetic Task: - The subject was asked to performed nontrivial multiplication. An example of such a nontrivial task is to multiply 49 by 78. The subject was instructed not to vocalize or make movements while solving the problem.

Geometric Figure Rotation: - The subject was given 30 seconds to read the complex three dimensional objects, after which the object is removed. The subject was instructed to visualize the object being rotated about an axis. The EEG signals will be recorded during this period.

Visual counting: - The subject was asked to imagine a blackboard and to visualize number being written on a board sequentially.

Mental letter composing task:-the subject was instructed to mentally compose a letter to a friend or relative .since the task was repeated numerous times. The subject was asked to pick up the writing from where it was left off in the previous time.

In all the task, the subjects were instructed not to verbalize or vocalize and not to make any movement. EEG signal for each mental task was segmented into 20 segments with length 0.5 seconds, so each EEG segment was 125 samples in length.

A. Feature Extraction and Classification

The main advantage of choosing artificial neural network for classification was due to fact that ANN's could be used to solve problems, where description for the data is not computable. ANN could be trained using test data to discriminate the feature .The five Different training methods used for Classification in the present study were Gradient Descent method Resilent Back propagation, Levenberg-Marquardt, Conjugate Gradient Descent and Quasi Network .

The frequency spectrum of the signal was first analyzed through Fast Fourier Transform (FFT) method. The FFT plot of signals from all electrode pairs was observed [10]. The change in EEG power was consistently observed. When the mental tasks from all four subjects are considere.it is evident that mental multiplication task is the most important task followed by object rotation and letter writing tasks and finally counting task (least important).basic neuroscience knowledge that one hemisphere of the brain (left) is dominate for calculation while other hemisphere (right) of the brain is dominate for visual tasks [11-14].

For the present study the feature function was formed using wavelet coefficients in the relevant frequency band that gives the best discrimination between the mental tasks. Then these coefficients are scaled and WPT coefficients are used as the best fitting input vector for ANN. Thru wavelet transform we were able to reduce 1 second of EEG data to 16 coefficients. For feature classification a two layer neural networks is used for the instance a topology of {10, 1} indicate a 16 input, 10 neurons in hidden and one output architecture. The neural network was designed to accept a 16 element input vector and give a single output. The output was designed to give 0 for baseline and 1 for task. The mean square error (MSE) is the condition to terminate training is originally set at exp (-4), the number of Epoch is set at 5000 originally. The net is trained for the determined number of epochs. The training is done using a number of learning techniques. Early stopping has been used to prevent over fitting [15 17].

The 40% data remaining was then used to test the trained neural net and the performances were recorded. All data sets were visually checked for artifacts before final selection. The entire analysis of the recorded data was carried out using Matlab® 7.0 from Mathworks Inc., USA.

Performance (R_C) is defined as ratio between correctly classified patterns in the test set to the total number of patterns in the test set in percentage.

$$Rc = \frac{\text{Number of correctly classified test patterns}}{\text{Total number of patterns in the test set}}$$

With the help of above formula we calculate the performance of each method for each task [18].

B. Results

Table 1. showed the comparison of the performance of five neural network (NN) methods in classification of five mental tasks. From this table we can say that in classification For Multiplication and Baseline state "Resilient Back Propagation" method has highest performance (95%).For Letter composition and Baseline state "Resilient Back Propagation" and "Variable Learning Rate" method has highest performance (90%). For Rotation and Baseline state "Resilient Back Propagation" method has highest performance (90%). For Counting and Baseline state "Resilient Back Propagation" method has highest performance (90%).

TABLE I
Comparisons of different NN training methods

Tasks / Methods	Base & multi	Base &letter comp	Base & rotational	Base & counting
Gradient Descent BP	90%	90%	85%	85%
Resilient Back Propagation	95%	90%	90%	90%
Conjugated Gradient BP	85%	80%	80%	85%
GD BP with Momentum	75%	75%	70%	75%
Levenberg-Marquardt	85%	80%	80%	85%

III. CONCLUSION

For the application to the BCI system, it is necessary that EEG Feature related to the human intent were analyzed with EEG signals. Wavelet packet analysis results in signal decomposition with equal frequency bandwidth at each level of decomposition, which leads to an equal number of the approximation and detail coefficients. We further compare the five neural network training methods for the classification of five mental tasks. The NN techniques are gradient descent back propagation, Resilient Back Propagation, Conjugated Gradient BP, Gradient Descent BP with Momentum and Levenberg-Marquardt. We have successfully simulated a system which can distinguish between predetermined mental tasks. Out of five neural networks (NN) method in classification of For Multiplication and Baseline state "Resilient Back Propagation" method has highest performance (95%). For Letter composition and Baseline state “Resilient Back Propagation” and “Variable Learning Rate” method has highest performance (90%). For Rotation and Baseline state “Resilient Back Propagation” method has highest performance (90%). For Counting and Baseline state “Resilient Back Propagation” method has highest performance (90%).

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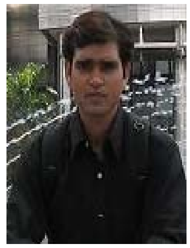
VI. Biographies



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