CLASSIFICATION OF EEG SIGNAL

BY

LAKSHMI S

(17PCS010)

Project Report Submitted

In Partial fulfillment of the requirements for the award of

Master's Degree in Computer Science

Department of Computer Science

Avinashilingam Institute for Home Science and Higher Education for Women, (Deemed to be University),

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Signature of the Head of the Department **Signature of the Supervisor**

Viva Voice held on.....................................

Signature of the Examiners

ACKNOWLEDGEMENT

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ABSTRACT

ABSTRACT

Human brain is a focal point and takes part important functions related to nervous system. The system is divided into three separate areas. They are the cerebrum, the cerebellum and the brain stems which are circulated by the electrical field of nerve fibers are found in the cerebrum. A device that measures this electrical action in the brain is called EEG. So, the EEG is a method used for measuring the electrical impulses that are generated on the cerebral cortex by placing electrodes on scalp.

The project named “**Classification of EEG signal**” is developed for classifying the EEG signal. EEG signals related to Healthy control and paranoid schizophrenia. Healthy control is, a person who does not have the disorder or disease. Schizophrenia is a kind of psychosis, which means mind doesn't agree with reality. It affects how people think and behave. This can show up in different ways and at different times, even in the same person. The illness usually starts in late adolescence or young adulthood. People with paranoid delusions are unreasonably suspicious of others. This can make it hard for them to hold a job, run errands, have friendships, and even go to the doctor. 10-20 EEG montage with 19 channels are used to record the healthy control and Paranoid schizophrenia signals. EEG recordings often contaminated with several artifacts. So, the removal of artifact is necessary to get the correct information. There are several artifacts removal techniques. In this project two algorithms were used. They are Non local Mean algorithm (NLM) and Empirical Mode Decomposition algorithm. After removing the signals feature extraction will take place. Mel Frequency Cepstral Coefficient method is used for feature extraction. Based on feature extraction coefficient value Healthy control and paranoid schizophrenia signals were classified using Support Vector Machine and Artificial Neural Network with accuracy of 89.2857 and 82.1429 respectively.

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INTRODUCTION

1. INTRODUCTION

The **Electroencephalogram (EEG)** is a recording of the electrical activity of the brain from the scalp. The first recordings were made by Hans Berger in 1929 although similar studies had been carried out in animals as early as 1870.

The electroencephalogram (EEG) consists of a time series data of evoked potentials resulting from the systematic neural activities in a brain. The recording data of the human EEGs are carried out by placing the electrodes on the scalp, and plotted as voltage magnitude against time. The voltage of the EEG signal corresponds to its amplitude. The general voltage range of the scalp EEG lie between10 and 100 μV, and in adults more frequently in the range of 10 and 50μV.In the frequency spectrum range of the EEG, the frequency range extends from ultraslow to ultra-fast frequency components. The extreme frequency ranges play no significant role in the clinical EEG. The general frequency range of interest lies between 0.1Hz and 100Hz for the classification purpose. The frequency range is generally classified into several frequency components, or delta rhythm (0.5 -4Hz), theta rhythm (4-8Hz), alpha rhythm (8 -13Hz) and beta rhythm (13-30Hz).For normal adults, the slow ranges (0.3 -7Hz) and the very fast range (>30Hz) are sparsely represented, and medium (8 -13Hz) and fast (14 -30Hz) components predominate.

One of the most common disease is paranoid schizophrenia which is very common and it is occurs in about 1.1 percent of the population, while paranoid schizophrenia is considered the most common subtype of this chronic disorder. The average age of onset is late adolescence to early adulthood, usually between the ages of 18 to 30. It is highly unusual for schizophrenia to be diagnosed after age 45 or before age 16. Onset in males typically occurs earlier in life than females. To diagnose such disorder, EEGs or Scalp are used clinically, also this can be detected by using MRI test. EEG recordings are more reliable in diagnosing paranoid schizophrenia but they are expensive and difficult to obtain in patients.

1.1 Motivation of the project

EEG is used to record the electrical activity of the brain. The EEG signal data set is collected from Olejarczyk, E.; Jernajczyk, W. (2017) EEG in schizophrenia. RepOD. This data set consists of healthy and paranoid schizophrenia signal. This signals often contaminated by noise. With the noisy signal it is very difficult to extract the features from the noisy signal so the noise will be removed using adaptive algorithms and then features are extracted for classify the healthy and paranoid schizophrenia signal

1.2 Objective of the project

To detect EEG signals, remove noise using Non Local Mean and Empirical Mode Decomposition algorithms, extract the features using Mel Frequency Cepstral Coefficient algorithm and classify whether it is healthy control or paranoid schizophrenia signals using Support Vector Machine (SVM) and Artificial Neural Network (ANN) algorithm .The performance of classification EEG signals are measured by Accuracy, Specificity, Precision, Sensitivity, F1_score.

SYSTEM SPECIFICATION

2. SYSTEM SPECIFICATION

2.1. Hardware Specification

- Processor :Intel @Core ™ 2 Duo
- Hard disk: 80 GB
- RAM:4GB RAM
- Keyboard: 104 keys

2.2. Software Specification

- Operating system: Windows 7
- Software : MATLAB 2013a

2.3 About the software

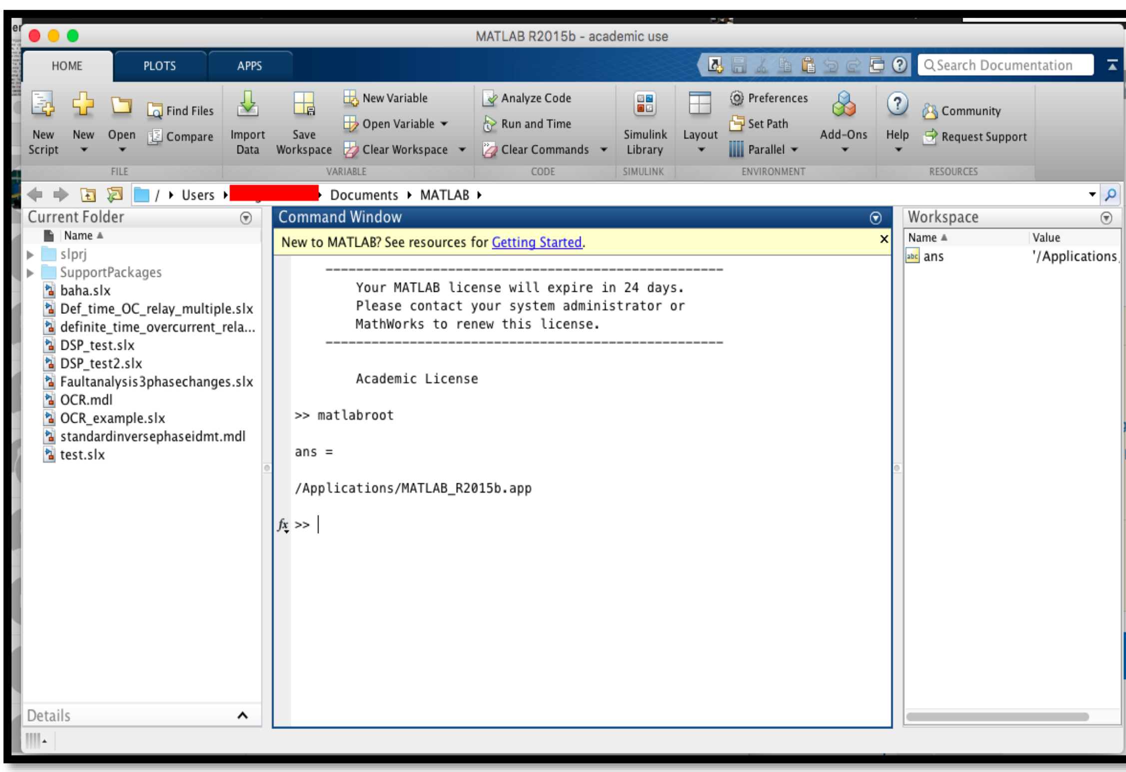
- **MATLAB**

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include:

- Math and computation
- Algorithm development
- Modeling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics
- Application development, including Graphical User Interface building
- MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows you to solve many technical computing problems,

especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar non interactive language such as C or Fortran.

- The name MATLAB stands for matrix laboratory. MATLAB was originally written to provide easy access to matrix software developed by the LINPACK and EISPACK projects, which together represent the state-of-the-art in software for matrix computation.
- MATLAB has evolved over a period of years with input from many users. In university environments, it is the standard instructional tool for introductory and advanced courses in mathematics, engineering, and science. In industry, MATLAB is the tool of choice for high-productivity research, development, and analysis.
- MATLAB features a family of application-specific solutions called toolboxes. Very important to most users of MATLAB, toolboxes allow you to *learn* and *apply* specialized technology. Toolboxes are comprehensive collections of MATLAB functions (M-files) that extend the MATLAB environment to solve particular classes of problems. Areas in which toolboxes are available include signal processing, control systems, neural networks, fuzzy logic, wavelets, simulation, and many others.



Advantages of MATLAB

- It has a number of easy functions and a toolbox of formats
- The syntax for writing this program is simple and easy to learn & understand
- Data analysis becomes extremely easy with MATLAB as every piece of data is stored in the form of matrices
- It functions on a simple syntax format that is easier to implement
- MATLAB allows you to test algorithms immediately without recompilation
- It has the ability to process both still images and videos
- Allows you to work interactively with your data, helps you to keep track of files and variables.

METHODOLOGY

3. METHODOLOGY

3.1 Overview of the Project

EEG signals related to Healthy control and paranoid schizophrenia. Healthy control is, a person who does not have the disorder or disease. Paranoid schizophrenia or schizophrenia is the most common example of this mental illness. Schizophrenia is a kind of psychosis, which means your mind doesn't agree with reality. It affects how people think and behave. This can show up in different ways and at different times, even in the same person. The illness usually starts in late adolescence or young adulthood. People with paranoid delusions are unreasonably suspicious of others. This can make it hard for them to hold a job, run errands, have friendships, and even go to the doctor.

In this system, EEG signals were acquired with the sampling frequency of 250 Hz using the standard 10-20 EEG montage with 19 EEG channels: Fp1, Fp2, F7, F3, Fz, F4, F8, T3, C3, Cz, C4, T4, T5, P3, Pz, P4, T6, O1, O2. The reference electrode was placed between electrodes Fz and Cz. EEG recordings often contaminated with several artifacts. So, the removal of artifact is necessary to get the correct information from the signal. There are several artifacts removal techniques such as Non Local Mean (NLM), Empirical Mode Decomposition (EMD) algorithm, Least Mean Square (LMS) etc. This project makes use of two algorithms namely, local Mean algorithm (NLM) and Empirical Mode Decomposition algorithm. After removing the artifact feature extraction is done. Mel Frequency Cepstral Coefficient method is used for feature extraction. Based on feature extraction coefficient value healthy control and paranoid schizophrenia signals were classified.

3.2 About the dataset

The dataset comprised 14 patients with paranoid schizophrenia and 14 healthy Control. Data were acquired with the sampling frequency of 250 Hz using the standard 10-20 EEG montage with 19 EEG channels: Fp1, Fp2, F7, F3, Fz, F4, F8, T3, C3, Cz, C4, T4, T5, P3, Pz, P4, T6, O1, O2. The reference electrode was placed between electrodes Fz and Cz. The collected EEG signals are shown in the **Table 4.2.1.1 and 4.2.1.2**

. This dataset is in the format of EDF file. **European Data Format (EDF)** is a simple and flexible format for exchange and storage of multichannel biological and physical signals. It was published in 1992 in Electroencephalography and Clinical Neurophysiology. Since then, EDF became the de-facto standard for EEG and PSG recordings in commercial equipment and multicenter research projects. This data file consists of a header record followed by data records. The variable-length header record identifies the patient and specifies the technical characteristics of the recorded signals.

Dataset description

Dataset is in the format of EDF file. EDF file consists of 19 fields which are described below

S.No	Fields	Description
1	Ver	Ver indicates version of data format that is always ‘0’
2	Patient ID	Patient Identification
3	Record ID	Recording Identification
4	Start Date	Start date of recording(dd.mm.yy)
5	Start Time	Start time of recording(hh.mm.ss) • It should contain only characters 0-9, and the period (.) As a separator, for example "02.08.51".
6	Bytes	Number of bytes in record • The duration of each data record is recommended to be whole number of seconds and its size(number of bytes)is recommended not to exceed 61,440 bytes

7	Duration	Time duration of records in seconds
8	Ns	Number of signals in data record
9	Label	Electrode names(e.g. Fz,Fp1)
10	Transducer	It is a device that converts variates in a physical quantity into an electrical signal.
11	Units	Unit is used to measure the EEG activity(e.g. uV or degree C)
12	PhysicalMin	Physical Minimum(eg.-32767) Physical Maximum(eg.32767) • The physical minimum and maximum of each signal should specify the extreme values that can occur in the data records. These often are the extreme output values of the A/D converter
13	PhysicalMax	
14	Prefilter	Prefiltering (HP:0.1Hz LP:75Hz) • A **filter** is a device or process that removes some unwanted components or features from a signal. • High pass filtering and low pass filtering is reserved value. It should be fixed before recording.
15	Samples	Number of samples in each data record
16	Frequency	Reserved(250Hz) • The *sampling frequency* or sampling rate, fs, is the average number of samples obtained in one second (samples per second), thus fs = 1/T.
17	DigitalMinimum	Digital Minimum(eg.-32767) Digital Maximum(eg 32767) • The digital minimum and maximum of each signal should specify the extreme values that can occur in the data records. These often are the extreme output values of the A/D converter.
18	DigitalMaximum	
19	Records	Number of data records in recording.

3.3 Artifacts removal

Artifacts are unwanted signal arising from sources other than cerebral area. This noise may be physiological and extra physiological. The patient related artifacts are the physiological artifacts (e.g. Muscle artifact, sweating, ECG, eye movements) and technical artifacts are the extra physiological artifacts (e.g. 50/60 Hz artifact, electrode popping) which have to be handled differently. In this project muscle artifact will be removed.

Physiological artifact

Muscle artifact: It is one of the common forms of artifact and is caused by the electrical activity in the muscles caused due to activity in the neck or facial muscles. Muscle artifacts are of shorter duration and have a frequency much higher than the cerebral activity.

To remove muscle artifacts two algorithms were used. They are

(i)Non local mean algorithm

(ii)Empirical Mode decomposition algorithm

3.3.1 Non Local Mean algorithm

The NLM filter deals with the problem of retrieving the signal u from the noisy signal, v= u+n , n is "noise". The estimated of an arbitrary sample s is a weighted aggregate of values at different points t that are inside some "search neighborhood" N(s) can be determined using Eq(1)

$$\overline{u(s)} = \frac{1}{Z(s)} \sum_{t \in N(s)} w(s,t)\, v(t) \qquad (1)$$

Where

$$z(s) = \sum_{t} w(s,t)$$

The weights can be calculated using Eq(2)

$$w(s,t) = \exp\left(-\frac{\sum_{\delta\epsilon\Delta}[v(s+\delta)-v(t+\delta)]^2}{2L_\Delta\,\lambda^2}\right) = \exp\left(-\frac{d^2(s,t)}{2L_\Delta\,\lambda^2}\right) \quad (2)$$

Where:

λ: bandwidth parameter.

Δ: local patch of samples Enclosing s, consisting samples; a patch of similar shape also encloses t.

The samples of the patch are centered on the interested points. In Eq.(2) the squared, summed point to point difference between samples of the patches. The samples in the patches are centered on s and t points. Each patch in Eq.(2) is submitted to self-averaging with the weight w(s,s)=1. A central patch corrector is applied to obtain smoother results as given in Eq(3)

$$w(s,s) = \max_{t\,\epsilon N(s),t\neq s} w(s,t) \quad (3)$$

The innovation of NLM filter is that the weight w(s,t) relies on patch correlation, not on the distance between s and t points. The averaging process of the identical patches keeps edges, as opposed to the most common filters. By considering self similarity expands along the signal, the N(s) is perfectly taken to be the complete signal, so the averaging operation is completely non-local.

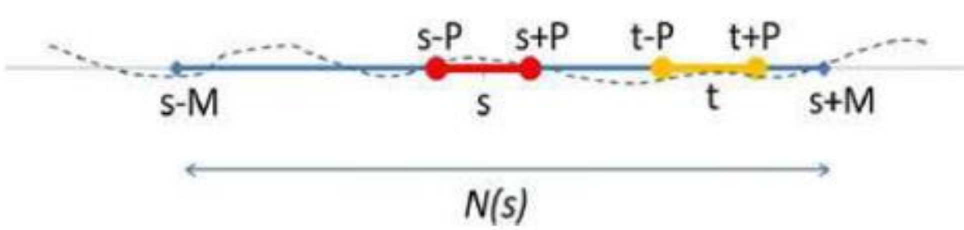


Figure 1: Representation of NLM parameters. The tiny patch centered on s is compared to patches centered on other points t in N(s)

The EEG signal with noise is shown in **Table 3.1.1.1 and 3.1.1.2.** An examination for parameters selection of EEG NLM filter was done. This examination aims to evaluate the optimal parameters of the NLM filter which reject the noise efficiently. The most effective NLM parameters are the bandwidth, the size of neighborhood search width, and the Patch Half Width. Figure 1 demonstrates the schematic geometric parameters of the one dimension patches centered on the point's s and t. The bandwidth governs the smoothing process of the signal. The bandwidth must be scaled by the noise standard deviation. NLM filter was applied to different signals. The best results are achieved with bandwidth 0.7. **Figure 3.1.1.3** shows the NLM filtered EEG signal after implementing the NLM filter with the optimum values of its parameters. NLM algorithm was found to be a best algorithm when compared with EMD algorithm which gave best results and the execution time for the processing of the artifact removal was less.

3.3.2 Empirical Mode decomposition algorithm

The Empirical mode decomposition (EMD) method is an algorithm for the analysis of multi component signals that works by breaking the signal into a number of amplitude and frequency modulated (AM/FM) zero mean signals, termed intrinsic mode functions (IMFs). In contrast to conventional decomposition methods such as wavelets, which perform the analysis by projecting the signal under consideration onto a number of predefined basis vectors, EMD expresses the signal as an expansion of basic functions which are signal-dependent, and are estimated via an iterative procedure called sifting.

The IMF must satisfy the following condition

The difference between total number of maxima and minima should be zero.

Steps for determining IMF

X(t) – original signal as shown in the **Table 3.1.1.1 and 3.1.1.2**

Q(t) – denoised signal

Calculate all minima and maxima of source signal X(t). With the help of local extremas i.e. maxima and minima, upper envelop eup and lower envelop edn are created respectively with interpolation. The mean is calculated by

$$M(t) = (eup+edn)/2$$

Filtered signal extracted from the difference of X(t) and M(t) as shown in the **Figure 3.3.2.1**

EMD algorithm was used to remove the muscle artifacts. EMD algorithm error rate was high when compared with NLM algorithm. The performance of the EMD algorithm was less when compared with NLM algorithm

3.3.3 Performance measures

The performance of Non Local Mean (NLM) and Empirical Mode Decomposition (EMD) measured using Mean Square Error(MSE), Signal to Noise ratio(SNR), Peak Signal to Noise Ratio(PSNR).These performance measures are done using original signal and denoised signal.

(A) Mean Square Error (MSE)

MSE is the average of the **squared error** that is used as the loss function for least squares regression. It is the sum, over all the data points, of the **square** of the difference between the predicted and actual target variables, divided by the number of data points.

$$MSE = \frac{1}{N}\sum_{i=1}^{N}(f_i - y_i)^2$$

where N is the number of data points,
f_i the value returned by the model and
y_i the actual value for data point i.

Mean Square error values were found by subtracting denoised signal from the original signal. These values are squared and then summed. Then the summed values get divided by the number of samples.

So, mean squared error (MSE) of data measures the average of the squares of the errors will be displayed as shown in the **Figure A.1 and A.2**

(B)Signal to Noise Ratio (SNR)

Signal-to-noise ratio is a measure used to compares the level of a desired signal to the level of background noise. SNR is defined as the ratio of signal power to the noise power, often expressed in decibels.

$$SNR(dB) = 10\log\frac{P_s}{P_n}$$

SNR was found by divide the value of the original signal by the value of the noise, and then take the common logarithm of the result.

So, SNR value represents the ratio of the signal power and the noise power as shown in the **figure B.1 and B.2**

(C)Peak Signal to Noise Ratio (PSNR)

Peak signal-to-noise ratio PSNR is the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation.

$$PSNR = 10log_{10}\left(\frac{MAX_I^2}{MSE}\right)$$

PSNR value was found by dividing square of original signal by mean square error value and then take the logarithm of the result.

So, PSNR values represent a measure of the peak error as shown in the **Figure C.1 and C.2**

The signal quality has been done by calculating MSE, SNR and PSNR value. These performance measures are applied for both NLM and EMD algorithm. From the results of two algorithms NLM algorithm which gave the best results.

3.4 Feature extraction

Feature extraction was used to extract more useful/dominant information hidden in the signals by avoiding unnecessary or redundant information. Now with regards to relation with signal processing, usually signal is pre-processed to remove noise, interferences and artifacts before performing feature extraction. This project makes use of MFCC algorithm.

3.4.1 Mel Frequency Cepstral Coefficient

MFCC method is to extract brain signal features from EEG signal. The first step is dividing the EEG signal into frames by applying a windowing function at fixed intervals. The windows function used was hamming windows that removes edge effects then we applied fast Fourier transform in order to compute Magnitude spectrum computation, then triangular filter bank was used which is uniformly spaced filters on Mel space. In order to individualize part of magnitude spectrum, Triangular filter bank multiplied with magnitude spectrum. Take the logarithm of Filter bank energies after that by applying Discrete Cosine Transform (DCT) to log filter bank energies to get 13 cepstral coefficients as shown in **Figure 3.4.1.1 to 3.4.1.28.**

These 13 coefficients were obtained from each frame.

To reduce the number of features following statistics were followed:

* Mean of coefficient values i.e. [mean (MFCC)] that was taken were consider

* Standard deviation of coefficient values i.e.[std(MFCC)] that was taken were consider

* Variance of coefficient value i.e. [var(MFCC)] and mean value of [(mean, standard deviation, variance)] that was taken were consider.

These results are considered for evaluating the performance of feature vector and it is used for classification.

3.5 Classification

A *classification* is an ordered set of related categories used to group data according to its similarities. It consists of codes and descriptors and allows survey responses to be put into meaningful categories in order to produce useful data. A *classification* is a useful tool for signal processing. Based on feature extraction value classification will be done.

In this project Support Vector Machine (SVM) and Artificial Neural Network (ANN) algorithms were used.

3.5.1 Support Vector machine algorithm

A Support Vector Machine (SVM) is a supervised machine learning algorithm that can be employed for both classification and regression purposes. SVMs are more commonly used in classification. For a dataset consisting of features values, an SVM classifier builds a model to predict classes for feature values.

For a given two-class linearly separable classification problem, SVM tries to find a hyper plane which separates the healthy control and paranoid signals with a maximum margin. The optimum hyper plane is found as follows:

$$w.x_i + b \geq +1, if\ y_i = +1 \qquad (1)$$

$$w.x_i + b \leq +1, if\ y_i = -1 \qquad (2)$$

where xi is the ith input vector , yi is the class label of the ith input, w is the weight vector which normal to the hyper plane, and the b is the bias. Optimal hyper plane is found by two margins which parallel to the optimal hyper plane. Margins are found by Eq. 3

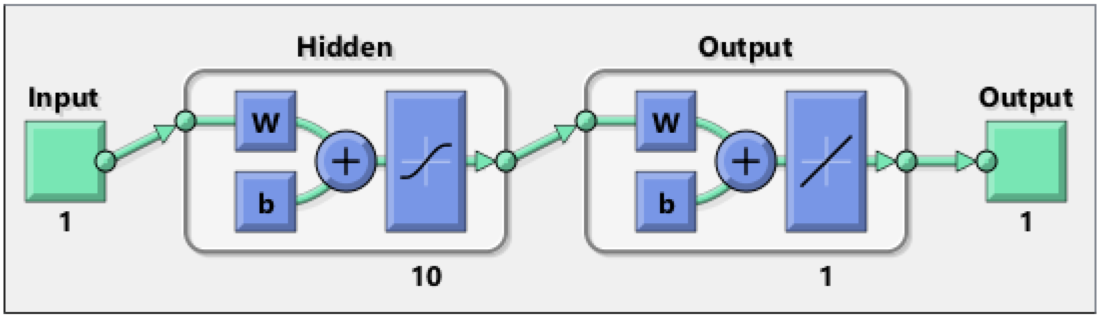
$$w.x_i + b \leq \pm 1 \qquad (3)$$

The input feature values that determine the margins are called as support vectors. After separate the trained model, test model is given for classifying healthy control and paranoid schizophrenia as shown in the **Figure 3.5.1.1**

SVM classifier classified the healthy control and paranoid schizophrenia signals. From the SVM classifier result it was correctly classified 89% of data and misclassified 11% of data. SVM algorithm results were found to be a best algorithm when compared with ANN algorithm.

3.5.2 Artificial Neural Network algorithm

ANNs consist of a great number of processing elements (neurons), which are connected with each other; the strengths of the connections are called weights. A feed forward neural network is commonly used for classification. Feed forward networks often have one or more hidden layers of sigmoid neurons followed by an output layer of linear neurons. Multiple layers of neurons with nonlinear transfer function allow the network to learn nonlinear and linear relationships between input and output vectors.



The function newff() creates a feed forward back propagation network architecture with desired number of layers and neurons. The general form of use of the function is given below, which returns an *N*-layer feed forward back propagation network object:

net = newff([PN],[S1 S2 ... SN],{TF1 TF2 ... TFN},BTF,LF,PF);

Where the first input PN is an $N \times 2$ matrix of minimum and maximum values for *N* inputelements. S1 S2 . . . SN are the sizes (number of neurons) of the layers of the network architecture.

TF*i* is the transfer function of the *i*th layer; the default is 'tansig'. The transfer functions TF*i* can be any differentiable transfer function such as tansig, logsig or purelin.

The function creates a two-input single-output feed forward network with single hidden layer. The first input specifies the minimum and maximum values for each of the input vectors. The second input is an array containing the sizes of each layer, The third input is a cell array containing the names of the transfer functions to be used in each layer, i.e., tansig for hidden layer and purelin (linear) activation function for output layer. The final input contains the name of the training function to be used. 'traingd' is one of the training functions used by the network. newff() will also automatically initialize the weights and biases of the network.

Training Networks:

Different back propagation training algorithms are available as functions in MATLAB . They have their own features and advantages. Some of the most widely used functions are:

- traingd – basic gradient descent learning algorithm. It has slow response but can be used in incremental mode training.

- traingdm – gradient descent with momentum. It is generally faster than traingd and can be used in incremental mode training.
- traingdx – adaptive learning rate. It has faster training time than traingd but can only be used in batch mode training.
- trainrp – resilient backpropagation. It is a simple batch mode training algorithm with fast convergence and minimal storage requirements.
- trainlm – Levenberg–Marquart algorithm. It is a faster training algorithm for networks of moderate size. It has a memory reduction feature for use when the training set is large.

In this project trainrp is used as training network. There are several parameters associated with training algorithms. The parameters are learning rate, error goal, epochs and show.

These parameters are defined as:

- net.trainParam.lr - specifies learning rate
- net.trainParam.goal - specifies error goal
- net.trainParam.epochs - specifies the number of iterations
- net.trainParam.show - displays status for every show.

Once the network has been defined and the parameters are set, the network can be trained using the function train().

[net, tr] = train (net, P, T)

where net is the network object, tr contains information about the progress of training, P and T are the input and output vectors, respectively.

The network is then updated according to the results of all those presentations. Training occurs until a maximum number of epochs occur, the performance goal is met or any other stopping condition of the function is met. In this network,

```
net1.trainParam.show = 1000;
net1.trainParam.lr = 0.04;
net1.trainParam.epochs = 700;
net1.trainParam.goal = 1e-5;
```

The network will be trained using the input and output data P and T, respectively for up to 700 epochs or when an error goal of 0.04 is reached.

Simulating Networks

The function sim() simulates a network. It takes the network input P (feature values) and the network objects net and returns the network output *y*. i.e. classified EEG signals as shown in the **Figure 3.5.2.1**

.

ANN algorithm classified healthy control and paranoid schizophrenia. It is observed that the ANN classifier correctly classified 82% of data and misclassified 18% of data.

3.6 Performance measures

Confusion matrix method is used for examine the prediction success of the classifier. A value of "1" is utilized for detecting the healthy control and "2" for paranoid schizophrenia.
TPR (true positive ratio) and TNR (true negative ratio) are calculated by using confusion matrix method for analyzing the output data.

Confusion matrix

The confusion matrix is a two by two table that contains five outcomes produced by a binary classifier. Various measures, such as accuracy, specificity, sensitivity, F1_score and precision, are derived from the confusion matrix.

	Class 1 Predicted	Class 2 Predicted
Class 1 Actual	TP	FN
Class 2 Actual	FP	TN

Here,

• Class 1 : Positive

• Class 2 : Negative

Definition of the Terms:

• Positive (P) : Observation is positive.

• Negative (N) : Observation is not positive.

• True Positive (TP) : Observation is positive, and is predicted to be positive.

• False Negative (FN) : Observation is positive, but is predicted negative.

• True Negative (TN) : Observation is negative, and is predicted to be negative.

• False Positive (FP) : Observation is negative, but is predicted positive

Accuracy (ACC) is calculated as the number of all correct predictions divided by the total number of the dataset.

Accuracy = TP+TN/TP+TN+FP+FN

Sensitivity (SN) is calculated as the number of correct positive predictions divided by the total number of positives. It is also called recall (REC) or true positive rate (TPR).

Sensitivity = TP/P

Specificity (SP) is calculated as the number of correct negative predictions divided by the total number of negatives. It is also called true negative rate (TNR).

Specificity = TN/N

Precision (PREC) is calculated as the number of correct positive predictions divided by the total number of positive predictions. It is also called positive predictive value (PPV).

Precision = TP/(TP+FP)

F1 score is the weighted average of Precision and Recall. Therefore, this score takes both false positives and false negatives into account.

F1 score = ((1+beta^2))*(Sensitivity*Precision))/((beta^2)*(Precision+Sensitivity))

EXPERIMENTAL RESULTS AND ANALYSIS

4. EXPERIMENTAL RESULTS AND ANALYSIS

The confusion matrix is a two by two table that contains five outcomes produced by a binary classifier. Various measures, such as accuracy, specificity, sensitivity, F1_score and precision, were derived from the confusion matrix. **Classification accuracy** is the ratio of correct predictions to total predictions made. It is often presented as a percentage by multiplying the result by 100. For SVM and ANN algorithm the accuracy results were found with 89.2857% and 82.1429% respectively. **Sensitivity** is the ability of a test to correctly identify those with the disease (true positive rate), whereas test **specificity** is the ability of the test to correctly identify those without the disease (true negative rate). **Precision** was found the actual predicted positive values and the **F1 score** was interpreted as a weighted average of the precision and recall. So the confusion matrix describes the performance of the classification model as shown in **Table 4.1**

S.NO	**PERFORMANCE MEASURES**	**SVM**	**ANN**
1	ACCURACY	89.2857	82.1429
2	SENSITIVITY	85.7143	78.5714
3	SPECIFICITY	92.8571	85.7143
4	PRECISION	0.9231	0.8462
5	F1_SCORE	0.8889	0.8148

Table 4.1

Graphical representation of performance measures

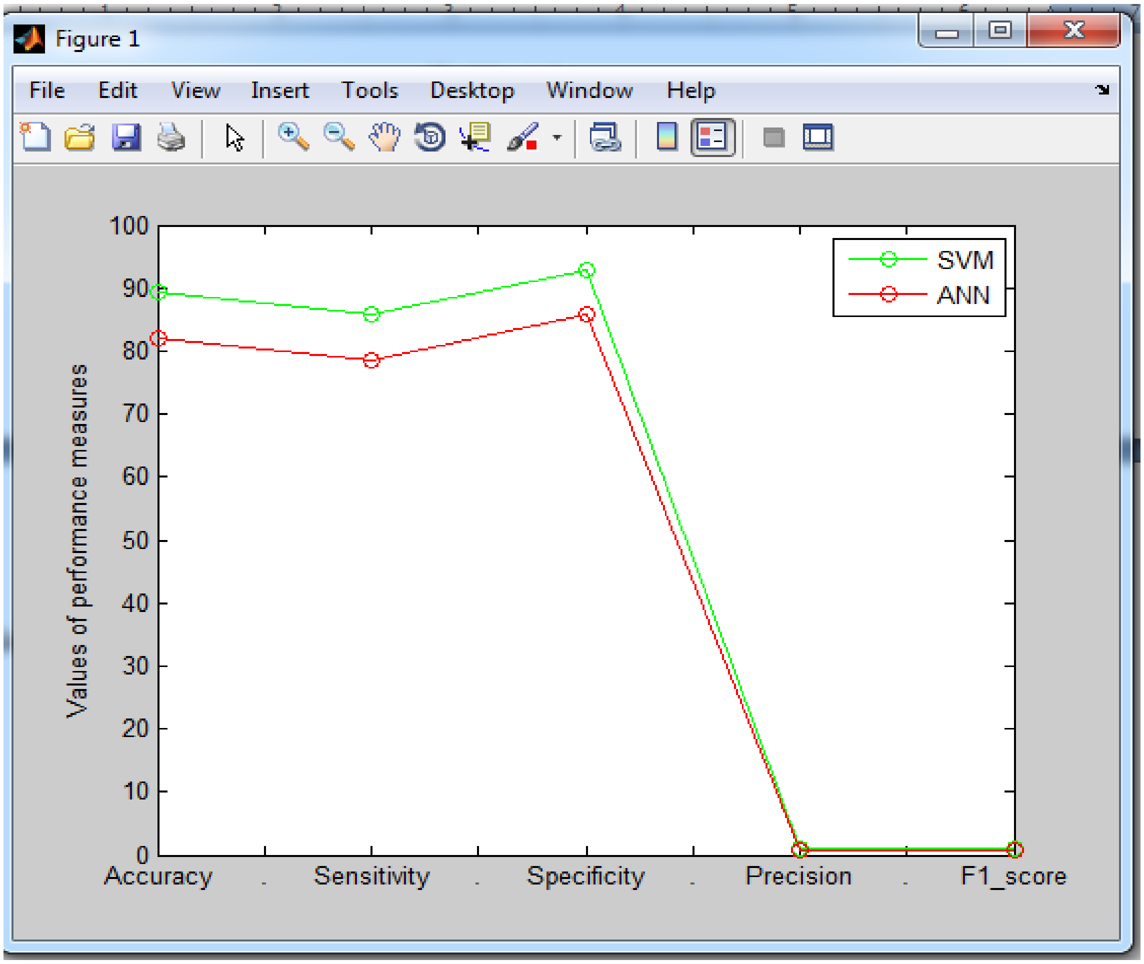


Figure 4.2 Values of performance measures

CONCLUSION

5. CONCLUSION

Electroencephalography (EEG) signals provide valuable information to study the brain function and neurobiological disorders. Digital signal processing gives the important tools analysis of EEG signals. 14 patients of healthy control and paranoid schizophrenia signals were analyzed and artifacts were removed using Non Local Mean and Empirical Mode Decomposition algorithm. Performance of denoised techniques of two filters were compared and tabulated. The used performance measures are Signal to Noise Ratio (SNR), Mean Square Error (MSE), Peak Signal to Noise Ratio (PSNR). To raise the accuracy and to find the most relevant features, MFCC algorithm was applied to the signals. The extracted features were used for classification. To improve classification accuracy of the EEG signals various methods were suggested, this project is make use of SVM and ANN for EEG signal classification. The extracted features are suggested for the classification of EEG signals which are trained and tested using SVM and ANN. This system has achieved sensitivity, specificity and classification accuracy for SVM and ANN which are 85.7143, 92.8571, 89.2857 and 78.5714, 85.7143, 82.1429 respectively. The best accuracy for the original data was reached by SVM algorithm with the accuracy value of 89.2857%. The best accuracy results were found using true positive rate and false positive rate.

Finally, the comparison of classifier based on performance accuracy has been furnished. The accuracy rate achieved by the SVM classifier is offered for the classification of the EEG signals which are found to be higher than ANN algorithm.

SCOPE FOR FUTURE ECHANCEMENTS

6. SCOPE FOR FUTURE ECHANCEMENTS

In this project healthy control and paranoid schizophrenia signals were collected in which removal of muscle artifact, feature extraction and binary classification has been done. Non Local Mean (NLM) and Empirical Mode Decomposition (EMD) have been used to do artifacts removal. For feature extraction Mel Frequency Cepstral Coefficient (MFCC) algorithm has been used whereas for binary classification Support Vector Machine (SVM) and Artificial Neural Network (ANN) algorithm has been used. In future, other adaptive filter algorithms can be used for removal of artifacts like electrode artifact, transmission line artifact, eye moment artifacts etc.. Also for multiway classification Support Vector Machine (SVM) and Artificial Neural Network (ANN) algorithms can be modified.

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7. BIBLIOGRAPHY

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- https://in.mathworks.com/help/matlab/creating_guis/about-the-simple-guide-gui-example.html

APPENDIX

8. APPENDIX

System flow diagram

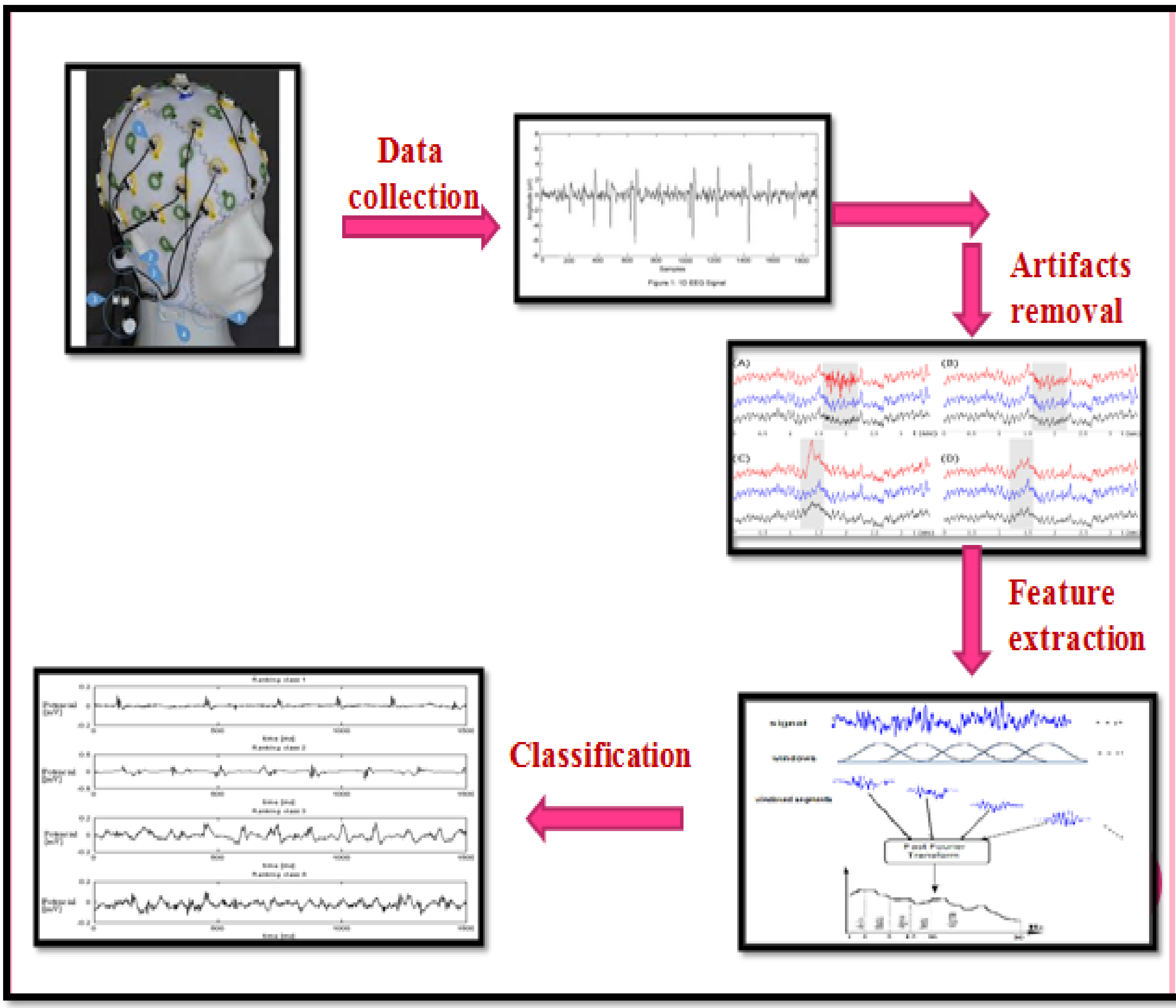


Figure 1

8.1 Screen Screenshots

Input signals

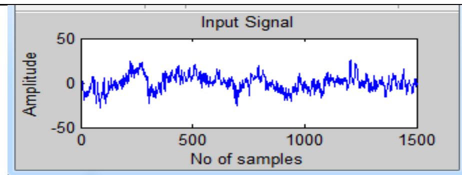
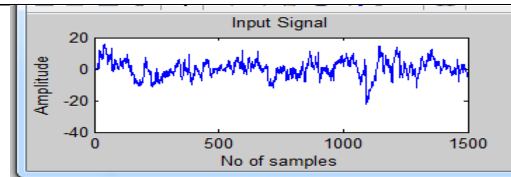
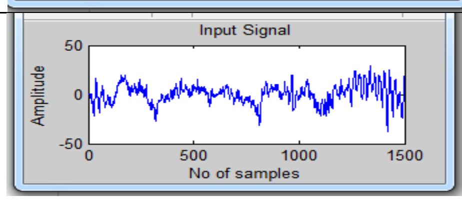
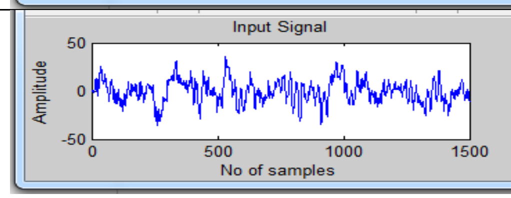
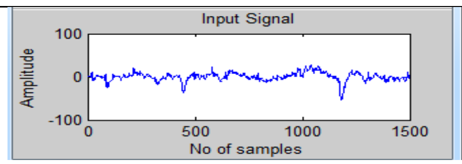
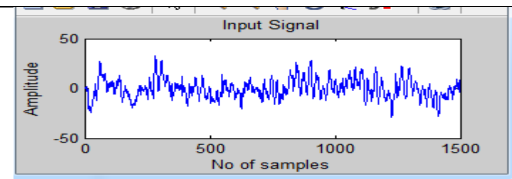
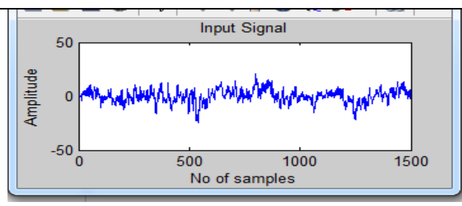
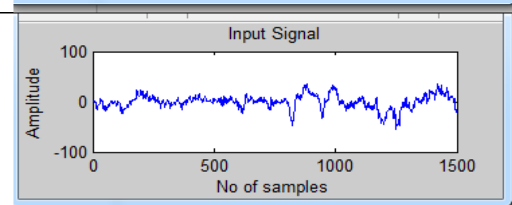
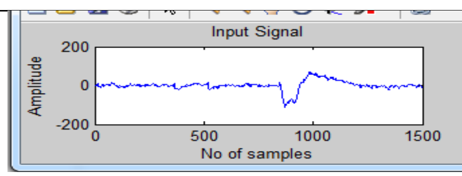
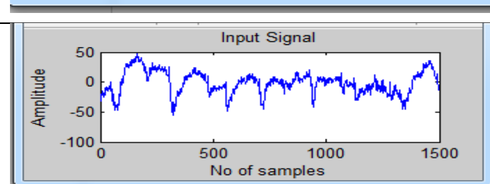
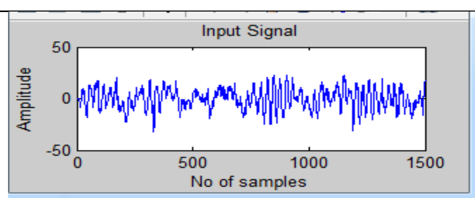
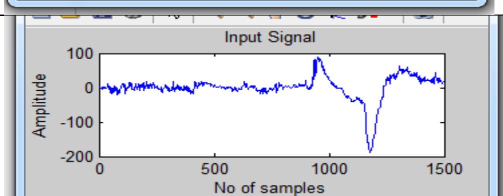
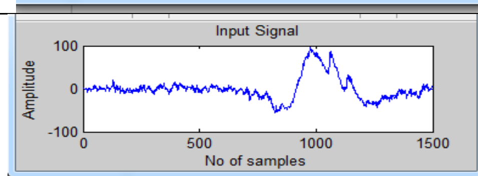
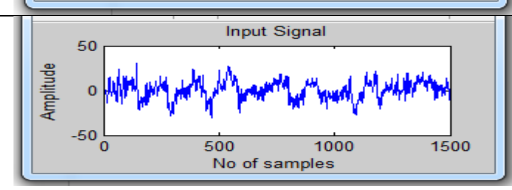
S.No	Healthy control signal	S.No	Healthy control signal
1		8	
2		9	
3		10	
4		11	
5		12	
6		13	
7		14	

Table 3.1.1.1 Input signal of healthy control

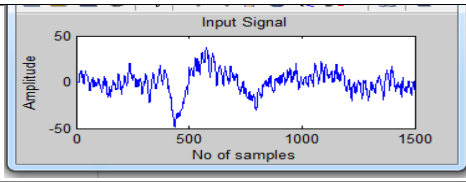
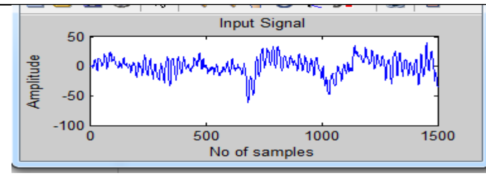
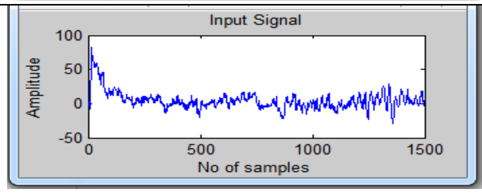
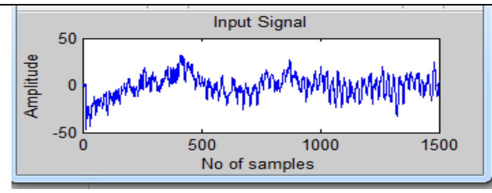
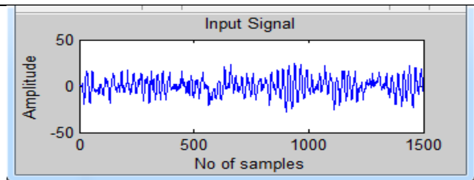
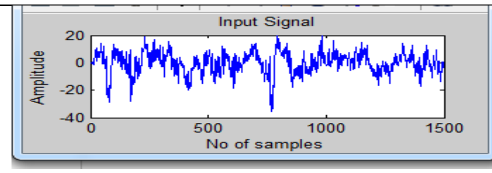
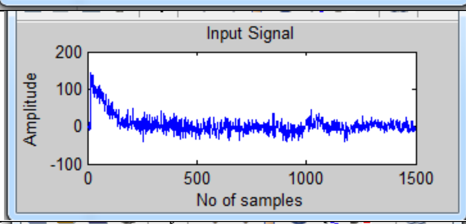
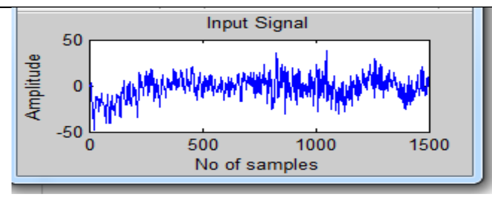
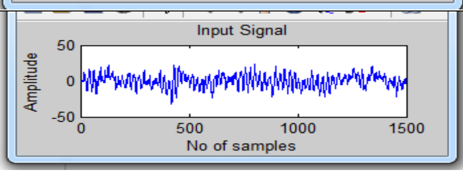
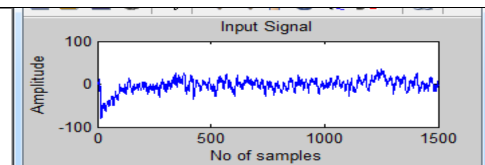
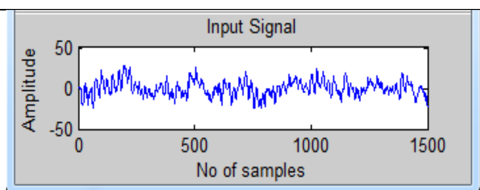
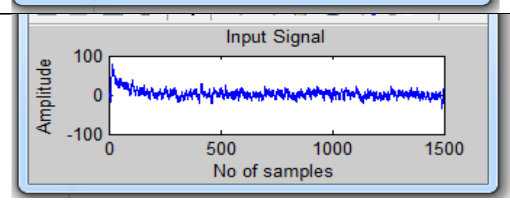
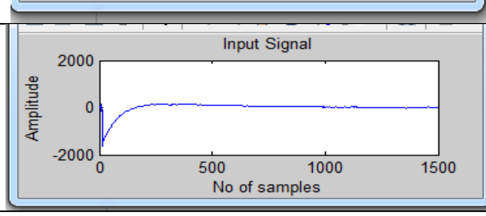
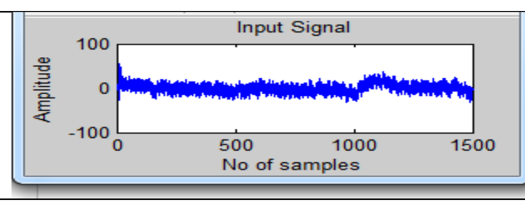
S.No	Paranoid schizophrenia signal	S.No	Paranoid schizophrenia signal
1		8	
2		9	
3		10	
4		11	
5		12	
6		13	
7		14	

Table 3.1.1.2 Input signal of Paranoid schizophrenia

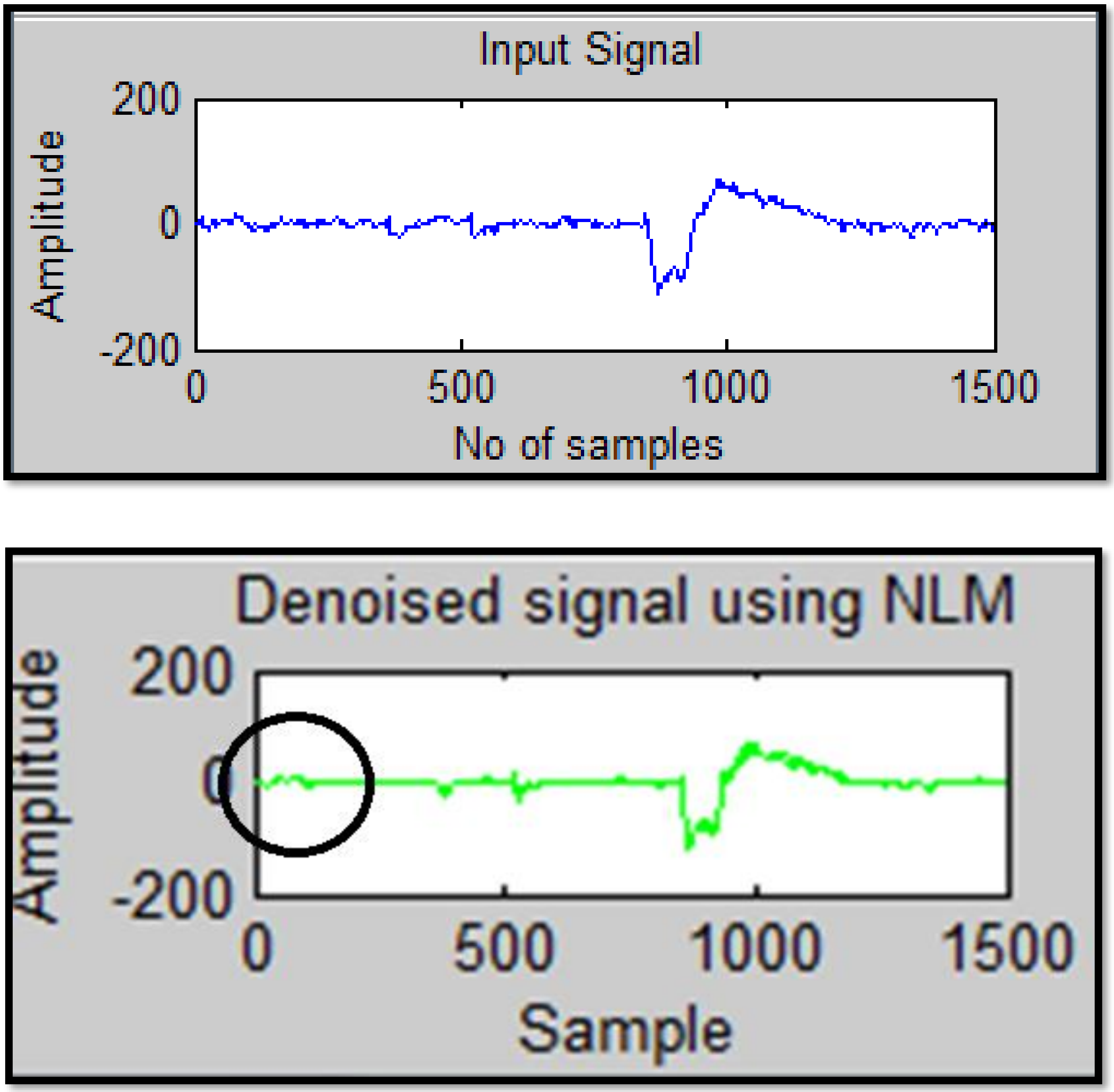


Figure 3.1.1.3 Denoised signal using Non Local Mean algorithm

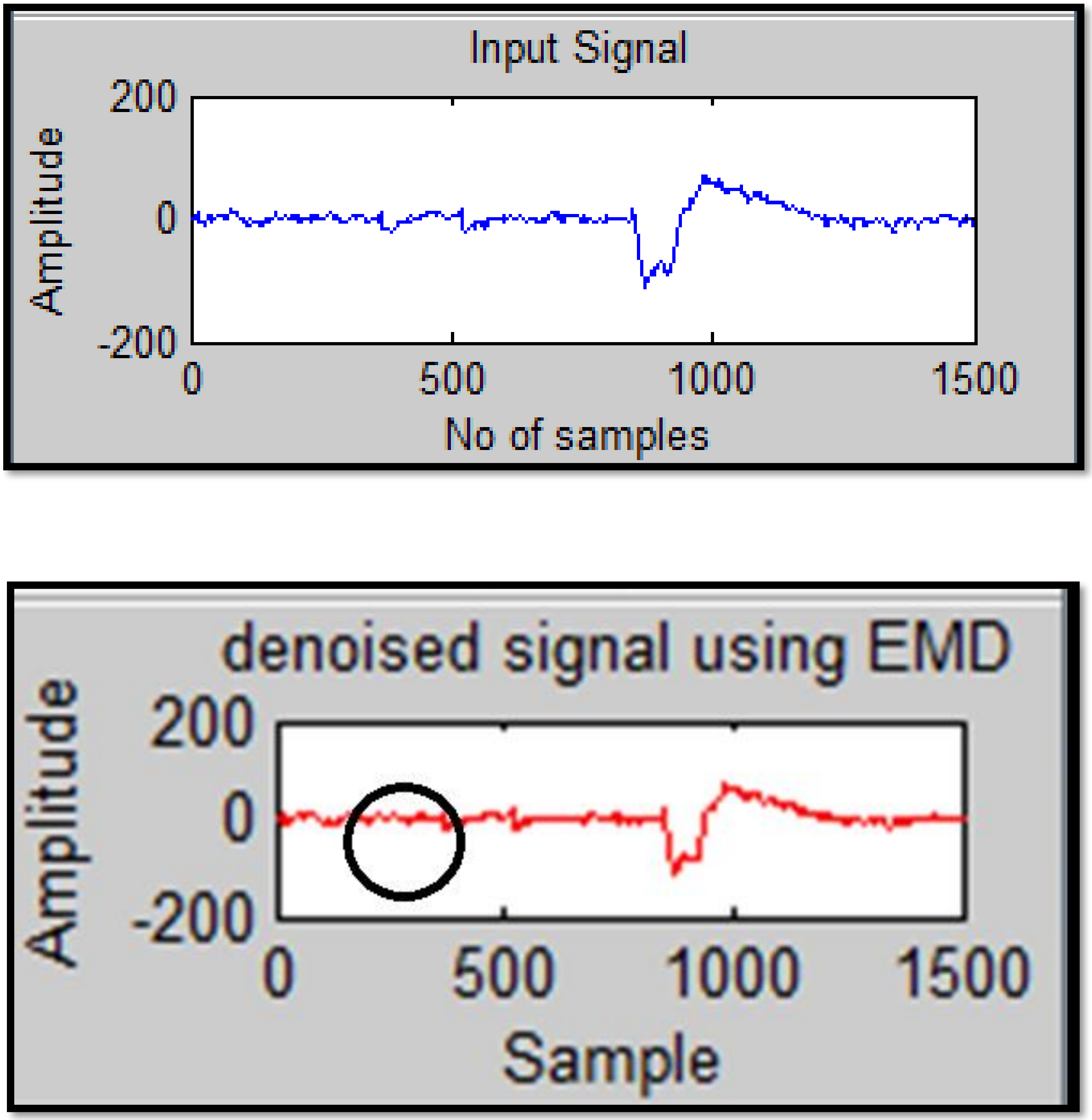


Figure 3.3.2.1: Denoised signal using Empirical Mode decomposition algorithm

Performance measures of Non Local Mean (NLM) and Empirical Mode Composition (EMD) algorithm

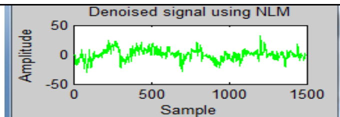
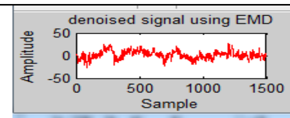
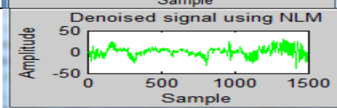
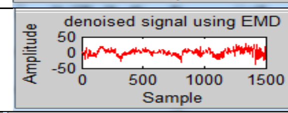
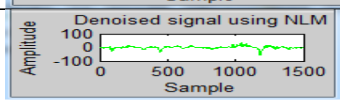
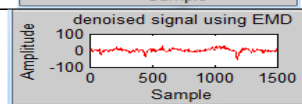
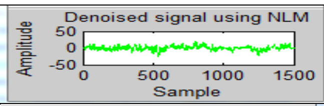
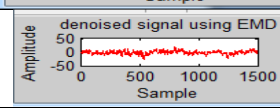
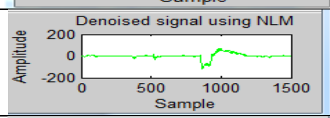
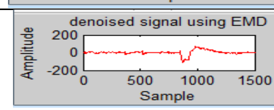
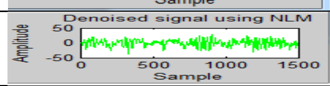
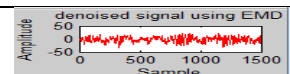
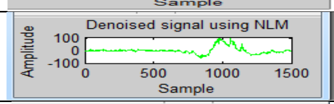
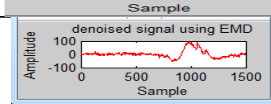
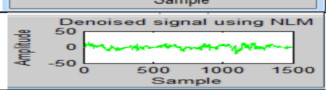
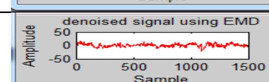
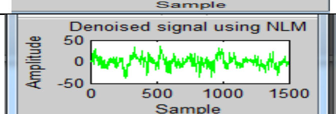
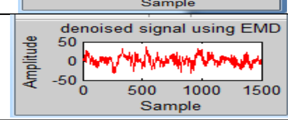
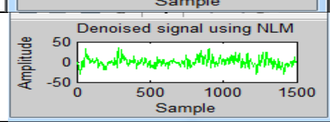
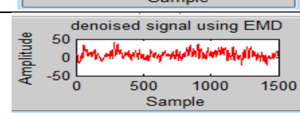
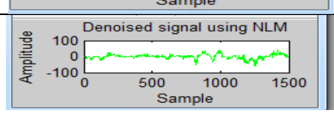
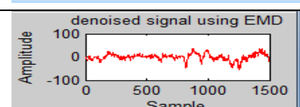
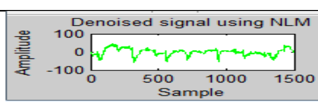
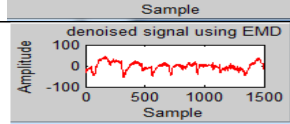
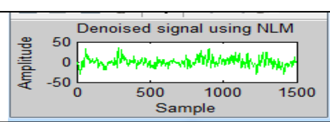
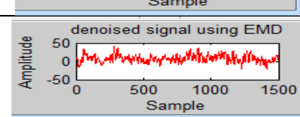
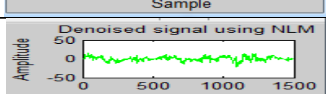
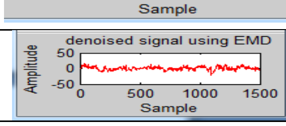
SNo	Signal	NLM Algorithm	Signal	EMD Algorithm
1		8.4099		7.4087
2		5.9475		9.9835
3		4.6253		9.8951
4		9.4797		8.2371
5		9.3975		9.9949
6		7.9670		6.1130
7		6.2947		6.8462
8		9.2063		9.7703
9		7.3977		5.7842
10		8.1236		8.7047
11		1.8526		1.9429
12		10.9408		9.3554
13		8.5287		9.9913
14		7.9000		9.9982

Figure A1: Mean square error for healthy control using Non Local Mean and Empirical Mode Decomposition algorithm

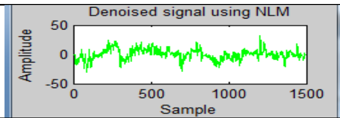
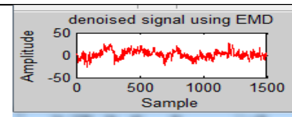
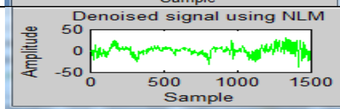
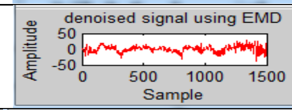
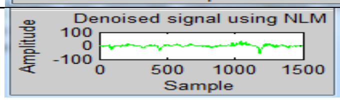
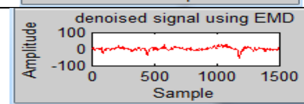
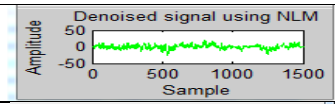
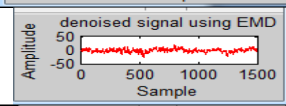
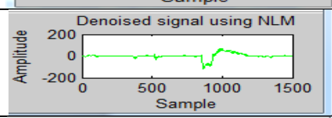
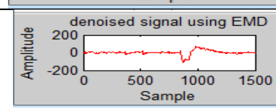
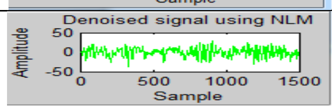
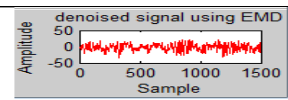
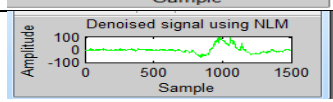
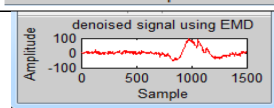
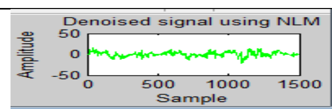
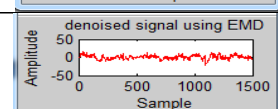
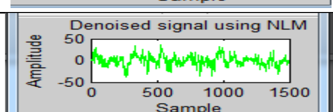
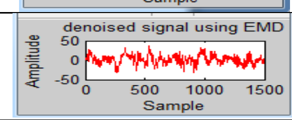
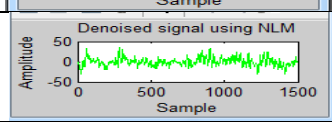
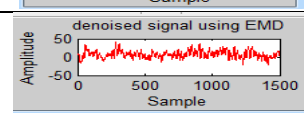
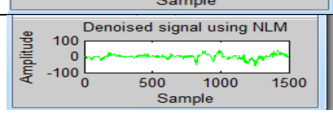
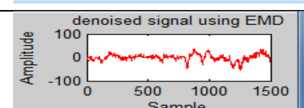
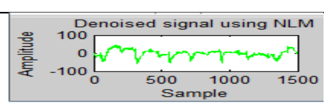
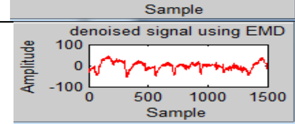
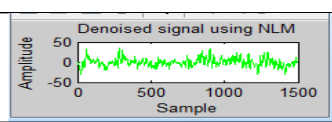
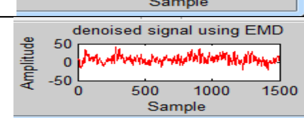
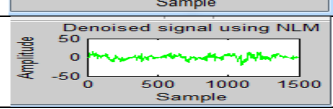
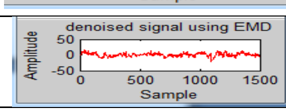
SNo	Signal	NLM Algorithm	Signal	EMD agorithm
1		3.8716		9.3605
2		0.8276		9.6726
3		8.1524		9.8221
4		1.5644		1.5308
5		9.2600		8.6007
6		6.8923		6.6542
7		3.5796e+03		4.6747
8		7.1615		7.3107
9		6.5730		6.3107
10		9.0733		9.9387
11		8.5433		7.6577
12		2.4405		9.6473
13		5.1845		5.1698
14		2.6823		2.0923

Figure A2 : Mean square error for Pranoid schizophrenia using Non Local Mean and Empirical Mode Decomposition algorithm

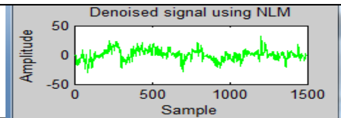
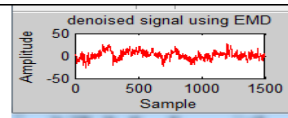
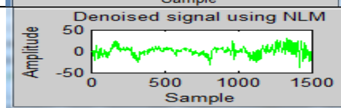
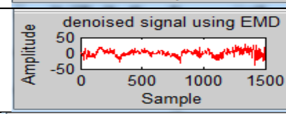
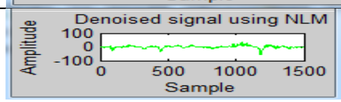
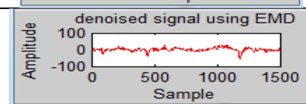
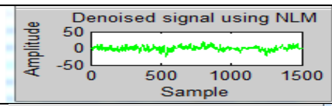
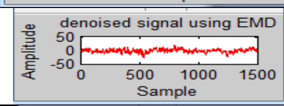
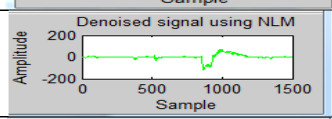
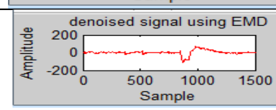
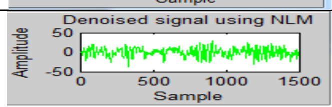
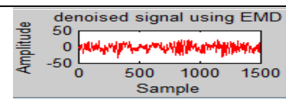
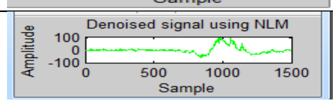
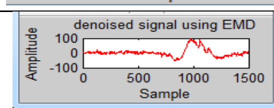
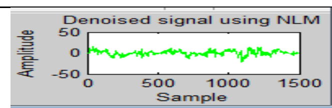
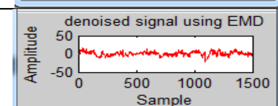
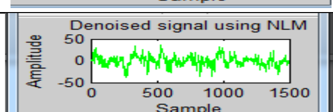
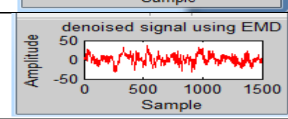
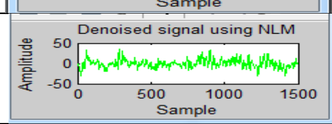
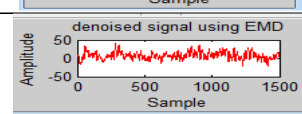
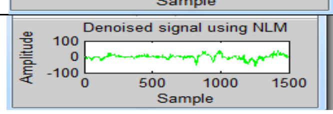
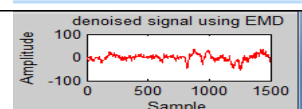
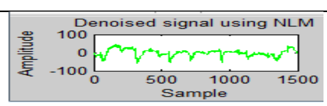
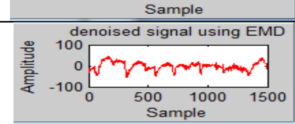
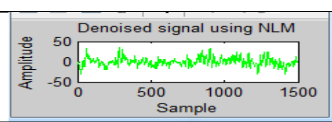
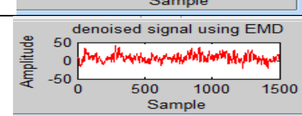
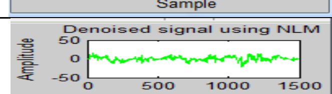
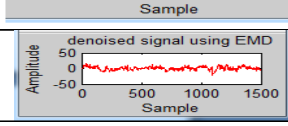
SNo	Signal	NLM Algorithm	Signal	EMD agorithm
1		27.8487		24.6404
2		24.1173		47.5102
3		23.0787		39.7955
4		28.9549		23.1207
5		21.8996		60.7739
6		27.2257		23.7416
7		22.0944		33.7580
8		26.0121		30.9509
9		27.7751		24.9556
10		27.9741		12.1615
11		23.0307		45.3392
12		22.2931		37.3445
13		22.0048		61.7514
14		28.0547		57.1682

Figure B1: Signal to Noise Ratio for healthy control using Non Local Mean and Empirical Mode Decomposition algorithm

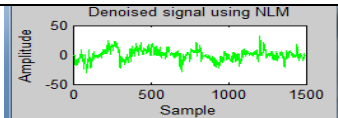
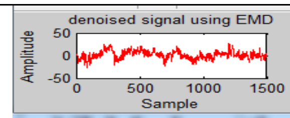
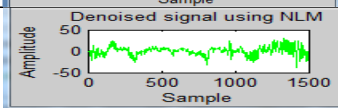
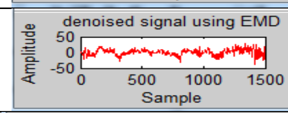
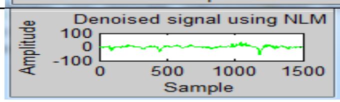
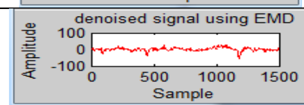
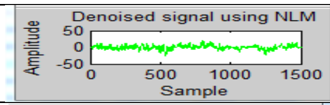
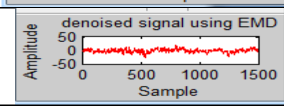
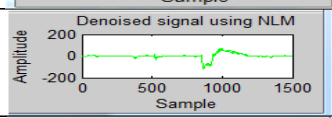
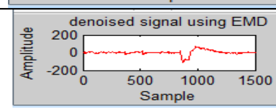
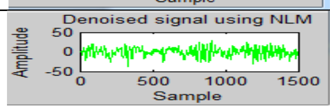
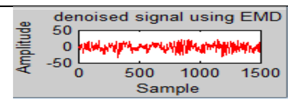
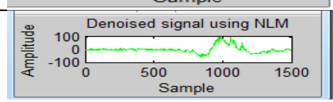
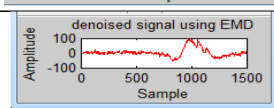
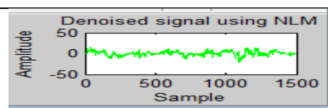
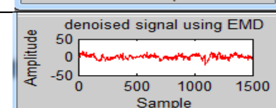
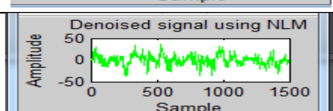
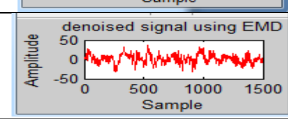
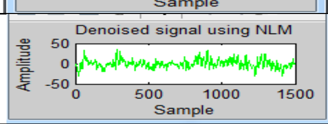
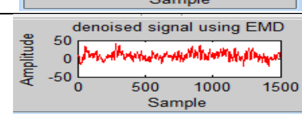
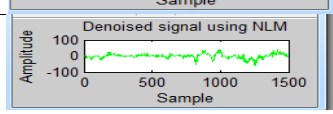
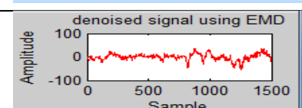
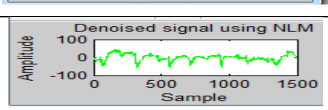
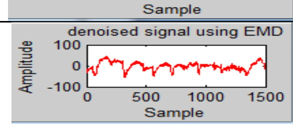
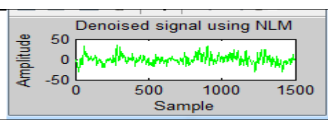
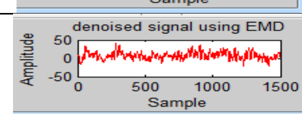
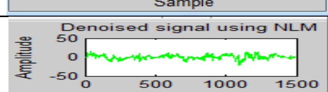
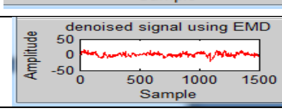
SNo	Signal	NLM Algorithm	Signal	EMD algorithm
1		24.1001		33.8067
2		23.7799		37.5560
3		26.6693		36.7904
4		24.1634		28.8600
5		30.0173		27.3268
6		25.0181		24.0664
7		21.9828		49.7475
8		23.9185		30.2885
9		26.7313		17.3245
10		28.4850		40.1547
11		29.0275		18.9752
12		25.9753		38.3374
13		24.7345		19.8007
14		24.0147		10.5309

Figure B2 : Signal to Noise Ratio for Paranoid schizophrenia using Non Local Mean and Empirical Mode Decomposition algorithm

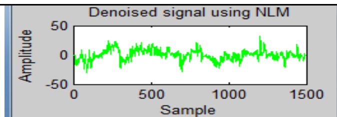
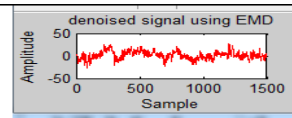
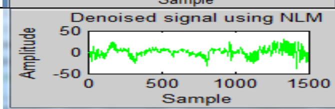
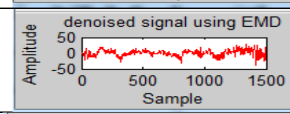
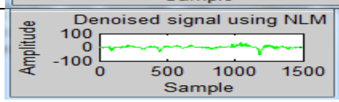
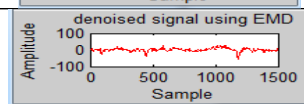
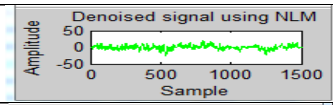
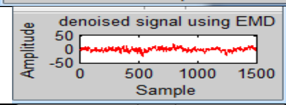
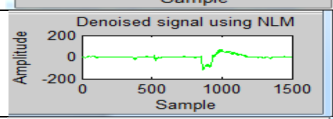
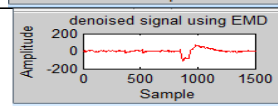
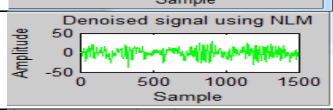
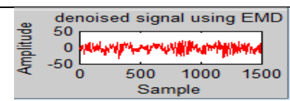
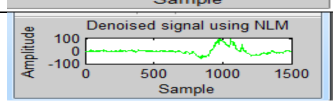
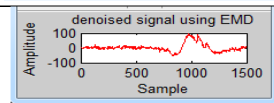
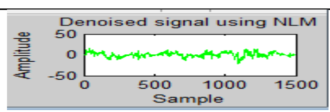
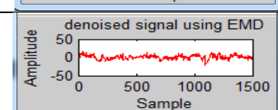
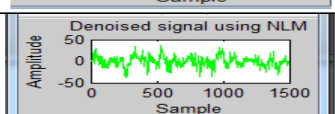
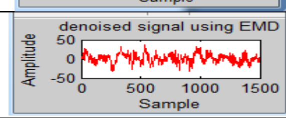
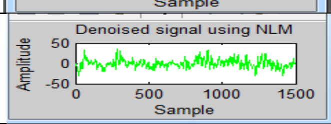
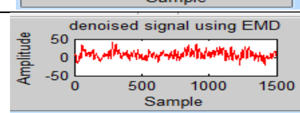
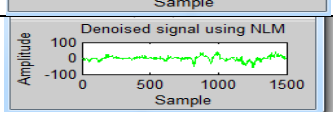
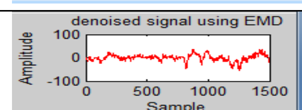
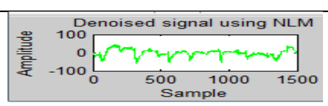
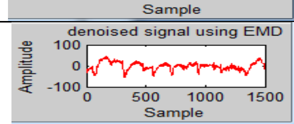
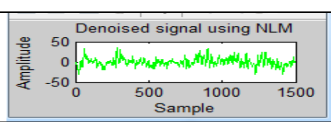
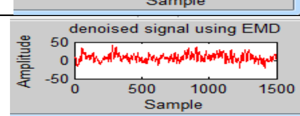
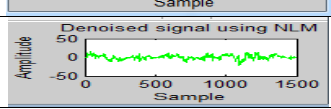
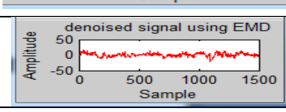
SNo	Signal	NLM Algorithm	Signal	EMD algorithm
1		29.9744		29.5496
2		31.8189		29.3170
3		33.0008		29.1253
4		26.4026		27.0739
5		31.9553		36.6777
6		29.9567		29.2321
7		34.6314		41.2518
8		26.5344		23.9627
9		33.3613		33.3764
10		32.1805		23.6651
11		43.7468		31.2089
12		33.8116		33.8058
13		31.4888		38.9009
14		31.1811		29.6670

Figure C1 : Peak Signal to Noise Ratio for healthy control using Non Local Mean and Empirical Mode Decomposition algorithm

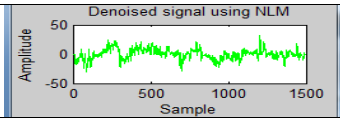
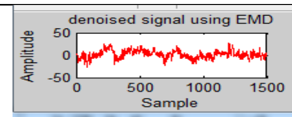
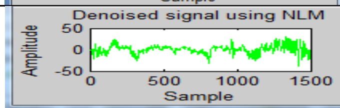
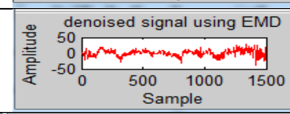
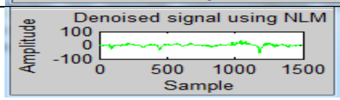
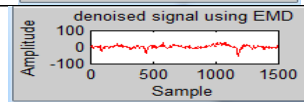
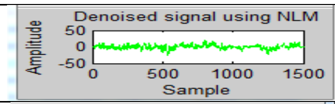
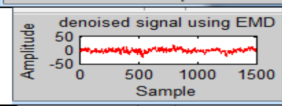
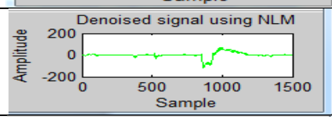
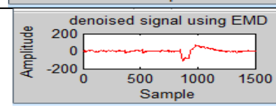
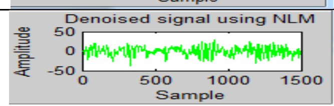
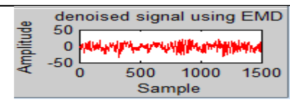
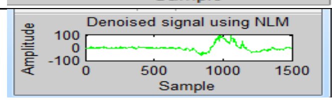
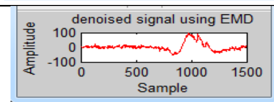
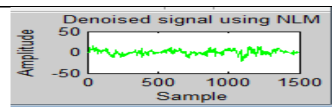
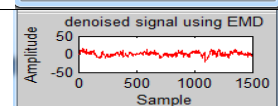
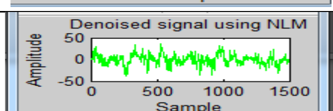
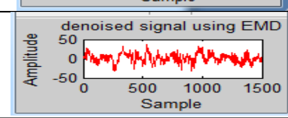
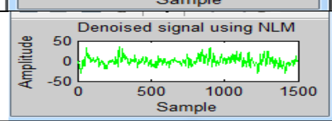
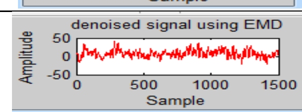
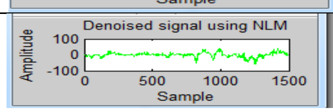
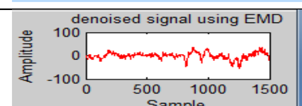
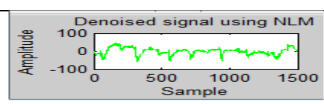
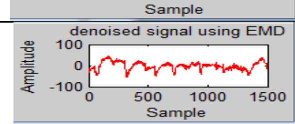
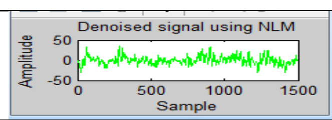
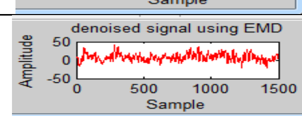
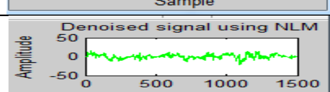
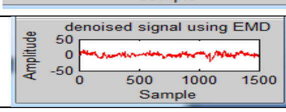
SNo	Signal	NLM Algorithm	Signal	EMD algorithm
1		36.1719		31.7238
2		49.1074		38.5078
3		30.4124		27.6853
4		42.1663		51.3829
5		28.8804		27.9356
6		30.8997		30.5637
7		25.1763		47.4390
8		45.1850		33.0960
9		32.1223		28.2585
10		27.3890		25.9951
11		31.7274		32.7780
12		35.7767		31.0967
13		40.3409		40.6265
14		39.4830		23.3776

Figure C2 : Peak Signal to Noise Ratio for Pranoid schizophrenia using Non Local Mean and Empirical Mode Decomposition algorithm

Feature Extraction Coefficient values

Signal 1

13x8 double

	1	2	3	4	5	6	7	8
1	32.1197	32.7741	31.4855	31.3850	32.2987	31.3343	32.5119	32.9942
2	-5.5775	-4.8715	-3.2600	-4.9729	-4.7176	-6.7957	-6.0492	-3.2102
3	-3.9538	-3.6958	-4.3863	-7.1538	-3.1344	-2.0383	-1.8696	0.6297
4	-0.4581	-3.9106	-1.6737	1.4766	-0.6080	0.4159	1.8212	1.8829
5	-1.2754	-7.9507	-1.9804	3.3239	-2.0373	-3.7931	1.7837	-3.7769
6	-3.8664	-2.5177	-3.3189	1.4790	-1.4949	-3.8173	-4.6700	-4.1428
7	-2.3259	0.9867	-3.5835	3.1373	-7.8961	-4.4295	-4.3317	-7.5594
8	-8.9278	-4.7697	-3.5925	-0.2187	-0.7908	-8.4355	2.3071	-4.7475
9	6.2044	0.2119	-0.9857	-1.5671	-3.6910	-3.4607	-1.2478	-5.2474
10	-4.5876	-0.7274	-3.3643	-8.8237	-2.6659	-4.6036	-4.5358	-4.4675
11	-5.3403	-0.2139	-0.0320	-1.7661	-3.6050	1.4722	-2.3955	-0.3253
12	1.6034	-1.4049	3.5007	-1.8315	-2.1453	0.9760	-7.4927	-1.5602
13	3.9536	3.9396	1.7368	-2.8235	-1.9818	-1.6834	1.8318	1.1951

Figure 3.4.1.1

Signal 2

13x8 double

	1	2	3	4	5	6	7	8
1	30.5926	31.4523	28.2939	29.2161	30.3043	32.1496	33.1572	33.1928
2	-6.9914	-3.9586	-1.7497	-3.3980	-3.9754	-1.2390	-3.3057	-3.3101
3	-1.2966	-3.5513	-3.7873	-2.3141	-2.1255	-2.2246	-2.5957	-0.6373
4	-1.4485	2.9446	0.2987	-1.9541	0.7301	-0.6667	-1.9841	-2.5324
5	1.9040	0.9146	0.2732	1.7852	-4.2501	0.4102	1.3933	0.2363
6	-3.9914	-2.3820	-3.3551	-5.7868	-3.4208	-7.7756	-3.2012	-2.0973
7	0.0957	0.6767	-11.6164	-3.6924	-1.4045	-5.5544	0.2542	0.5701
8	2.7741	-2.9441	-0.7699	4.8293	1.6210	-2.2444	-5.2878	-9.4091
9	-4.4891	1.5369	-3.1247	-0.6815	6.1657	6.8998	-0.8802	-12.4762
10	-1.8572	2.5285	2.3090	3.0869	6.6075	-1.3804	-2.3375	-6.3708
11	-5.3572	1.7604	1.2235	1.4132	6.5634	-3.8980	1.8267	2.8374
12	-2.2362	-4.3672	-1.4630	0.7666	-1.5468	-3.4511	0.6227	-3.0961
13	-5.6428	-2.5707	1.1584	3.5455	4.3346	-0.9918	3.6169	1.4762

Figure 3.4.1.2

Signal 3

13x8 double

	1	2	3	4	5	6	7	8
1	29.2645	28.1387	30.5599	30.1127	26.0254	27.7324	30.5608	30.8100
2	-6.1625	-4.3462	-2.9973	-4.6689	-6.7404	-4.7833	-4.4028	-3.6539
3	1.8885	0.8306	-0.7565	-3.1194	-0.3092	4.3350	4.3585	6.2674
4	1.3138	1.2938	4.7458	1.7195	1.5118	3.4693	1.6116	5.7498
5	-2.8140	1.9572	0.5814	-3.9016	0.3764	0.2838	-2.6972	-0.4219
6	-4.1369	-0.6160	2.5779	-3.1012	-1.1965	0.2400	-3.9449	-2.9679
7	1.0141	3.8376	0.8931	-3.8231	3.6678	-3.4785	-2.6197	-3.8787
8	-0.2432	1.0021	-1.3713	-1.8606	0.3456	-7.6125	0.8889	3.6054
9	-0.1907	3.7851	-3.8342	-2.7291	0.5263	-5.0537	-1.4687	1.0854
10	-1.3998	0.3433	1.2411	-5.0907	-2.9992	-3.9248	-3.9263	-11.0610
11	-5.4151	-3.3474	0.4824	0.7793	-5.8099	-3.7138	-4.9160	3.7921
12	-0.3763	-2.0860	-4.1597	-5.6131	-2.4131	-4.7697	-6.3424	0.4465
13	-3.2663	1.0491	8.5712	-0.5144	2.1152	1.8907	-5.3200	-1.6231

Figure 3.4.1.3

Signal 4

13x8 double

	1	2	3	4	5	6	7	8
1	31.3837	32.3687	33.1554	31.7373	30.8665	31.7967	30.3981	30.8341
2	-3.6063	-4.5919	-2.0873	-3.2333	-4.3940	-4.4018	-5.0544	-4.7775
3	-3.3944	-2.1392	-4.9720	-4.6211	-4.8851	-3.8664	-4.8740	-2.4008
4	-0.5521	1.9013	1.4626	2.7553	4.3748	0.8910	1.8096	0.8244
5	-0.9392	-0.4212	-1.6990	-0.4812	3.3107	-1.0279	-2.4742	2.0774
6	-0.5569	1.7527	-0.8354	-0.3906	-2.2152	-2.2420	0.5494	0.0301
7	-2.2428	5.2855	3.7751	1.4202	1.5484	-0.3841	3.8263	0.0385
8	0.8275	1.5052	0.1931	1.1589	-4.0183	-1.6202	1.4919	-6.0164
9	4.2201	6.8901	4.5975	4.5388	-2.1168	8.1377	2.4690	-2.6628
10	-0.7260	-1.5999	4.9898	6.4165	-3.2149	-4.7889	-2.2770	3.4551
11	0.6781	-3.5161	-0.4999	1.8165	0.3864	1.2009	6.3366	4.9260
12	0.1904	-0.3816	-0.3368	-2.1662	0.8008	5.3845	4.0107	1.0996
13	-2.1223	1.5369	1.2725	-1.3041	-2.6287	-0.6630	0.5388	4.6082

Figure 3.4.1.4

Signal 5

13x8 double

	1	2	3	4	5	6	7	8
1	25.1456	26.2496	28.1866	26.0746	29.9822	36.0966	32.4822	28.0351
2	-6.9280	-7.6970	-5.0185	-5.4484	-7.2538	-6.8225	-7.5894	-9.9601
3	0.8061	-1.7082	1.7671	2.7035	3.5794	2.0039	-1.6247	-1.5853
4	-1.2883	-1.6878	1.0239	1.6138	8.4683	2.7681	0.7021	4.3752
5	1.9013	8.3705	6.4900	4.5284	3.4995	-0.3707	3.3852	2.0921
6	0.5159	-2.0006	-3.2241	-5.9172	0.1070	1.4681	2.4590	-6.4583
7	4.0371	1.1390	3.8438	6.3315	-0.2991	0.2136	-2.6840	-0.7394
8	3.7727	0.2139	-1.5759	1.8429	0.2822	0.0323	1.7881	-0.8545
9	-1.6825	3.1277	6.1599	2.0620	-3.4350	3.0523	2.3174	-10.7054
10	4.2108	4.5820	0.7446	-1.4075	-2.9800	1.4707	1.2450	6.0908
11	-1.9911	6.2115	-4.8292	-5.9158	7.0820	8.8324	7.3831	4.4705
12	5.6417	5.7385	3.3771	0.8271	-1.6268	-2.8745	-1.8344	-2.0981
13	-2.9080	-0.6378	-2.1096	-0.1918	-2.6048	-3.3518	-2.4614	7.7204

Figure 3.4.1.5

Signal 6

13x8 double

	1	2	3	4	5	6	7	8
1	31.5236	33.6379	31.5835	32.2536	33.3094	33.5452	32.9687	34.0145
2	-3.0291	-2.7783	-3.1720	-6.0034	-3.4457	-1.3947	-3.1217	-2.2150
3	0.8168	1.2149	0.3091	-0.7722	1.4982	3.1238	3.2178	0.3085
4	0.2563	4.7224	3.1969	4.2514	3.1885	-1.4509	2.9353	1.9892
5	5.4345	7.3163	-0.0086	-1.8943	2.3694	5.6841	-2.9254	-3.0266
6	-1.5698	3.2009	-5.0749	-6.5691	-4.9809	-5.7093	-3.9863	-0.5253
7	3.6220	-1.0379	-2.9970	-0.4391	-3.6658	-8.0224	-0.5117	2.7073
8	-3.9237	-6.0349	-6.3642	-8.5301	-12.7753	-9.1553	-4.3417	-12.6985
9	-12.5799	-5.4677	-1.0777	-2.6765	-5.0550	-6.8684	-8.7180	-15.9766
10	-5.7503	-5.4643	1.2838	-1.9860	-11.8493	-5.2649	-5.2119	-8.4914
11	-4.1699	-2.3841	-3.3986	0.9508	-7.1020	-3.8119	-2.8076	0.4792
12	-7.8266	-6.4481	-1.6096	1.9615	-0.9640	-3.5827	-0.3231	-2.8529
13	-2.9329	-1.8687	-2.3396	0.8983	-1.6092	-1.9545	-5.4929	-2.7735

Figure 3.4.1.6

Signal 7

13x8 double

	1	2	3	4	5	6	7	8
1	25.6645	24.0443	25.5818	25.2105	27.3829	31.2457	35.8861	30.6827
2	-7.3433	-4.9629	-6.1145	-5.8829	-6.2286	-7.1430	-3.6903	-8.0065
3	-1.7223	1.9564	2.4581	2.8398	0.4670	1.4625	-0.5766	-0.6505
4	1.5786	4.6963	-0.1448	0.0954	2.8091	-0.6408	-1.3990	3.6757
5	-0.7670	4.6095	3.9552	1.2548	8.6186	8.0473	-0.0935	4.5708
6	-2.3788	-1.3572	-1.9574	-3.8148	-7.9051	-0.6721	1.7878	-4.0797
7	0.2043	3.1280	-6.3603	1.5036	1.6668	0.8695	-4.9354	0.5093
8	-5.3599	0.5175	-0.8208	-5.6149	-5.6633	2.9771	3.2549	-1.4557
9	-7.3903	-0.3930	6.4148	-2.0893	-5.8542	-1.5058	-5.8003	-5.8438
10	-6.1470	-1.5639	1.1776	-0.5233	8.9297	-0.1688	0.2001	-3.6155
11	1.0264	-0.3771	-3.5532	-1.8850	2.1290	-4.5396	-1.9340	-2.7533
12	-0.3617	-1.1633	1.0463	1.5703	-3.5338	-4.4651	-3.7075	-1.1020
13	-3.4591	1.4245	-3.8663	-2.2796	0.3578	1.3382	10.0928	8.9408

Figure 3.4.1.7

Signal 8

13x8 double

	1	2	3	4	5	6	7	8
1	28.8736	29.9999	27.4760	29.4299	28.3195	29.2740	31.0719	30.2685
2	-5.3174	-5.6809	-4.4698	-4.5904	-4.4004	-4.4477	-4.6711	-3.2549
3	-3.2552	-1.5415	-0.0473	-2.3485	-3.0684	-3.8245	-1.3143	-3.0714
4	1.5936	1.0103	3.3708	3.0883	0.4481	3.1987	2.8212	2.8394
5	-0.7757	-2.4712	-0.4541	-4.8513	-0.5429	-2.3724	2.1601	2.4996
6	1.2909	1.6299	3.3929	-0.0729	0.1986	5.4452	0.1984	1.3241
7	0.4158	-2.3863	-0.8708	1.6220	2.7425	0.4531	-1.0000	7.6560
8	-4.9910	-0.1722	-1.0370	-5.2934	-4.1480	-4.2641	-2.3324	-1.0566
9	5.2193	11.1712	7.6492	-1.9861	-0.9127	-2.8963	-2.1405	0.3322
10	4.0092	1.1617	1.8847	-6.4583	-2.2965	-7.2739	-1.6662	2.7656
11	-0.6733	-0.7648	1.2616	2.3680	-1.3160	-3.9250	1.8558	-4.9882
12	3.7582	3.6445	1.0814	-0.0531	-2.4058	-7.3569	-1.2235	-2.2603
13	6.0070	0.4443	-1.7179	0.3766	2.3592	2.1344	0.0387	-0.8754

Figure 3.4.1.8

Signal 9

13x8 double

	1	2	3	4	5	6	7	8
1	33.1523	34.0995	35.1297	34.2152	33.8248	34.3413	33.8455	32.8687
2	-6.0443	-3.8712	-4.1257	-3.4638	-3.5688	-3.9000	-3.8692	-5.5498
3	-2.8160	-2.9644	-0.1527	0.9110	0.5092	0.9393	-0.1247	-1.2475
4	1.9658	2.9503	2.9508	-0.2792	2.2557	-0.3438	-0.9957	-2.1103
5	-1.6092	-5.6401	-1.6762	-2.0413	-3.2075	-3.5653	-4.3119	-6.5585
6	-3.2026	-4.3684	-4.7820	-1.5382	-5.7672	-6.9443	-0.0060	-4.7408
7	2.8649	0.0488	-3.0800	-6.5453	-11.4039	-13.0793	-5.7476	0.1114
8	-6.5017	-5.5373	-4.1677	0.4437	-10.6584	-5.8533	-1.3526	-3.1701
9	-2.2358	-0.4153	-1.4995	-1.3207	-14.2078	-3.7563	1.2109	1.6442
10	-0.3099	-3.0260	-0.5223	4.7723	-6.9241	-5.3529	-1.3132	3.1129
11	2.0998	-0.4449	-0.1167	0.8689	0.3753	0.9093	2.2043	5.8685
12	2.6797	0.9976	3.5565	-3.2084	-1.1828	-2.1395	-1.3364	3.1859
13	-1.3290	0.1369	3.6785	0.0691	-1.8206	0.8259	-1.5144	-2.9846

Figure 3.4.1.9

Signal 10

13x8 double

	1	2	3	4	5	6	7	8
1	31.2670	32.9136	32.6665	31.6298	33.3617	33.2724	32.3642	33.7389
2	-2.6883	-3.3516	-3.5691	-4.3385	-3.5556	-2.2310	-3.1762	-3.5664
3	4.8181	3.2495	1.2512	-2.1960	0.4011	1.3670	-0.3722	-0.3112
4	-0.2720	-2.0727	2.3866	1.6827	-1.8833	2.7818	-2.8825	-1.3145
5	-3.5330	-5.3547	-3.9412	-4.8587	-10.4170	-3.0655	-0.7748	0.4044
6	-0.5524	-2.8771	-3.4662	-3.8762	-8.3166	-4.2658	-9.0618	-4.3646
7	-4.1927	-11.1766	-3.2216	-3.1516	0.6155	-6.9801	-7.8350	-8.3908
8	-7.0661	-10.5506	-4.3548	-4.7686	-7.7847	-5.9010	-3.8845	-8.6477
9	1.7803	-4.5416	-3.3306	-5.6381	-7.7415	-5.9879	-4.8700	1.4891
10	2.6961	-0.6166	-4.6238	-2.7559	0.7150	-9.5359	0.1474	-4.3913
11	-1.0252	5.0302	0.5502	-2.1632	-1.7645	1.1134	1.1298	-6.9386
12	2.3429	0.9161	-2.2635	-3.1714	-5.4466	-3.0494	-3.6775	-8.5240
13	2.6071	0.3646	4.7349	7.3386	-3.3243	3.9594	0.7896	-2.2738

Figure 3.4.1.1

Signal 11

13x8 double

	1	2	3	4	5	6	7	8
1	30.6025	28.9143	27.8727	30.8250	32.4222	33.9843	31.3296	34.3689
2	-6.1080	-7.6669	-4.6171	-0.7909	-5.2112	-3.6337	-5.7701	-7.0708
3	-3.5872	-2.1505	-3.4995	-2.4564	3.7711	0.7289	-1.0154	-5.1724
4	-2.7771	-0.0232	2.7254	0.3653	4.4123	0.7080	1.5822	-0.5641
5	-0.7867	-2.9318	-1.9715	-1.8991	2.6824	2.8803	1.5261	-4.5357
6	-6.1332	-6.1373	-8.6492	-2.7867	-2.1626	0.9678	-4.1314	-0.3223
7	0.9588	-1.3257	-0.9453	-0.8927	0.1288	0.6881	1.2488	4.6347
8	-0.6277	2.0320	-1.5241	-5.2929	3.7964	-0.5771	-0.9816	-7.3348
9	5.8881	5.7498	-0.8101	-0.6163	-4.9509	0.4821	-1.0467	0.7479
10	7.1217	8.6620	4.5255	2.0587	4.1988	7.6144	1.0905	-4.4361
11	5.9595	11.5146	12.0518	2.8251	-1.6464	-3.8790	-0.4097	2.6279
12	6.5971	5.0559	4.7152	-1.9756	-3.2981	-0.6761	2.6485	-3.3648
13	4.7547	4.2248	3.2059	-3.4374	4.4354	2.6777	2.5786	-0.1994

Figure 3.4.1.11

Signal 12

13x8 double

	1	2	3	4	5	6	7	8
1	32.9551	34.9930	33.3312	32.3747	30.0220	31.9914	32.9321	33.2258
2	-6.5125	-6.0575	-6.2434	-5.2562	-3.5757	-3.7381	-5.8241	-5.9919
3	2.1338	3.2384	2.4715	1.9876	0.3361	3.6707	-0.5383	-1.4904
4	1.3899	2.9605	1.2431	-0.8620	1.4881	3.1554	1.3619	-1.7116
5	-3.0823	-1.1215	1.7199	1.7004	6.3160	0.2370	1.7226	3.3813
6	-1.6790	-3.6048	-1.0045	-2.4749	1.0656	0.0717	-0.7533	4.1179
7	1.1335	0.9735	2.3808	-2.5444	5.7639	2.9417	-3.2448	0.3962
8	-3.2221	-1.9524	-0.7877	1.7946	-1.6557	-3.9184	0.1045	2.7636
9	2.4676	6.6470	-2.9767	4.8123	-3.4022	-3.6372	-1.9638	1.6096
10	-0.7639	-2.0260	-2.5240	0.3872	-2.8460	-0.7172	-0.9099	-4.1981
11	0.4751	3.5264	2.5662	4.7830	0.7636	-0.7244	-0.7858	-4.2299
12	4.5611	-1.4479	-3.5360	-1.5927	2.7628	-0.1957	-5.3877	-9.8460
13	-1.7078	-1.3648	-0.2292	-3.1851	-1.9755	-3.0452	-3.4599	-3.4837

Figure 3.4.1.12

Signal 13

13x8 double

	1	2	3	4	5	6	7	8
1	27.5846	28.6692	28.0960	27.5749	28.2282	34.5823	32.8558	35.6577
2	-6.2358	-9.4433	-7.8559	-7.1290	-8.7758	-10.9386	-8.7986	-8.6536
3	2.3305	-0.5335	0.2918	-0.4615	-0.2002	-4.8308	1.0252	1.5658
4	2.9293	2.2757	0.4343	-0.2129	-0.1134	-0.9796	-0.8045	2.0099
5	3.4122	3.3486	5.7522	4.8799	0.6218	3.8532	4.6559	0.4392
6	-1.8635	-1.8452	-7.5772	-14.2017	-12.1832	1.5848	-2.9464	-1.7079
7	-2.7394	3.7965	1.9396	-7.3264	-3.5108	2.2180	-1.0855	-0.7658
8	2.6254	0.5476	0.3808	0.1560	0.2203	1.9713	-0.5498	-6.5734
9	0.2519	3.9203	-5.8643	-8.3879	-7.8578	11.6097	9.0425	5.0914
10	-5.1741	1.1273	-3.7988	4.1014	0.9053	-3.5212	1.4288	6.2156
11	-7.9804	-4.2903	-2.5914	2.0619	3.2943	-3.9090	-4.5819	1.0475
12	-1.7523	4.9173	6.1238	3.6445	1.6258	-3.8092	2.6724	2.0322
13	-1.0613	-3.9639	-3.5493	-0.3921	1.8450	-3.5147	0.7803	-7.0503

Figure 3.4.1.13

Signal 14

13x8 double

	1	2	3	4	5	6	7	8
1	35.4641	33.5497	33.6184	33.3725	32.6659	32.6979	33.9007	33.6861
2	-4.9804	-6.6918	-4.5531	-5.2146	-7.1307	-4.4273	-4.2845	-4.3702
3	-4.8087	-5.7335	-3.8265	-3.9284	-3.7143	-2.1143	0.9523	-1.5972
4	0.7411	0.7618	-1.5426	2.9261	0.3139	0.4273	4.9114	4.9392
5	-1.0037	2.2750	2.3406	1.9917	-2.0307	1.0131	-3.5471	2.3277
6	0.0961	1.6099	-2.1594	-1.3424	-8.0044	-3.3980	-5.9916	-2.2106
7	-1.2115	-3.1489	-5.0809	5.2736	-2.5977	-3.0614	3.0023	0.6322
8	-5.1784	-9.7205	-3.6130	-6.0330	-8.2658	-1.5924	-1.9550	-1.3680
9	3.9055	-1.6957	1.4631	-2.3943	-5.2965	0.6780	2.7937	1.9494
10	3.1101	7.4877	3.2015	-0.3502	-6.6477	-0.4854	3.6688	-1.7289
11	-1.9728	5.0745	2.1760	-1.6910	-7.0719	-1.6274	-0.1794	5.4155
12	8.7884	5.9652	11.0632	-0.0669	-3.4397	-1.0109	0.4138	3.3609
13	-0.1302	2.7928	4.9363	-1.4199	-0.7012	1.1174	-0.0093	-1.0351

Figure 3.4.1.14

Signal 15

13x8 double

	1	2	3	4	5	6	7	8
1	30.4578	30.9780	32.5632	33.4783	31.8567	29.9360	31.9069	30.5395
2	-3.1551	-2.4277	-4.2848	-2.2389	-3.7165	-3.7863	-2.8837	-3.5178
3	1.7747	5.6275	-1.0895	1.4496	0.9345	1.5285	1.8063	2.8189
4	0.8638	-0.2580	-3.4705	-2.1355	-0.5170	-2.7056	-1.1133	0.0332
5	0.2514	-1.0029	-1.5955	4.2751	-1.5349	-1.5452	-7.4654	-6.3049
6	-3.8033	-1.7275	1.7943	-2.7725	-1.2253	-1.9031	-2.6036	-0.7446
7	-0.3879	-0.9412	-2.6186	-0.7562	-1.4518	-5.0872	-6.0404	-4.5580
8	-6.5473	-2.3193	-1.5487	-0.8638	-2.7504	-2.7094	-3.4507	-11.2602
9	-8.8579	-2.9864	-7.2791	-13.2038	-1.3919	-1.5877	-3.3668	-9.9714
10	2.7567	-4.7968	-1.9451	-2.6492	-0.0837	-1.4020	-1.8854	-5.1893
11	-0.6036	-7.0185	0.3674	-2.2337	7.6683	4.0339	0.4324	-0.8155
12	2.6928	-6.0042	5.5671	3.6117	-2.9616	-4.3723	-0.0104	-3.1504
13	3.8307	-0.0102	-1.5766	2.6858	-5.5312	3.8322	3.5890	5.9786

Figure 3.4.1.15

Signal 16

13x8 double

	1	2	3	4	5	6	7	8
1	29.1828	26.6833	29.9745	29.0252	28.5166	30.4347	29.7893	30.9841
2	-5.5667	-3.9580	-3.3211	-4.7500	-3.8307	-1.9065	-3.0798	-3.7151
3	1.8003	3.2715	-2.0883	-0.4080	-0.5137	1.4787	0.8162	6.4758
4	1.5671	1.3419	1.8576	3.9350	1.1645	3.3183	-2.3391	-0.6644
5	-0.6204	-4.3184	3.9391	-0.9533	0.2095	1.6119	-0.4173	-0.3515
6	-4.0015	-2.2557	-4.7298	0.7018	-2.4977	-1.9330	-1.4223	-8.0265
7	1.8339	3.3076	-0.2773	-0.1906	0.8315	-2.3990	-3.2685	-3.1796
8	-2.8363	1.1844	2.5706	-5.4188	-2.9766	-5.3519	-5.0238	-4.2399
9	0.0180	-0.1100	-2.7099	-4.5915	-2.0199	3.0319	-0.0437	-3.9152
10	-1.9791	2.4843	-8.2312	-11.0619	-3.9472	-0.3712	-2.2793	-10.8150
11	-0.3254	0.4640	5.1376	1.6039	1.7467	-0.2392	-1.9813	-6.4741
12	-0.7893	0.1921	-4.8944	0.7677	5.1525	3.3689	5.1144	2.1907
13	1.5750	3.1766	-0.9773	3.4774	2.6335	-1.2662	-0.4966	-3.2270

Figure 3.4.1.16

Signal 17

13x8 double

	1	2	3	4	5	6	7	8
1	32.4261	33.1141	32.4987	33.7028	31.5681	32.9821	32.4456	32.4087
2	-0.6946	-0.5686	-1.3996	-1.9222	-1.4355	-0.4852	-0.5890	-2.8689
3	0.1500	-2.2986	-3.1342	-1.8605	2.9430	3.4425	-0.4767	-1.4176
4	-0.5272	-6.9344	-6.1433	-3.3527	-6.8601	-6.0842	-6.0670	-2.6050
5	-0.9214	-6.2862	-2.2595	-1.5415	-8.0482	-0.0665	-1.2876	1.3093
6	-0.9604	-4.5824	-7.3485	-5.8577	2.9600	-8.3334	-9.3243	-9.9271
7	-2.8047	-2.9018	-1.8145	-1.4731	-8.0270	-8.8437	-7.7781	-4.0175
8	-5.9813	-14.0815	-7.2684	-12.3260	-9.1794	-13.2264	-10.0125	-9.9389
9	-6.5675	-6.5164	-5.5027	-2.4992	-8.8833	-10.5604	-9.7941	-19.6847
10	-2.7586	-5.8650	-1.9652	-4.0095	-8.1796	-6.5623	-3.9295	-9.3476
11	-4.4321	1.3926	-2.4611	-2.8837	-4.0107	-0.2577	-1.5335	-0.6516
12	0.9466	1.6351	-2.3746	-3.8098	-1.9631	1.3985	-2.0563	0.6036
13	-2.0729	-0.0181	4.0781	2.3574	1.5264	1.9652	-2.4705	3.8871

Figure 3.4.1.17

Signal 18

13x8 double

	1	2	3	4	5	6	7	8
1	38.6377	38.1397	38.4165	38.0426	36.0970	38.5423	37.3733	35.7749
2	-9.9385	-9.6902	-10.1912	-10.0227	-11.7977	-10.5545	-11.0787	-9.0757
3	-6.4982	-6.4731	-8.3866	-8.7449	-7.4986	-10.2154	-8.5916	-6.4079
4	-5.6328	-4.0410	-3.7789	-3.5193	-0.9058	-3.0303	-1.8551	1.4680
5	-0.8702	-4.1537	-1.6981	-0.6771	-4.8548	-2.5239	5.8040	2.5946
6	3.5063	-0.1646	0.4589	-0.5055	-0.3963	0.4895	3.9234	0.6936
7	-0.3079	-0.8482	1.6455	1.1869	-1.3960	3.1930	1.5215	1.6345
8	-3.3249	-6.7293	-5.8029	-2.8872	-1.5367	4.1147	3.6995	6.8716
9	-3.5499	-2.9357	-3.0074	-2.0853	-0.3780	3.8080	-3.6653	-5.5265
10	-3.1815	-0.8045	-1.0072	-2.3503	4.8366	7.5804	-0.7256	-0.6037
11	-6.4618	-2.1080	-1.3302	-1.5267	-0.2659	1.5225	1.0623	-4.5966
12	-0.0655	2.5568	4.9198	-3.4256	-0.8362	6.3601	-0.7805	0.2017
13	-4.7394	-6.2719	-1.3975	-2.0900	-2.2066	2.4031	1.9943	-0.8454

Figure 3.4.1.18

Signal 19

13x8 double

	1	2	3	4	5	6	7	8
1	33.9693	33.4591	34.0908	34.0824	33.9002	34.4541	33.6494	33.0911
2	-4.3734	-2.8817	-1.9392	-3.4038	-4.9821	-2.5177	-2.1866	-2.8718
3	-1.3642	-3.0758	-1.8695	0.9166	-4.9435	-0.2899	-0.0092	1.2079
4	0.1381	-5.5929	-2.9721	-2.3444	0.6114	2.0415	-2.6701	-2.3485
5	-7.2003	-4.7532	-5.9212	-3.9444	-7.4141	-4.5865	-7.2273	-3.8973
6	-3.0963	-7.6939	-9.0758	-3.8194	-12.3256	-8.9476	-6.7403	-4.8432
7	-4.1093	-7.8391	-10.7799	-4.8190	-13.5175	-9.9004	-4.4434	-7.0495
8	-5.3875	-1.7826	-4.7875	-2.6729	-11.9773	-7.8887	-7.8369	-7.1269
9	-0.1991	-0.6081	-4.2780	-1.4481	-5.9328	1.1867	2.5217	-4.6566
10	-6.9044	-2.1131	3.1016	5.2956	2.9474	4.1292	1.5275	1.7118
11	-2.0294	3.3959	2.3096	4.5488	8.3953	2.4463	0.8709	0.2377
12	3.5153	9.4991	5.1930	1.3553	2.8200	1.0920	-0.7074	5.4938
13	0.6178	1.0648	-4.0537	-2.7288	0.3338	2.9238	2.2647	-1.1198

Figure 3.4.1.19

Signal 20

13x8 double

	1	2	3	4	5	6	7	8
1	33.1698	30.7814	31.9549	32.1303	31.8650	30.1152	31.8179	32.1816
2	-2.7346	-1.5396	-4.4286	-2.6934	-2.8066	-2.3096	-1.6295	-2.3903
3	1.0653	0.9399	0.2675	0.6271	-2.0169	-1.1102	0.0922	-0.2985
4	-4.2960	-3.9998	0.8832	-1.2002	-8.6104	-4.3393	-1.3999	-0.0233
5	-2.5586	-2.3152	-7.1234	-3.5056	-3.1762	-4.7730	-1.2969	0.7472
6	-1.6361	-1.7012	-3.5584	-10.8431	-12.2638	-6.2579	-6.8427	-5.5666
7	-8.6106	-0.8893	-1.6412	-3.4773	-3.8003	-4.1201	-3.5251	-0.6621
8	-8.0047	-9.0863	-6.1765	-3.8544	-8.7503	-7.6812	-7.0352	-3.4678
9	-6.6665	-2.2738	-6.4361	1.7750	-14.2725	-7.3842	-3.9851	-3.3993
10	-6.1952	-0.3701	-1.1120	5.0730	-8.0131	-3.3450	0.9945	0.4191
11	4.9352	4.9710	1.1282	-0.8629	0.4085	1.3395	6.1227	2.8961
12	5.5668	3.1509	-2.1269	3.3385	6.0849	3.7555	2.7146	1.1497
13	8.9331	6.2765	0.8769	5.6560	5.2325	5.5650	4.5625	4.2479

Figure 3.4.1.20

Signal 21

13x8 double

	1	2	3	4	5	6	7	8
1	43.9904	34.6994	35.5751	34.0689	34.8472	34.8685	35.3425	34.7670
2	-7.2309	-13.5995	-13.5925	-13.0167	-11.3024	-11.8093	-8.5083	-11.7292
3	0.6484	3.8799	4.5264	5.7687	2.2692	3.1600	2.2366	3.4855
4	-0.3188	7.7557	5.3996	6.6671	7.6981	6.3271	3.0295	5.3355
5	1.5397	11.0033	6.5673	9.3333	6.6650	7.8067	4.2681	2.3129
6	-1.3111	-2.7915	-5.5668	-9.3236	-9.4670	-11.3406	-10.6353	-5.5511
7	-0.4632	2.7370	1.4558	-7.2167	1.0422	2.0032	-5.1625	2.0703
8	3.9195	1.6366	5.6344	6.1465	-0.4889	-0.8905	-1.7110	0.1965
9	-2.4049	2.3079	1.1042	-3.2560	9.2614	3.7512	0.1751	-4.6885
10	1.1511	0.7270	7.3512	-3.0623	2.9492	0.1312	-1.1356	-4.5231
11	2.1396	0.0132	0.7368	-4.5543	-0.3805	-1.3746	1.1135	0.8254
12	-0.0288	0.5209	8.8321	2.9857	-1.4807	-0.0446	-5.5007	-2.6480
13	-0.8314	-4.7990	-0.7584	2.7129	-2.4560	0.3258	-3.9284	-6.1204

Figure 3.4.1.21

Signal 22

13x8 double

	1	2	3	4	5	6	7	8
1	33.0485	35.6095	31.6886	32.7613	35.2907	32.8373	34.6031	33.7145
2	-4.9261	-2.3226	-3.0530	-0.8888	-1.9526	-0.7866	-2.2725	-2.0789
3	-0.5932	0.8633	2.3902	3.3138	2.2401	1.9770	1.7696	2.1300
4	-1.8669	-2.0789	-5.5820	0.5337	-3.5536	-3.4730	-2.7835	-1.2309
5	-3.1975	0.2236	-6.4882	-3.1787	-3.9085	-3.5868	-0.5426	-3.5095
6	-6.6607	-9.1171	-8.0483	-6.4446	-7.9995	-6.7702	0.5050	1.5091
7	-9.9567	-6.3606	-3.5774	-7.7069	-7.1354	-4.5925	-2.8354	-0.7557
8	-12.0207	-7.2980	-6.5247	-7.0892	-3.9289	-9.2040	-5.0381	-5.9063
9	-6.4642	-11.2233	-6.7251	1.2108	-10.5007	-5.7637	-3.8691	-8.8836
10	2.8267	-1.3170	3.2844	2.9533	-5.8657	-3.6384	-11.9328	-0.2151
11	8.5651	1.2117	-1.0556	-4.6896	-4.3046	-4.0577	-5.5422	0.5275
12	5.1471	1.0214	-1.0668	-0.4989	1.7761	0.6638	-1.7024	-5.2287
13	1.5428	3.6651	1.5198	3.7676	3.9131	2.0012	7.3725	7.6451

Figure 3.4.1.22

Signal 23

13x8 double

	1	2	3	4	5	6	7	8
1	31.9813	32.8354	33.4341	33.6030	32.2935	34.1219	33.5509	33.1707
2	-2.9100	-5.0569	-4.1914	-4.5889	-4.0099	-3.3142	-4.0937	-3.3788
3	-1.6792	-1.0920	0.5423	0.1489	0.2166	-0.7271	-1.4710	-1.6855
4	-8.7379	-10.1389	-6.2588	1.9035	-2.6583	-3.0100	-5.7397	-3.8053
5	0.7033	0.0752	3.4756	0.6980	0.7854	-0.6174	-0.0993	3.4375
6	-5.1335	6.1612	6.5261	2.7577	-2.5372	-3.6733	-4.7241	-4.4033
7	-3.9263	-1.9648	-2.2770	2.8173	-6.2614	-5.7634	-13.0176	-10.0435
8	-1.3825	2.3618	-6.5277	-4.5701	-8.5739	-4.5498	-12.3964	-9.2326
9	-7.3545	0.9832	-4.7830	-9.6758	-12.4089	-5.7416	-14.9330	-12.4375
10	5.2531	5.4741	1.7192	-5.1259	-5.2796	4.1414	-1.1600	-3.9470
11	0.5335	0.8081	0.5136	2.6745	0.1244	-6.0556	-2.2387	-1.6538
12	-3.8726	4.9951	0.8244	2.0504	2.6657	0.6779	0.3580	1.1192
13	1.1169	-0.6157	6.0388	-5.7795	0.6840	1.2014	1.5477	1.3777

Figure 3.4.1.23

Signal 24

13x8 double

	1	2	3	4	5	6	7	8
1	33.0456	32.9606	32.0467	32.0731	33.8730	33.0037	32.2169	30.8333
2	-4.8987	-6.6698	-5.4064	-5.7782	-4.4112	-6.1786	-5.8194	-6.2510
3	-7.2513	-5.9013	-8.3745	-8.8212	-1.8847	-4.8340	-5.6815	-7.1653
4	4.8650	0.7616	-3.3964	0.8387	4.9476	1.8452	0.2888	3.1728
5	6.4905	0.4405	0.0773	0.6043	-0.8352	-2.0046	-2.3502	0.9735
6	2.6659	1.0555	-3.0027	0.2161	2.3566	7.1478	-1.5268	-1.5978
7	6.3735	6.1297	3.4970	3.7164	9.2131	6.0369	5.3076	-1.3326
8	-0.8821	-5.7496	-4.2488	-3.1876	-5.7912	-0.3483	-6.1813	-5.4742
9	-4.7384	-1.4537	-3.0270	-1.6579	-3.4388	3.0641	-2.5814	-1.1182
10	-1.0426	-4.6568	-4.9145	-5.5290	3.0633	2.5926	-4.6769	3.7514
11	2.2703	-2.0607	-0.5863	5.9942	-0.9616	2.1945	-0.0814	3.7153
12	0.4633	-0.4416	1.3031	7.0263	0.6672	-2.2567	-3.7056	3.3027
13	2.5677	-1.6631	3.4715	6.4587	-1.5032	-2.2514	-0.5010	3.6349

Figure 3.4.1.24

Signal 25

13x8 double

	1	2	3	4	5	6	7	8
1	36.2216	34.8471	34.7269	34.9499	36.8419	38.1528	38.6317	36.4320
2	-4.9219	-7.0790	-6.0233	-5.8400	-5.9106	-6.6756	-5.2235	-7.0876
3	-1.8835	-2.3994	-1.4236	-0.8890	-2.4631	-7.0341	-7.3760	-5.5562
4	0.5078	1.6071	2.9279	-0.9158	-0.6168	-2.3994	-0.0569	3.2690
5	-1.4151	-3.0334	1.7486	-0.9406	-5.3505	-6.1305	-4.2847	0.1189
6	-1.8197	-6.6689	-2.9029	-1.4701	-1.5517	-1.7269	-1.0414	-1.2947
7	-2.3316	-3.8779	-1.6136	-1.3624	-6.3822	-0.8856	4.4284	-0.0184
8	-5.9292	-11.8730	-6.7749	-9.0074	-10.9371	-4.7849	-2.7176	-5.5596
9	-11.1859	-10.3519	-5.7071	-2.2787	-6.3962	-10.8733	-2.9404	-2.9274
10	-2.9701	-4.7304	-5.3904	0.3790	-1.6025	-0.0981	1.0698	-1.5307
11	2.3673	-4.4398	-3.9029	-1.7742	-3.9965	-2.0512	3.1218	-2.1625
12	7.7991	3.9144	1.2514	3.7793	-3.1767	-1.7306	3.2840	-5.2088
13	2.2424	2.2371	3.3377	-3.3849	0.4370	-1.0424	-0.4481	-5.4989

Figure 3.4.1.25

Signal 26

13x8 double

	1	2	3	4	5	6	7	8
1	34.0798	35.7946	35.8683	34.0441	33.8485	34.9580	34.8609	34.8058
2	-4.4452	-3.7308	-3.0092	-4.3451	-4.8336	-5.3016	-4.2224	-3.4307
3	0.4752	-0.1140	0.5635	3.8803	2.5679	3.5538	0.6904	3.4743
4	-1.4894	1.2382	-0.7606	-1.5936	0.8829	0.2787	-1.4985	-5.4252
5	-2.9249	-2.2074	-1.8572	-6.0435	-2.6544	-5.5826	-6.5318	-0.6997
6	-0.1412	2.6141	0.4706	-2.8306	-1.5856	-3.6281	0.4005	-0.1887
7	-3.8934	0.1583	2.1129	1.6020	-2.5690	0.3077	-2.2156	-0.1447
8	-2.6049	1.8681	3.0477	4.2321	-2.6914	2.6453	4.2573	-4.8016
9	-1.2344	-8.7546	-3.7511	1.2617	-1.4247	0.2755	2.4779	-3.1390
10	5.4421	-3.0816	-1.8337	3.1591	4.1216	0.3574	-0.8005	-3.3950
11	-0.1069	-0.8720	-7.5334	-6.6243	-8.3347	-7.6399	-7.1968	-9.7531
12	-0.5567	1.7240	-4.0390	5.6371	-1.5017	4.1646	5.7912	4.3934
13	-1.9564	-5.3544	-5.4102	2.0154	-3.6516	0.4765	-0.9715	-0.7429

Figure 3.4.1.26

Signal 27

13x8 double

	1	2	3	4	5	6	7	8
1	34.7758	33.9450	35.0257	33.4950	34.2740	33.6321	34.6380	33.8764
2	-4.6218	-6.2502	-5.3416	-7.3893	-6.3739	-6.5413	-6.1242	-7.1907
3	1.6167	5.0000	4.2773	1.3216	1.4453	2.4157	0.4855	-1.0187
4	-3.6190	-2.7026	-5.7037	-3.8235	-3.8999	-1.3804	-1.6511	-2.6499
5	-0.8613	-1.3965	-5.2260	-5.8045	-4.0667	0.2117	-3.2909	1.9935
6	-2.5549	0.3283	-0.3585	-2.7936	-0.3035	-3.1624	-0.9697	1.8210
7	-5.6793	-2.5379	-4.8131	-8.3503	-0.5795	-4.4048	-2.7631	0.2579
8	8.6157	6.7359	3.5157	-0.0972	5.8036	3.4682	8.3085	9.7322
9	-7.2728	-7.8127	-9.4400	-7.2647	-6.8187	-3.3054	-5.5842	-6.3987
10	5.7809	3.2212	-1.7121	4.4442	6.7751	10.6864	3.5443	7.0106
11	-7.0529	-7.7588	-11.6431	-11.5223	-7.2095	-5.3819	-11.1484	-12.2554
12	1.8186	-3.3510	-3.7222	-4.7193	4.4264	0.2837	-2.9002	-2.4587
13	-6.7304	-3.7033	-8.3880	-1.6184	-6.6907	-5.2082	-5.0063	-8.0187

Figure 3.4.1.27

Signal 28

13x8 double

	1	2	3	4	5	6	7	8
1	31.5927	30.5039	31.8659	31.4216	31.3799	32.1965	33.1338	32.8526
2	-9.6196	-9.5798	-8.9241	-9.3034	-8.5665	-9.0179	-8.3672	-8.3006
3	2.8974	1.3656	2.6070	2.5363	3.5669	4.8877	3.5105	3.0380
4	-3.7764	-5.4473	-6.4978	-8.3391	-6.2494	-1.1280	-5.1209	-4.0717
5	0.6047	4.9592	-1.6486	0.0156	-0.7169	6.3416	2.3763	3.0985
6	-1.4924	-5.4035	-5.3284	-1.9445	-1.3519	-2.5000	-4.7881	-4.3281
7	-0.5198	-7.5013	-3.7113	-0.7185	-0.8966	-11.1605	-6.9850	-7.2532
8	12.7660	14.8018	15.6324	10.7977	5.9110	4.4744	3.7455	9.9228
9	-6.9270	-13.3325	-7.2493	-12.0549	-14.7792	-6.4072	-10.2450	-11.0386
10	17.2920	8.8072	10.0669	12.8731	21.5059	13.2502	20.1492	12.2380
11	-16.6022	-16.7254	-11.0626	-10.6087	-4.7404	-3.1112	0.7451	-6.1934
12	2.2849	3.8143	8.8781	9.3558	9.0202	13.0495	11.4244	12.9084
13	-2.8591	-4.1979	-6.4154	-4.3032	-6.9229	-11.4028	-7.0243	2.9669

Figure 3.4.1.28

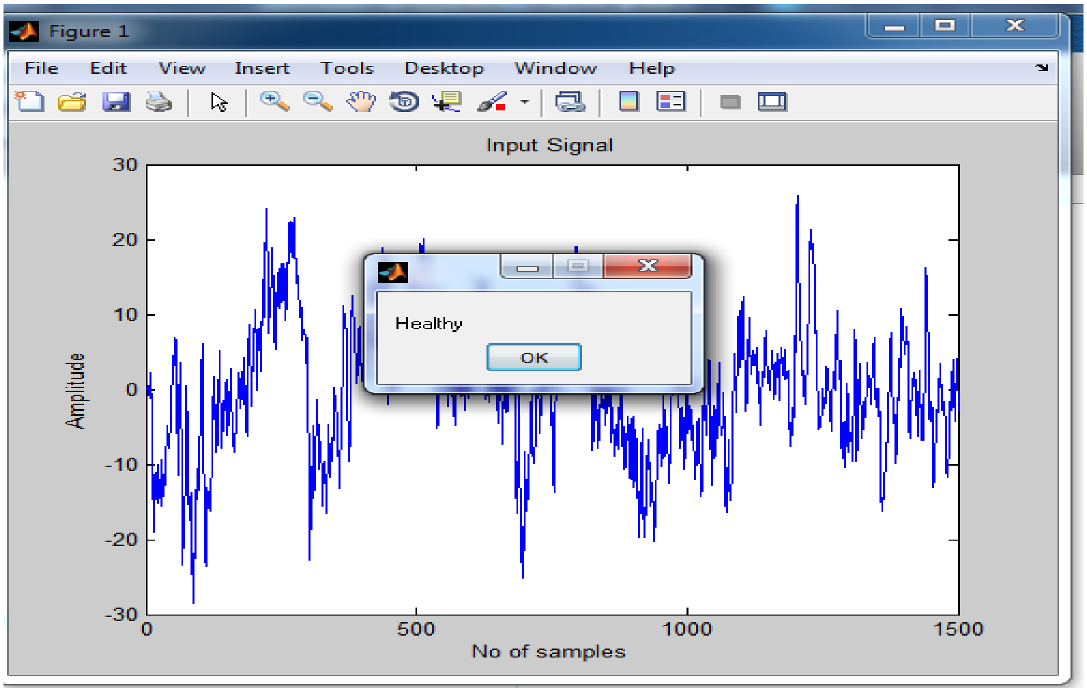


Figure 3.5.1.1 Classification of EEG signals using Support Vector Machine algorithm

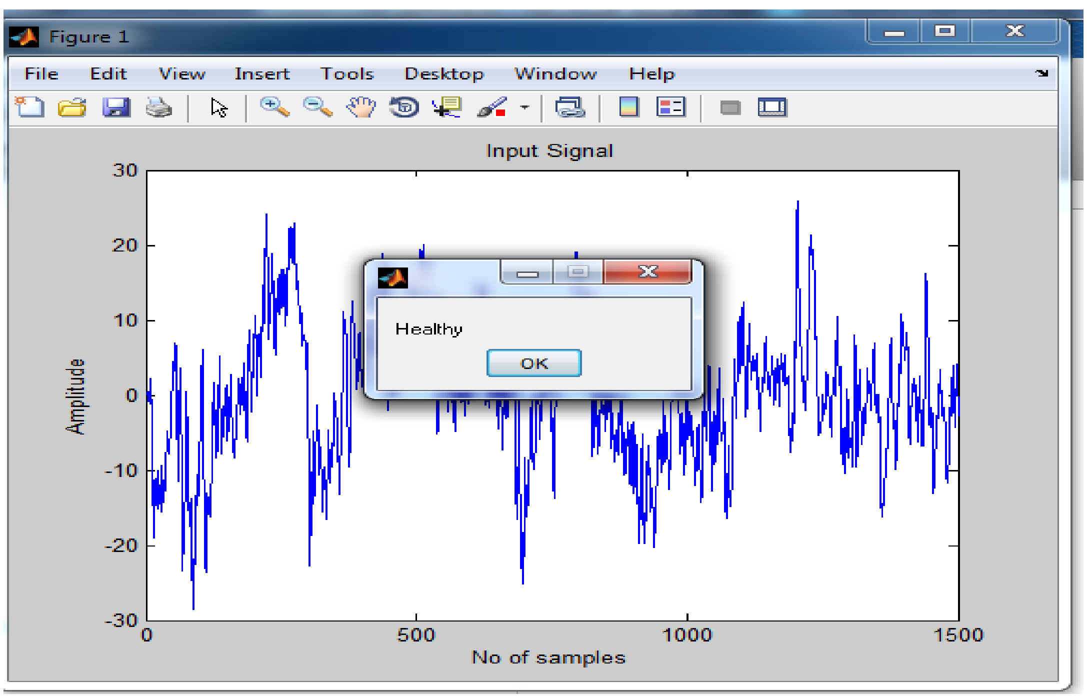


Figure 3.5.2.1 Classification of EEG signals using Artificial Neural Network algorithm

8.2 SAMPLE CODING

```
clc;
clear all;
close all;
warning off all
% Read the edf file
[aa bb]=uigetfile('.edf');
[header, recorddata] = edfread([bb aa]);

%PLOT THE RECORD DATA
x=recorddata(1,1:1500);
figure,plot(x)
title('Input Signal');
xlabel('No of samples');
ylabel('Amplitude');
X=x;
% Noise signal generation and removal using NLM
ix=1:length(x);
PatchHW=10;
P = 1000;
lambda = 0.6*.02;
[dn,debug]= NLM(x,lambda,P,PatchHW);
[noisySig,targetNoiseSigma] = createSignalPlusNoise(x,10);
lambda=0.6*targetNoiseSigma;
dn= NLM(noisySig,lambda,P,PatchHW);
xlim_vals = [1000 2000];
dn(isnan(dn))=0;

figure,plot(ix,dn,'g'),title('Denoised signal using NLM')
mse = metricscalc(noisySig,dn);
mean_square_error1=mse.mse
mean_absolute_error1=mse.mae
signal_to_noise_ratio1=mse.SNR
peaksignal_to_noise_ratio1=mse.PSNR

% Noise removal using EM
 E=emd(x);
```

```
 Si=size(E);
y=zeros(1,Si(2));
s1=x;
for i=1:Si(2)
y(i)= estimate_hurst(E(1,i));
if(y<0.01)
    signal=s1-E(1,i);
end
end
figure,plot(signal),title('Denoised signals using EMD');
mse = metricscalc(x,signal);
mean_square_error2=mse.mse
mean_absolute_error2=mse.mae
signal_to_noise_ratio2=mse.SNR
peaksignal_to_noise_ratio2=mse.PSNR



%Feature extraction mfcc
%spectrum analysis
s=dn;
fs=14500;
[CC1, FBE, frames] = mfcc( s, fs);
[M N]=size(CC1);
mi=min(min(CC1));
for i=1:M
    for j=1:N
    if isnan(CC1(i,j))
        CC1(i,j)=mi;
    end
    end

end
mfcc1=CC1;
figure,plot(CC1(1,:))
xlabel('Coefficient');
ylabel('Amplitude');
title('mfcc for denoised signal using lms')
```

```
% f1=mean(mean(mfcc1))
s=signal;
fs=14500;
[CC2, FBE, frames] = mfcc( s, fs);
[M N]=size(CC2);
mi=min(min(CC2));
for i=1:M
    for j=1:N
    if isnan(CC2(i,j))
        CC2(i,j)=mi;
    end
    end

end
mfcc2=CC2;
s=mean([mfcc1 mfcc2]);
figure,plot(CC2(1,:))
xlabel('Coefficient');
ylabel('Amplitude');
title('mfcc for denoised signal using EMD');
s=X;
IB=s;
m1=mean(mean(IB));
s1=std(std(IB));
v1=var(var(IB));
Stat_fea1=abs(mean([m1 s1 v1]))
feat=abs(mean([Stat_fea1]))
%save f28 feat28
```