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Classifying Mood Disordered Patients and Normal Subjects Using Various Machine Learning Techniques

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Abstract: Mood disorders strikes millions each year, often with debilitating consequences. This psychological disorder is so common that it is sometimes referred to as the "common cold" of mental health, with nearly 10% of the population suffering from a depressive disorder at any given time. A major mood disorder significantly affects a person's family and personal relationships, work or school life, sleeping and eating habits, and general health.

The use of Electroencephalogram (EEG) signals in the field of Brain Computer Interface (BCI) has obtained a lot of interest with diverse applications ranging from medicine to entertainment. In this paper, we are going to study nonlinear analysis of EEG signal for discriminating mood disordered patients and normal controls. Power of four EEG bands and four nonlinear features including detrended fluctuation analysis (DFA), higuchi fractal, correlation dimensions and lyapunov exponent is considered. For classification of the two groups, k-nearest neighbor (KNN), linear discriminate analysis (LDA) and logistic regression (LR) as the classifiers are used. Machine learning techniques such as detrended fluctuation analysis (DFA), higuchi fractal, correlation dimensions and lyapunov exponent are mainly considered to distinguish between the normal subject and the normal one. Machine learning techniques are easy to implement and it gives best accuracy. It will be a complementary tool for psychiatrists to operate on the mood disordered patients.

Keywords: Mood disorder, EEG, Detrended fluctuation analysis, Higuchi fractal, Correlation dimensions, Lyapunov exponent.

I. INTRODUCTION

Non linear methods required number of data to research, but in linear methods requirement of data is less. Non linear methods are very sensitive to noise, but in linear methods are robust to noise. In the case of EEG, non linear methods are applied on linear data but not opposite. Non linear methods are simple to implement. Fractal dimension is used to characterize the short phenomena like eye blinking. We use non linear signal because biomedical signal are non stationary and linear methods are only used for stationary signal [1]. The medical side they use linear methods like FFT [1].Chaotic transition represent the behavior of system in short period of time, which are very small change. Recent research suggests that stressful experiences lead to panic attack.

There are little difference between panic attack and phobia. Stressful experiences later leads to panic disorder and stressful memories lead to phobias. The stress disturbs the normal activities. Stressful memories may leads to rapid changes of mental state [2]. Ca++ and Cl- ions that are pumped through channels in neuron membranes in the direction governed by membrane potential [2], only large populations of active neurons can generate electrical activity recordable on the head surface. Between electrode and neuronal layers current penetrates through skin, skull and several other layers. Weak electrical signals detected by the scalp electrodes are massively amplified, and then displayed on paper or stored to computer memory [3]. Due to capability to reflect both the normal and abnormal electrical activity of the brain, EEG has been found to be a very powerful tool in the field of neurology and clinical neurophysiology. The human brain electric activity starts around the 17-23 week of prenatal development.

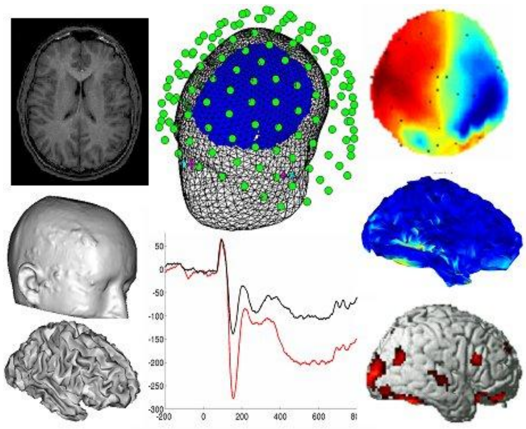

Fig.1-EEG Signals

II. MACHINE LEARNING TECHNIQUES

A. Detrended Fluctuation Analysis

Detrended Fluctuation Analysis (DFA) is a method for determining the statistical self-affinity of a signal. It is useful for analyzing time series that appear to be long-memory processes (diverging correlation time, e.g. power-law decaying autocorrelation function) or 1/f noise. The obtained exponent is similar to the Hurst exponent, except that DFA may also be applied to signals whose underlying statistics (such as mean and variance) or dynamics are non-stationary(changing with time)[23].It is related to measures based upon spectral techniques such as autocorrelation and Fourier transform.

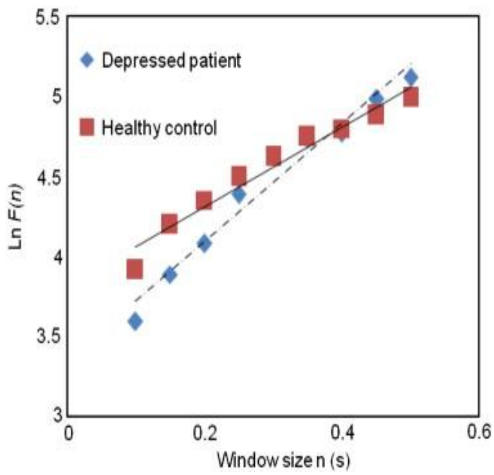

Fig. 2- Detrended fluctuation analysis (DFA) quantifies correlations in broad band EEG signals.

1. Working

In the DFA computation of a time series, $x(t)$ of finite length N, is integrated to generate a new time series $y(k)$ shown in.

$$y(k) = \sum_{i=1}^{k}[x(i) - (x)]$$

where _x_ is the average of *x*, is given by.

Next, the integrated time series, y(k) is divided into boxes of equal length and a least squares line is fit to the data of each box, represents by yn(k). Then, the time series y(k) is detrended by subtracting the local linear fit yn(k) for each segment. The detrended fluctuation is given after removing the trend in the root-mean-square fluctuation

$$F(n) = \sqrt{\frac{1}{N}\sum_{k=1}^{N}[y(k) - y_n(k)]^2}$$

This computation is repeated for different box sizes (time scale) to characterize the relation between F(n) and the box size n. A linear relation between logarithm of F(n) and size of the box, indicates presence of power-law scaling: F(n) ~n˛. The scaling exponent, can be calculated as the slope of log F(n) versus log n. This parameter represents the correlation properties of the time series.

2. Results of Classification based on nonlinear features

Result of nonlinear features, DFA, higuchi, cor- relation dimension and large lyapunov exponent are given for three classifiers. It can be seen that correlation dimension has been achieved the highest accuracy, 83.3%, when is used as the input of LR classifier among all features. At last, about 9 features are selected by GA in each classifier when 19 features are used as input. Fig. 2 indicates bar chart of these results. The DFA and higuchi[24] have approximately the same accuracy in classifying two groups in three classifiers and accuracy has the lowest value when lyapunov exponent is used as the input of classifiers.

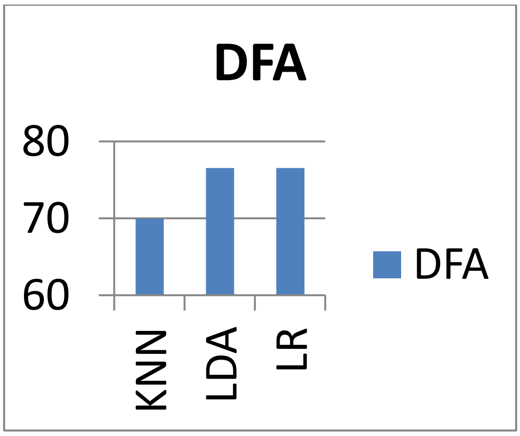

Fig. 3- Comparison of classifiers accuracy for each nonlinear feature.

B. Higuchi Algorithm

Higuchi proposed in 1988 an efficient algorithm for measuring the FD of discrete time sequences. Higuchi's algorithm calculates the FD directly from time series. As the reconstruction of the attractor phase space is not necessary, this algorithm is simpler and faster than D2 and other classical measures derived from chaos theory. FD can be used to quantify the complexity and self-similarity of a signal [9].A brain computer interface BCI enables direct communication between a brain and a computer translating brain activity into computer commands using pre-processing, feature extraction, and classification operations. Feature extraction is crucial, as it has a substantial effect on the classification accuracy and speed. While fractal dimension has been successfully used in various domains [11].The fractal dimension of a waveform represents a powerful tool for transient detection. In particular, in analysis of electroencephalograms and electrocardiograms, this feature has been used to identify and distinguish specific states of physiologic function. A variety of algorithms are available for the computation of fractal dimension [12].

Calculating the FD of waveforms is useful for transient detection, with the additional advantage of fast computation. It consists of estimating the dimension of a time-varying signal (waveform) directly in the time domain, which allows significant savings in program run-time [13].

$$X_m^k = \{x[m], x[m+k], \dots, x[m + \left\lfloor \frac{N-m}{k} \right\rfloor\}$$

The length of each k time series can be defined as:

$$L_m(k) = \frac{1}{k} \frac{\sum_{i=1}^{\lfloor (N-m/k) \rfloor} |x(m+ik) - x(m+(i-1)k)| \mathrm{x}(N-1)}{\lfloor (N-m/k) \rfloor}$$

An average length is computed for each time series having the same delay k, as the mean of k length Ln(k) for m = 1, 2, . . , k. The procedure is repeated for all k ranging from kmin to kmax. Yielding a sum of average length L(k) for each k as indicated in

$$L(k) = \sum_{m=1}^{k} L_m(k)$$

The slope of least square linear fit in the curve of ln(L(k)) versus ln(1/k) is estimated as fractal dimension[14].

1. *Results of Classification based on Nonlinear Features:*

Three classification techniques are used in experiments. There are other classification techniques such as SVM with nonlinear kernel and Naive Bayes using different types of features. However, our results with LDA, LR and KNN are superior to those obtained with other methods.

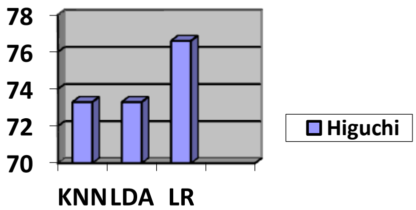

Fig.4-Classification of Higuchi algorithm w.r.t. classifiers

The highest accuracy was by combination of nonlinear features and LR classifier. LDA and LR classifier have better accuracy in all features in compare to KNN classifier. Accuracy of three classifiers is higher for all nonlinear features as the input in compare to power bands features. In this study, it is shown that the accuracy of all classifiers is significantly increased when nonlinear features are used as the input of classifiers. This result shows LR classifier can achieve the accuracy of 90% when all nonlinear features are applied to this classifier [18].

C. Lyapunov Exponent:

The aim of this study is to classify streesful patients and control subjects based on features .improving the accuracy of classification. It is the one of the feature extraction algorithm .Two groups of features are studied in this study [19]. Power of four EEG bands: delta, theta, alpha and beta as frequency and linear features and DFA, higuchi, correlation dimension and maximum lyapunov exponent are four nonlinear features that are used. For evaluation these features, LDA (linear discriminant analysis), LR (logistic regression) and KNN (k nearest neighbors) classifier are adopted used.

The Lyapunov exponent is most useful to measure the chaotic system .Lyapunov exponent is a useful nonlinear dynamic measure that quantifies the exponential divergence of initially nearby trajectories. Also, LE can characterize instability or predictability of a system. Lyapunov exponent is an important approach to the analysis of dimensionality [20].In is the sensitive dependence on the initial condition .It is average rate divergence of two neighboring (points) trajectories. To discriminate between chaotic dynamics & periodic signal LE is used. The tranjectories follows the some pattern. The characterize average rate of divergence of this neighboring points.

1. Working:

In most applications, largest lyapunov exponent (LLE) is computed instead of all exponents. The positive LLE

$$d_j(i) = d_j(0)e^{\quad i\Delta t}$$

Where(i) is the mean Euclidian distance between two neighbor trajectories in phase space at time ti and(0) is Euclidian distance between the j th pair of initially nearest neighbors after i time step. Taking the algorithm of both sides [21].

We obtain:

$$\ln \ d_{j(i)} = \quad {}_1(i\Delta t) + \ln d_i\ (0)$$

The maximum lyapunov exponent is calculated by the slop of linear fit to the average log divergence curve defined by,

$$y(i) = \frac{1}{\Delta t}(\ln d_j(t))$$

is average over all value of j

The first positive Lyapunov exponent is one of the methods of checking whether a time series is chaotic or not. The divergence means that systems whose initial differences are very small will soon behave quite differently, and this marks the predictive ability of the time series is lost [22].

Negative LE implies that orbit approach a common fixed point. A zero exponent implies that orbit maintains their relative position .They is on stable attractor. Positive LE implies that orbits are a chaotic attractor.

$${}_1(y_i) = [1\Big/(t_n - t_0)] \sum_{k=1} log_2 L'(t_k)/L(t_{k-1})$$

Where n are the propagation steps.

The algorithm proposed by Wolf et al. is used to find Largest LE (LLE) from EEG data. For given the time series x (t) for m dimensional phase space with delay coordinate t that is a point on the attractor is given by:

$$\{x(t), x(t+t), \ldots, x(t+(m-1)t\}$$

We locate nearest neighbor to initial point, and denote the distance between these two points as L(t0). The mean exponential rate of divergence of two initially close orbits is characterized by [7]:

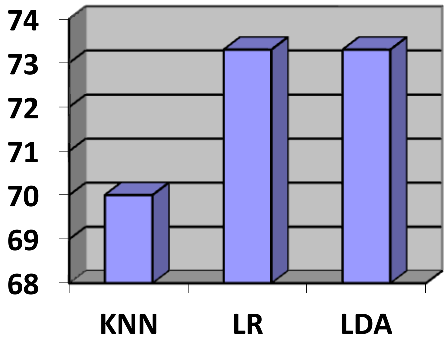

Fig. 5- Result of classifier for lyapunov exponent.

D. Correction Dimension:

Correlation dimension (D2) is one of the widely used measures of a chaotic. Dimension graph can give much information and detailed description about system. Dimensional graph determined by experimental data. It is very useful to understanding the system. It also used to approximate the dimension of these types of graphs.

It is computed from time series (cr) represent to find the closer point between r values. A fractal dimension id any dimension measurement that also allows the non integer values. To measure dimension of set is to measure the kalmogorov capacity (box counting).Set is covered with small cells (set of square) [19].

1. Working:

There are many different notions of fractal dimension measurements like correlation dimension because it permits the non integer values. The correlation dimension denoted by v. Assume a time series with N data points, $x = [x(1),x(2), . . ., x(N)]$, by choosing time delay r and embedding dimension m, a new m dimension vectors can be reconstructed as

$$X(i) = [x(i), x(i+\tau), \dots, x(i+(m-1)\tau)] \;\; i = 1,2,\dots, N-(m-1)\tau$$

An appropriate time delay τ and embedding dimension m is important for the success of reconstructing the attractor with finite data. [25]

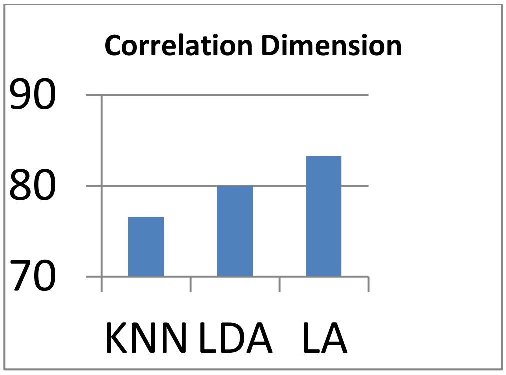

Fig.6 - Bar Chart of Classifier Result

Linear discriminate analysis, also known as Fisher's linear discriminate. It is a statistical method which is commonly used for data classification. LDA finds linear combination of features to classify two or more classes.

In KNN algorithm, k nearest training sample for a test sample is found .We can observe that LR has more accuracy level other than the LDA and KNN.

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III. CONCLUSION

In this paper we studied different machine learning techniques such that detrended fluctuation analysis (DFA), higuchi fractal, correlation dimensions and lyapunov exponent. The appropriate evaluation of patients with epileptic disorders is often impossible without an EEG. Digital EEG is the paperless recording of an EEG using computer-based instrumentation. The data are stored on electronic media, such as magnetic drives or optical disks and displayed on a monitor. EEG signal can be a useful tool in identifying mental disorders. Three well-known classifiers, KNN, LDA and LR were employed for classification. LR classifiers performed better than two other classifiers: LDA and KNN. We studied the working of four different algorithms for classification of mood disordered patients and normal subjects. We conclude that correlation dimension algorithm is most efficient algorithm among all these algorithms.

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