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Arousal Detection Using EEG Signal

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Abstract
An ANN based classification system for human emotionby using Electroencephalogram (EEG) is proposed in this paper. The data used in this study are features of the EEG. Total three statistical features are computed and feed-forward back-propagation neural network is applied for the classification of human emotion. In the experiment we classify emotion in two classes, high arousal(HA) and low arousal(LA).
Keywords: EEG, Human emotions,ArtificialNeural Network.

Introduction
Emotions are believed to be extremely potential for analyzing condition of mind. Recognition of emotions by physiological means is a subject of interest for both psychologists as well as engineers [1].A classifier is a system that divides data into different classes, and gives the relationship between the features and the emotion that belongs to that part of the EEG signal**.**EEG involves recording and analysis of electrical signals generated by the brain.A considerable amount of research effort has been channeled towards the classification of information about human emotions. Neural networks are used for applications where formal analysis would be difficult or impossible such as pattern recognition and nonlinear identification and control. MATLAB toolbox supports feed forward networks, radial basis networks, dynamic networks, SelfOrganizing maps and other networks. It would be impossible to cover the total range of applications for which neural networks have provided outstanding solutions [2].

Artificial neural network
A typical artificial neural network is made up of a hierarchy of layers, and the neurons in the networks are arranged along these layers. The neurons connected to the external environment form input and output layers. Weights are the basic means of long-term memory in artificial neural networks. A neural network learns through repeated adjustments of these weights. The weights are modified to bring the network inputoutput behavior into line with that of the environment. Each neuron is an elementary information-processing unit [3]. For the feedforward back-propagation networks, the mode of training is supervisory, because the steps in the algorithm involve the comparison of actual outputs with desired outputs associated with the set of training patterns. A feedforward neural network is of two one type is a single layer perceptron and another is a multilayer feedforward neuralnetwork. For the feedforward neural network, the information propagation is only in the forward direction and there are no feedback loops but the errors are back-propagation during training [4].

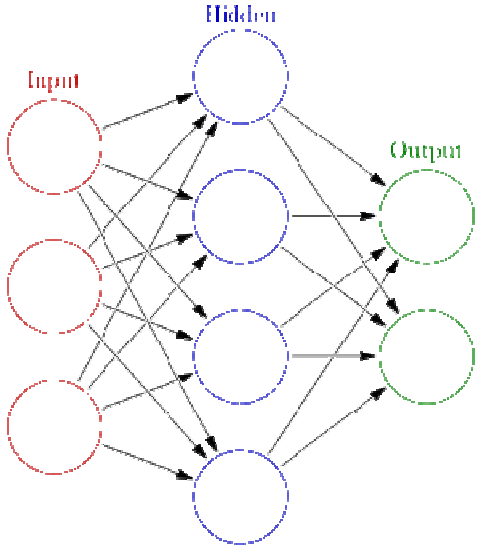

Figure1: Neural network with input layer, hidden layer and output layer

Classification using Neural Network

The neural networktoolbox consists of a set of functions and structures which easily handle neural networks. We can use graphical user interface (GUI) or command-line operations or simple coding by using m-file[6]. Neural networks are very good at pattern recognition problems. A neural network with enough elements (called neurons) can classify any data with reasonable accuracy.

First step design of ANN is to decide the structure of the Multi Layer Perceptron (MLP) network architecture such as the number of hidden layers and neurons (nodes) in each layer. The activation functions for each layer is also to be chosen at this stage. The unknown parameters to be estimated are the biases andweights. Many algorithms exist for determining the network parameters. In neural network literature the algorithms are called learning or teaching algorithms, in system identification they belong to parameter estimation algorithms [5]. The most well-known are back-propagation and Levenberg-Marquardt algorithms. Back-propagation is a gradient based algorithm, which has many variants. Levenberg-Marquardt is usually more efficient, but needs more computer memory. It isbetter to use the multilayer layer perceptron algorithm.

EEG is one of the most important sources of information for emotion classification.After extracting the desired features,these features are entropy of all five subbands i.e. Delta, Theta, Alpha, Beta and Gamma, Variance of all subbandsi.e. Delta, Theta, Alpha, Beta and Gammaand Power of all subbandsi.e. Delta, Theta, Alpha, Beta and Gammafor the signal obtained from Cz, Fz, C3, C4, P3 and P4 electrode of EEG standard 10-20 placement system [6].

In all, we have 30 parameters in terms of entropy, 30 parameters in terms of variance and 30 parameters in terms of power. For two state classification of emotion i.e. High Arousal and Low arousal,in first phase we experimented with five features at a time only say entropy of Delta, Theta, Alpha, Beta and Gamma subbands of electrode Cz. This is repeated for variance and power. In second phase we classified using 30 features say entropy of Delta, Theta, Alpha, Beta and Gamma subbands from all electrodes Cz, Fz, C3, C4, P3 and P4recognition of emotion is done by a suitable classifier.

Steps involved in this process are given below:

1. The input vector is created by taking five/thirty features.Target vector is created by taking 1 for HA and 0 for LA.
2. Create .Mat file of inputvector and target vector with the help of MATLAB.
3. Load the input data and target data in neural network toolbox window.
4. Define the structure of the network, the activation functions, thenetwork parameters.No. of hidden layers =3,
   No. of neuronsin both hidden layers=6
   Neurons in outputlayer= 1
   Training functions =trainlim
   Transfer functionsof both hidden layers=Tansig
   Transfer functions of output layers=Purlin

Weights and biases initialize itself by the network.

5. Create a network
6. Train the network with input and target values.
7. Error is computed from network_error.
   As algorithm for calculation of percentage error is given below:
   I. Roundsof this error to an integer value i.e. 0.78 becomes 1 and 0.36 becomes 0, Obtained from network_error in error data window.
   II. Square the rounded ofvalues so that all the values become positive.
   III. Add all the values.
   IV. A percentage error is calculated by multiplying sum by 100 and then dividedby numberof targets.
   V. Accuracy can be calculated by subtracting it from 100.

Results

In first phase classification is performed by considering entropy of all five subbands of EEG signal using with single electrodefor each the results are shown in Table1.

Table1: Accuracy of classification by entropy

Electrode	% Accuracy				
	Part1	Part2	Part3	Part4	Average
Cz	85%	75%	65%	72.5%	74.3%
Fz	53%	67.5%	62.5%	80%	65.75%
C3	55%	72.5%	67.5%	62.5%	64.37%
C4	70%	60%	50%	70%	62.5%
P3	60%	60%	52.5%	62.5%	58.75%
P4	62.5%	60%	62.5%	80%	66.25%

The results of table 1 are shown as Bar graph in figure1

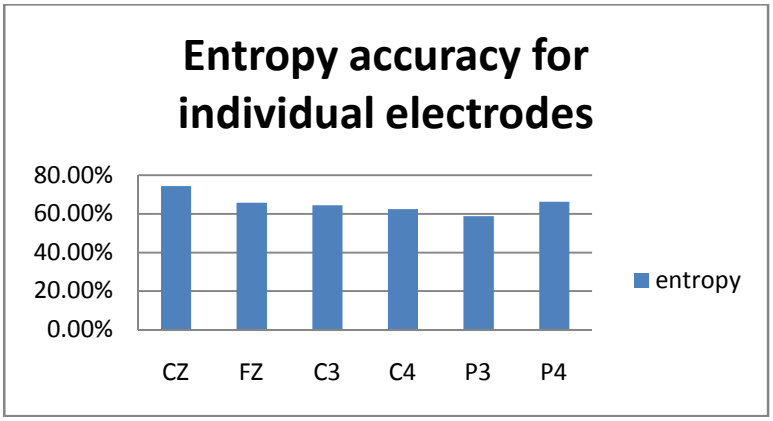

Figure1: Accuracy of classification through entropy

This Classification is then repeated by taking variance as the input feature. The results are shown in tabular form in Table2 and in Bar graph representation in Figure 2.

Table2: Accuracy of classification by variance

Electrode	% Accuracy				
	Part1	Part2	Part3	Part4	Average
Cz	67.5%	70%	55%	60%	63.12%
Fz	60%	62.5%	50%	52.5%	56.25%
C3	77.5%	67%	62.5%	67.5%	68.6%
C4	60%	66%	55%	55%	59%
P3	82.5%	70%	60%	67.5%	70%
P4	50%	66.5%	55%	66.5%	59.5%

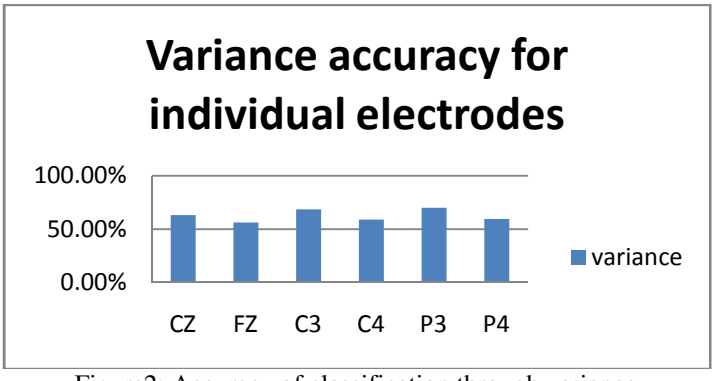

Figure2: Accuracy of classification through variance

Next classification is performed by considering power of all five subbands of EEG signal using with single electrode for each the results are shown in tabular form in Table3, and shown in Bar graph form in Figure3.

Table3: Accuracy of classification of power

Electrode	% Accuracy				
	Part1	Part2	Part3	Part4	Average
Cz	70%	62.5%	50%	55%	59.3%
Fz	67.5%	60%	52.5%	52.5%	58.6.%
C3	70%	55%	67.5%	57.5%	62.5%
C4	50%	65%	50%	57.5%	55.6%
P3	60%	67.5%	55%	72.5%	63.75%
P4	67.5%	57.5%	60%	70%	63.75%

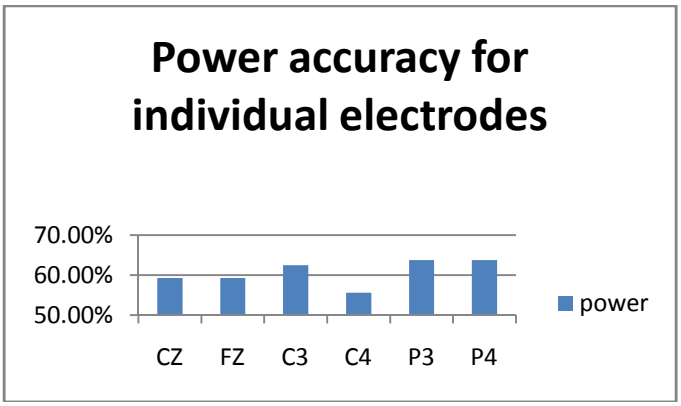

Figure3: Accuracy of classification through power

In second phase classification is performed through all electrode data and the results showthat entropy is the main feature to detect changesin arousal states. Accuracy through entropy is 79.17% which is higher than other two features.

Table4: Accuracy of classification

	% Accuracy				
	Participant1	Participant2	Participant3	Participant4	Average
Entropy	77.5%	80%	80%	79.2%	79.17%
Variance	77.5%	85%	70%	80%	78.12%
Power	62.5%	87.5%	70%	65%	71.25%.

A comparison of all the experiments is given in table 5. And in Bar graph form in Figure 5.

Table5: comprehensive results

Electrodes	Entropy	Variance	Power
Cz	74.3%	63.12%	59.30%
Fz	65.75%	56.25%	59.30%
C3	64.50%	68.60%	62.50%
C4	62.50%	59%	55.6%
P3	58.75%	70%	63.75%
P4	66.25%	59.50%	63.75%
All Electrodes	79.17%	78.12%	71.25%

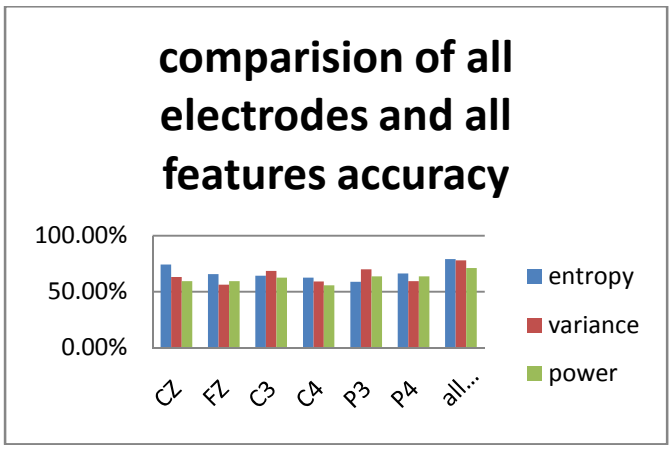

Figure 5: comprehensive results.

Conclusion & Future Scope

1. Of all the three features under considerationi.e.entropy, variance and power, classification of emotion for arousal is best obtained with entropy of all the subbandsi.e. Delta, Theta, Alpha, Beta and Gamma.
2. Though the best classification is obtained by using EEG signals from all six electrodes i.e.CZ, Fz, C3, C4, P3 and P4 to minimize the computational time, a reasonably goodaccuracy is obtained by taking entropy feature of central midline electrode (CZ)alone.
3. A central midline portion of the brain is possibly more involved in arousal.

The classifier designed only two states of emotion, namely Low arousal and High arousal. Other dimensions of emotion like violence and dominance may be added to design a multiclass classifier.

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