Analysis of Visual Colour Perception using EEG Spectral Features

**Analysis of Visual Colour Perception**

**using EEG Spectral Features**

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**ABSTRACT**

Electroencephalography

signals are the

electrophysiological measures of brain function and used

to develop a brain machine interface (BMI). BMI system

is used to provide a communication **and** control

technology for **the** differentially enabled people having neuromuscular disorders. In this paper, a simple BMI

system based on EEG signal emanated while visualizing of different colours has been proposed. The proposed

BMI uses the color visualization tasks (CVT) and aims

to provide a communication link using brain activated

control signal. For each EEG signal**,** using spectral analysis, alpha, beta and gamma band frequency statistical spectral features such as spectral energy, mean spectral energy and standard deviation spectral energy

are obtained. The extracted features are then associated

to different control signals and a probabilistic neural

network model **has** been developed to observe the

classification accuracy of this three features.

***Keywords*-**Spectral Features, Brain Machine Interface,

Colour Visualization Tasks, Neural Network.

I. **INTRODUCTION**

Electroencephalography (EEG) is defined as an electrical

activity recorded from the scalp using surface electrodes

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74

[1]. EEG signals are **the** electrophysiological measures

of brain function. While performing visual, mental and

physical actions, EEG signals are produced. Thus the

difference in EEG signals while performing various

actions helps us to develop a brain machine interface

(BMI). BMI is a system that provides communication link between the human brain and a digital computer. BMI aims to help the people who are suffering with neuromuscular disorders such as paralysis, quadriplegics, amyotrophic lateral sclerosis brain stem stroke, and spinal

cord injury to drive computers directly by brain activity rather than by physical means. In recent years many research works have been carried out in developing BMI

systems and it is mainly involved in recording an EEG

signals using surface electrodes [2]. Many significant

technological advancement have occurred in the past

decade towards developing a BMI, such as using visual evoked potential (VEP), slow cortical potential (SCP),

P300 evoked potential, sensorimotor activity mental tasks

and multiple neuromechanisms [3-6]. Few researchers

have investigated the effect of colour on the EEG signal

activity and analyzed whether different colours affect

can the behavior of EEG signals [7]. Using this

theoretical concept, the BMI using CVT has been

proposed and analyzed to help the differentially enabled

people.

!

In this paper, **a** simple protocol has been proposed for visualization of different colors namely black, blue, cyan,

green, magenta, red, white and yellow. As a preliminary

of the research, these eight colours were chosen as it

emanates high brain activity responses [7]. The features

corresponding to the alpha, beta and gamma bands were...

**Karpagam Jcs Vol**. 6 Issue **2** Jan. Feb. 2012

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extracted from the EEG signals using spectral energy entropy. The extracted features are fed as input to probabilistic neural network (PNN) model. The block

diagram of the proposed BMI system is shown in Figure

1. The rest of the paper is organized as follows: Section

II describes the data collection and feature extraction

method. Section III illustrates the designed network

model and its performances. Section IV and V presents

**the** results and conclusion, showing the potential of EEG

signals derived from vision perception for BMI.

experience in EEG experiments. The subjects were

requested to get seated in a silent room and also requested

not to make any overt movement while performing the

CVT. A 19 channel (FP1, FP2, F7, F3, FZ*,* F4, F8, T3,

T5, C3, CZ, C4, T4, T6, P3, PZ, P4, 01 & 02) electrode

cap was used for recording the brain signals from the

scalp as per the 10-20 system of electrode placement [10]

and the measurements were made with reference to

electrically linked mastoids, A1 and A2. A 19 channel

electrode cap along with the internal 10-20 electrode

positions are shown in Figure 2.

Data collection using Mindset24

Segmentation, ovedapping and Filtering

गु

Feature Extraction usingSpectral Features

Neural NetworkClassifier

π

Brain Machine Interface (BMI)

**Figure 1. Block diagram of proposed BMI system**

**II. FEATURE EXTRACTION**

A. *Protocol and Data Collection*

EEG brain signals were recorded using the Mindset-24

topographic neuro-mapping instrument along with an

electrode cap [8, 9]. This instrument is also called as 1.5

to 34 Hz data acquisition system. Ten healthy volunteers

(10 men), aged between 21 and 25, have participated in

this experiment. All the ten subjects had no prior

**Figure 2. Electrode position from International**

**10-20 Standard** [10**]**

In the experimental study, the subjects were asked to

perform eight different CVTs and their corresponding

EEG signals **were** recorded. All the subjects were free

from illness at the time of EEG recording. Before starting

the data collection, the data collection procedures were

explained clearly to the subject. The subjects were seated.

comfortably in front of a color LCD monitor and were

asked to view the displayed colors. All the ten subjects

were asked to view the colour screen in a relaxed

condition during the data collection. Before starting **the**

real data collection, for each colour task, a sample data

collection was conducted to find the difficulties in

performing the tasks and a feedback was also obtained

from the subjects. Each color was displayed on the color

75

Analysis of Visual Colour Perception using **EEG** Spectral Features

LCD and subjects were asked to visualize each colour, for 10 seconds and the EEG signals were recorded. Before recording the next CVT, the subjects *were* asked to be in a relaxed state for 20 seconds and this process was repeated for all the trails. For each subject, EEG signal was recorded for 10 seconds at a sampling

frequency of 256 Hz [9] and ten such trials session were performed for all the tasks. After completing each.

session, the subjects were asked to sit in a relaxed manner

for 2 to 5 minutes.

*A.* ***Feature Extraction*** *Process*

In this section, feature extraction processes using spectral features are described and carried out. Three spectral features namely spectral energy, mean spectral energy and standard deviation spectral energy were

proposed and analyzed based on the statistical approach

[16]. First the raw EEG data was preprocessed and then feature extraction was performed. The recorded signals

were segmented into number of frames with a

overlapping of 75% [11]. Each frame has 256 samples (corresponding to 1 second). The segmented signals were then filtered using passband elliptic filters and the alpha (7 to 14 Hz), beta (14 to 21 Hz) and gamma (21 to 34 Hz) from all the 19 channels [1, 11]. In this spectral feature extraction process, the filtered data, x) were first Fourier transformed to *X*() using Equation **(1**),

X(m) = [}= x(j) w¥§-OR-0

(1)

where M = is the complex exponential and *N* is the total number of data in the filtered signal. For the Fourier transformed signal (m), the spectral energy (SE) value is calculated using Equation (2),

SE

SF = XX[X(m)]?

(2)

Then the corresponding mean spectral energy (MSE) and standard deviation spectral energy (SDSE) is calculated

using Equation (3) and (4) respectively,

5055 =

MSE

[X=1[X(m)]2 / N

(3)

(4)

―

√N=1&w=1 [X{m} 2 − ¥€m)4]2

where N = 256, is the number of samples.

Similarly, the features corresponding to the CVTS

performed by all the ten subjects (for all trials) were extracted and associated to their respective colour codes.

Each CVT has 57 (19 channels x 3 bands) feature values

and it is given as input to the network model.

**III. NEURAL** NETWORK

To discriminate the colour perception using visualization

tasks, probabilistic neural network (PNN) has been

developed. PNN is a supervised neural network proposed

by Donald F. Specht [14, 15] and it is a variant of radial

basis network suitable for classification problems. The

PNN is direct continuation of the work based on

Bayesian classification and classical estimators for

probability density function [14]. The only factor that

needs to be selected for training is the smoothing factor/

spread factor which affects the classification accuracy.

The network structure of PNNs is similar to that of

backpropagation [12, 13]; the primary difference is that

uses exponential activation function instead of sigmoidal

activation function and also the training time is lesser

compared to multi-layer feed forward network trained

by back propagation algorithm.

PNN consists of four types of units, namely, input units,

pattern units, summation units, and an output unit. The

pattern unit computes distances from the input vector to

the training input vectors, when an input is presented,

and produces a vector whose elements indicate how close

76

Karpagam Jcs Vol. 6 Issue 2 Jan. Feb. 2012

the input is to a training input. The summation unit sums

these contributions for each class of inputs to produce

as its net output a vector of probabilities. Finally, a

complete transfer function on the output of the second

layer picks the maximum of these probabilities, and

produces a 1 for that class and a 0 for the other classes.

Furthermore, the shape of the decision surface can be

made as complex as necessary, or as simple as desired,

by choosing an appropriate value of the smoothing

parameter.

In this paper, PNN architecture and the feature extraction

process are constructed and analysed using MATLAB

software. For the CVTs, the eight different colours are

to be classified into eight different clusters. This problem

requires 57 input neurons. In the experimental study, EEG signals corresponding to eight different visualization

tasks were recorded and separate neural network model

was developed for each subject. The master data set has

2960 samples. The network is trained with 1776 samples

of data and tested with 1184 samples with a testing.

tolerance of zero. The accuracy results of each subject

for the corresponding smoothing parameter (K) ranges

from 0.10 to 0.20 are tabulated in Table 1, 2 and 3.

60% (1776 samples) of training samples are taken ran-

domly from the total samples and the remaining 40%

(1184) samples are tested using the network models. This

process of training and testing is repeated for 10 times.

From the Table 1, 2 and 3, the highest classification per- formance of three features and its smoothing parameter

value for each subject were highlighted. The highest

average classification accuracy of SE, MSE and SDSE

features has been tabulated in Table 4.

**TABLE 1. CLASSIFICATION PERFORMANCE** OF **PNN USING** SE FEATURE

**K**

**Sub** 1

**Sub** 2

**Sub 3**

**Sub 4**

**Sub 5**

Sub 6

**Sub 7**

Sub **8**

**Sub 9**

**Sub** 10

**0.10**

**83.14**

**81.01**

82.01

**84.74**

91.23

81.26

**83.33**

84.90

**88.95**

83.36

**0.11**

81.70

83.00

84.26

84.88

90.64

79.20

**81.47**

**83.85**

90.67

77.32

**0.12**

**83.14**

84.49

83.83

85.61

92.61

78.74

81.06

84.63

88.82

83.02

**0.13**

82.25

85.07

83.87

84.01

89.61

81.29

83.30

85.03

**91.23**

81.75

**0.14**

**84.36**

84.65

**84.70**

**86.04**

91.59

**83.56**

**85.84**

**88.44**

89.38

82.50

0.15

**81.38**

**85** 21

82.42

**83.26**

93.25

75.82

77.72

86.01

85.22

**86.89**

**0.16**

**83.18**

**84.58**

**81.01**

83.76

92.36

76.90

79.19

86.95

89.18

84.25

0.17

**81.73**

81.45

77.37

82.50

92.75

70.88

73.33

82.59

90.56

**83.88**

**0.18**

**80.42**

82.41

73.51

78.24

**93.43**

77.64

**79.37**

83.24

86.44

85.23

**0.19**

78.00

**85.59**

73.51

80.39

92.01

**80.65**

82.37

81.33

86.14

81.25

**0.20**

76.07

81.05

77.23

79.58

89.60

74.63

77.22

81.14

87.61

80.05

77

Analysis of Visual Colour Perception using EEG Spectral **Features**

**TABLE 2. CLASSIFICATION PERFORMANCE OF PNN USING MSE FEATURE**

**K**

Sub **1**

Sub **2**

**Sub 3**

**Sub**

**Sub 5**

**Sub** 6

**Sub 7**

**Sub 8**

**Sub 9**

**Sub** 10

**0.10**

86.34

84.54

**88.95**

**89.39**

**94.81**

85.94

88.24

**91.04**

**89.31**

**83.49**

**0.11**

86.54

85.69

89.72

90.10

**95.04**

**87.86**

**89.45**

**88.31**

90.27

85.85

**0.12**

82.62

86.22

**92.10**

**90.71**

94.29

86.88

89.01

84.21

**89.10**

87.13

**0.13**

**86.14**

86.74

89.82

90.45

**90.78**

**84.85**

86.94

**87.68**

89.41

**85.73**

**0.14**

**87.06**

**86.41**

91.45

90.53

**89.55**

**86.08**

**87.93**

86.78

**92.44**

84.60

**0.15**

85.20

**84.89**

89.00

**89.81**

**85.61**

87.31

89.16

84.64

**89.18**

88.75

**0.16**

85.64

87.63

89.93

89.99

**83.59**

86.15

87.66

**83.57**

**88.43**

90.45

**0.17**

**86.20**

89.32

91.23

89.35

83.06

86.73

**89.33**.

82.76

88.63

86.36

**0.18**

86.70

**85.81**

**88.43**

90.61

**83.30**

85.46

87.69

**86.05**

**87.43**

**83.86**

**0.19**

**89.61**

89.62

89.40

**89.95**

79.47

**87.50**

**89.90**

**82.80**

87.14

**85.36**

**0.20**

**88.35**

**90.35**

87.67

**88.01**

80.56

85.99

**88.30**

80.97

**86.38**

**84.38**

**TABLE 3. CLASSIFICATION PERFORMANCE OF PNN USING SDSE FEATURE**

**K**

Sub **1**

Sub **2**

**Sub 3**

Sub 4

**Sub 5**

**Sub 6**

**Sub 7**

**Sub 8**

**Sub 9**

Sub **10**

**0.10**

**83.17**

**79.96**

**83.29**

**88.78**

90.76

81.51

**87.15**

**83.01**

88.51

**83.53**

**0.11**

**81.08**

**80.84**

85.84

**87.39**

**90.55**

79.49

84.92

81.62

90.06

76.95

**0.12 81.03**

**82.33**

85.24

**83.86**

90.22

**80.53**

84.27

**83.03**

89.49

82.41

**0.13**

82.84

**83.22**

85.54

**85.07**

**90.68**

80.96

86.69

82.64

**91.16**

**81.09**

**0.14**

**84.56**

82.79

**86.66**

83.76

91.06

**82.36**

**89.28**

**86.61**

89.74

**82.06**

**0.15**

**76.94**

**83.93**

**84.89**

**83.47**

91.13

79.23

**81.88**

**83.49**

85.26

**86.77**

**0.16**

79.34

**82.90**

83.08

**83.24**

**88.99**

**80.53**

83.24

85.04

**88.95**

84.94

**0.17 73.37**

**80.01**

80.09

80.58

**91.69**

79.40

**77.35**

80.40

89.94

83.54

0.18

**79.18**

**81.20**

75.63

79.19

**90.74**

**78.12**

**83.68**

80.56

**86.55**

85.75

**0.19**

**82.67**

**83.09**

**74.75**

79.35

**89.57**

76.23

86.57

80.00

86.63

81.06

**0.20**

**76.71**

**78.97**

79.14

**79.81**

**88.46**

73.72

80.62

**78.83**

**88.31**

79.85

**Table 4: Classification Results Of Se, Mse and SDSE Features**

**Subject**

**Mean Classification Accuracy%**

SE **Feature MSE Feature SDSE Feature**

**Subject 1**

84.36

**89.61**

84.56

Subject **2**

**85.59**

90.35

**83.93**

Subject **3**

84.70

92.10

86.66

**Subject** 4

86.04

90.71

88.78

Subject **5**

**93.43**

**95.04**

**91.69**

**Subject** 6

**83.56**

**87.86**

**82.36**

Subject **7**

**85.84**

89.90

**89.28**

Subject **8**

**88.44**

91.04

86.61

**Subject 9**

91.23

92,44

91.16

Subject **10**

86.89

90.45

86.77

78

**IV**. **RESULTS**

To discriminate the colour perception using visualization

tasks, PNN has been developed. In this case, eight-class

classification was carried out using PNN to categorize

these different CVTs**.** The highest mean classification

accuracies of three spectral features for each subject were

tabulated in the Table 4. While comparing the

classification accuracy of three features, it has been also

observed that MSE feature performs well when compared

to other two features (SE and SDSE) for all ten subjects.

From the Table 4, it could be observed that, the highest

mean classification accuracy of 95:04% (for subject 5)

**Karpagam Jcs** Vol. 6 Issue 2 **Jan.** Feb. **2012**

and the lowest mean classification accuracy of *$*7.86%

(for subject 6) were obtained for MSE feature. Further,

it can be observed that the performance of the subject 5

is better than the other subjects.

V. **CONCLUSION**

**In** this paper, SE, MSE and SDSE features were extracted

from the EEG signal while performing the CVTs and the

results were compared. The extracted features were

associated to their respective tasks and the neural network

models were developed successfully. The performance

of the neural network models were tabulated and

compared. From the above experimental study, it has been

observed that the MSE feature using PNN model

performs better when compared to the other two features.

The proposed BMI using CVT is new in the development of BMI and it will be easy to implement**,** hence it involves

less mental **stress** and no need of special training to

control the BMI. **In** future, the proposed system will be

implemented in a real time analysis.

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79

Analysis of Visual Colour Perception using **EEG** Spectral Features

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80

**Karpagam** Jcs Vol. 6 **Issue 2 Jan. -** Feb. **2012**

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81