CHARACTERIZATION OF EEG SIGNALS FROM ALCOHOLIC SUBJECTS USING FRACTAL DIMENSIONS

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Abstract

Fractal dimensions have become an increasingly useful tool for the study of complicated dynamics in measurements across many fields of science and engineering. This paper explores the applications of nonlinear time series analysis using fractal dimensions for EEG signals classification. In particular, the fractal dimension was investigated as a tool for EEG signals characterization of two alcoholic subjects. The method is applied to several examples of both alcoholic and control subjects. Data sets were compiled and analyzed using fractal dimensions.

1. Introduction

Currently, there are many ways of looking at the brain cross sectional image to identify and isolate illness. These images are used to identify the activity in different areas of the lobes. In this paper, it is proposed that fractal analysis method can be used to identify also such illness. It is also proposed that fractal dimension changes as the EEG signal is being affected by the problem in the brain.

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The test cases used were seizure. The EEG signal contains three conditions: the pre seizure attack, the attack in process, and the post seizure attack. The data were analyzed using fractal software and the results plotted for comparison.

2. Fractal Dimensions

One of the often-used measures in fractals is the spatial correlation dimension computed from the algorithm of Grassberger and Procaccia [8]. In this algorithm, the correlation dimension is defined as [7].

$$d_c = {d \log C(r)} \Big/ {d \log r} \qquad (1)$$

For small $r > 0$, where $C(r)$ is the correlation integral and given by

$$C(r) = \lim_{N\to\infty} \frac{1}{N^2} \sum_{j=1}^{N} \sum_{i=j+1}^{N} \theta(r - \|R_i - R_j\|) \quad (2)$$

Where N is the number of points and θ is the Heaviside function.

Another measure of the fractal dimension is the capacity or the box method.

$$d_B = \lim_{N\to\infty} \log N_B(\varepsilon) / \log(1/\varepsilon) \qquad (3)$$

where, $N_B(\varepsilon)$ is the minimum number of boxes of size ε that cover the set.

Due its simplicity, the method of box-counting is often used in fractal dimensions application in signal processing. Several algorithms to calculate fractal dimensions were developed and reported in the literature [2-6]. One of the algorithms is based on the method described by T. Higuchi [2,3]. Another algorithm to calculate the fractal dimension of a time series was reported by Maragos, et al. [4-5]. Benoit 1.3, a fractal dimensions commercial software package was used in this study. The fractal dimensions method used in this paper is the rescaled range method using range over standard deviation (R/S) given as;

$$\frac{R}{s}(w) = w^H \qquad (4)$$

R(w) is the range of the input value in an interval. The range is measured with respect to the trend in the window (w). The trend is estimated using the line connecting the first and the last point within the window. S(w) is the standard deviation of the differences in the input values between one value and the previous value on a linear axis. The variable w is the window length and H is the Hurst component. The Hurst component also represents the slope of the line that is plotted on the log-log scale. If the data is self-affine, the points should follow the straight line. The fractal dimension is then defined as:

$$D_{R/s} = 2 - H \qquad (5)$$

$$H = \frac{\log(r_y)}{\log(r_x)} \qquad (6)$$

The fractal dimension per (2) is calculated by subtracting the Hurst component from 2. The smaller the value of the Hurst component the larger the fractal dimension. The trace with Hurst component that has value near zero is a rough trace. This type of trace has a fractal value that approach 2 in value. On a contrary, a trace with Hurst component value this is near one is a smoother trace. Its fractal dimension value approaches 1 in value.

The test cases used were EEG data of alcoholic subjects. The EEG signals used came from four different probes. The first probe is on channel 2, which is probe F7. The second probe is on channel 17, which is probe C4. The third probe is on channel 36, which is probe FT 7. The forth probe is on channel 51, which is probe P6. Each probe measures 256 data points for 1 second.

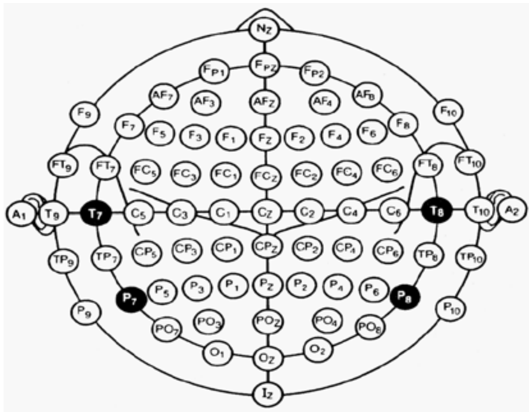

Fig. 1: Probe locations mapping (Courtesy, American Clinical Neurophysiology Society)

Table 1: Fractal Dimension Results for All Subjects

Channel #	Probe ID	FDC 338	FDA 365	FDA 368
Ch 2	F7	1.469	1.809	1.787
Ch 17	C4	1.563	1.687	1.855
Ch 36	FT7	1.402	1.675	1.805
Ch 51	P6	1.4	1.491	1.548

3. Biomedical Background

The data samples were acquired from two different alcoholic subjects and one control non-alcoholic subject. The data sets were taken from the study of the correlation of EEG signal to predisposition to alcoholism. The data were recorded with a scalp left frontal (F7), a scalp right central (C4), a scalp left frontal (FT7), and a scalp right rear (P6) electrode. Each probe measures 256 data points. The sample rate is 256 Hz.

There are many methods in finding fractal dimension. The method used here in this paper is the

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4. Results and Discussion

The data presented below displays three different plots within one figure. The large left hand plot displays the results of (1). The fractal dimension is calculated from the Hurst component in this plot. The upper right hand plot in the figure is a plot of the raw data used in calculating both the fractal dimension and power spectral density. Table 1 shows the comparison of the fractal dimensions between the alcoholic subjects and a control subject. FDC represents the fractal dimension of the control non-alcoholic subject and FDA represents the alcoholic subjects.

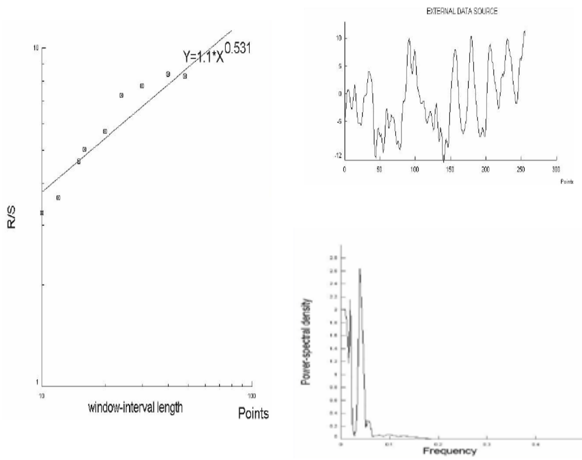

Fig. 2: Control Subject Co2c0000338
Channel 2

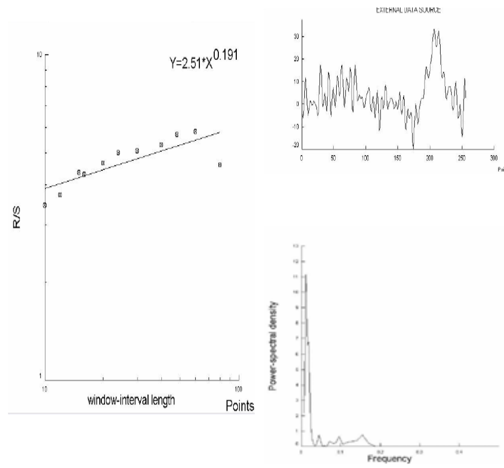

Fig. 3: Alcoholic Subject Co2c0000365
Channel 2

Figure 2 shows the fractal dimension, raw data, and power spectral density from channel 2 probe for the control subject Co2c0000338. The comparison is done with Figure 3 and Figure 4, which are from the channel 2 probes of alcoholic subjects Co2a0000365 and Co2a0000368.

Figure 5 shows the fractal dimension, raw data, and power spectral density from channel 17 probe for the control subject Co2c0000338. The comparison is done with Figure 6 and Figure 7, which are from the channel 17 probes of alcoholic subjects Co2a0000365 and Co2a0000368.

Figure 8 shows the fractal dimension, raw data, and power spectral density from channel 36 probe for the control subject Co2c0000338. The comparison is done with Figure 9 and Figure 10, which are from the channel 36 probes of alcoholic subjects Co2a0000365 and Co2a0000368.

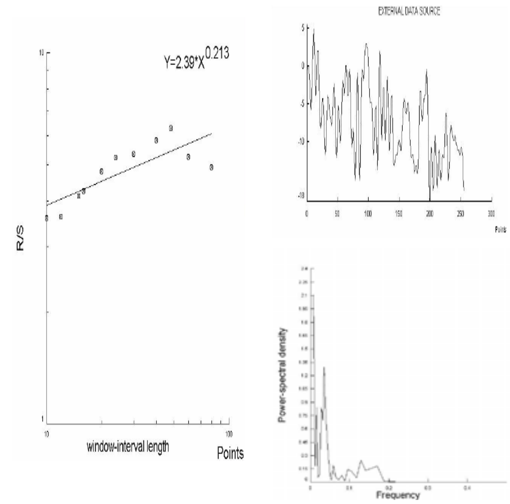

Fig. 4: Alcoholic Subject Co2c0000368 Channel 2

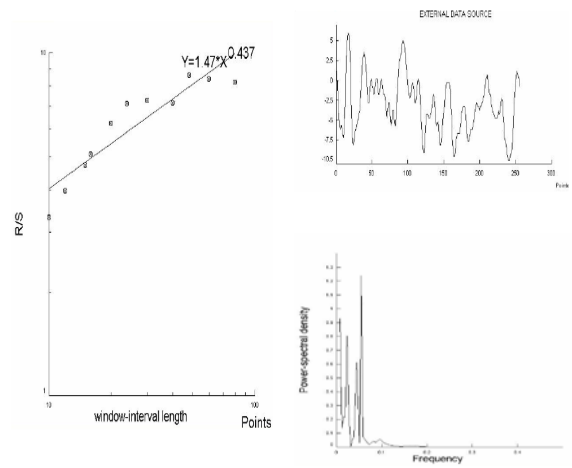

Fig. 5: Control Subject Co2c0000338 Channel 17

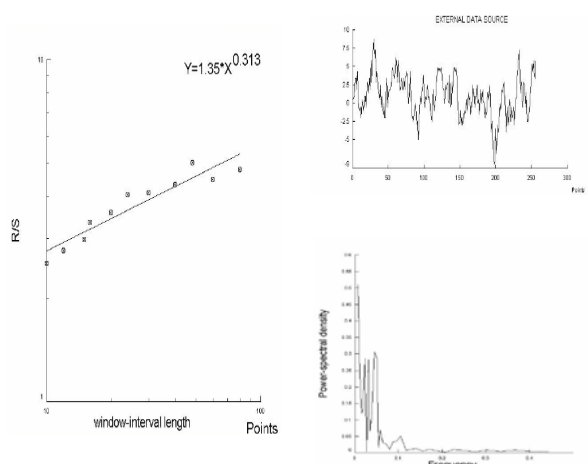

Fig. 6: Alcoholic Subject Co2c0000365 Channel 17

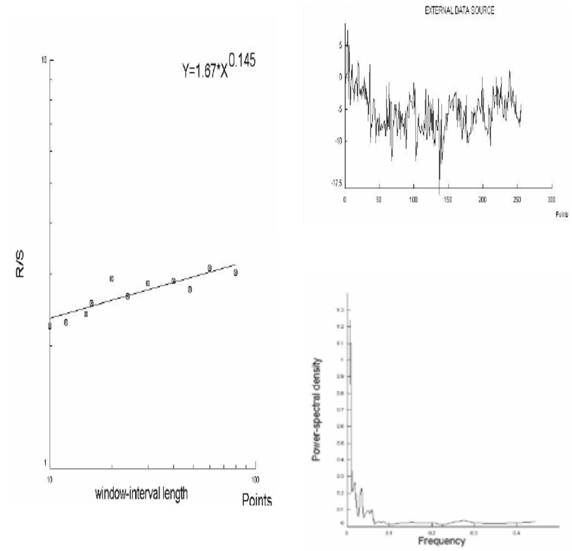

Fig. 7: Alcoholic Subject Co2c0000368 channel 17

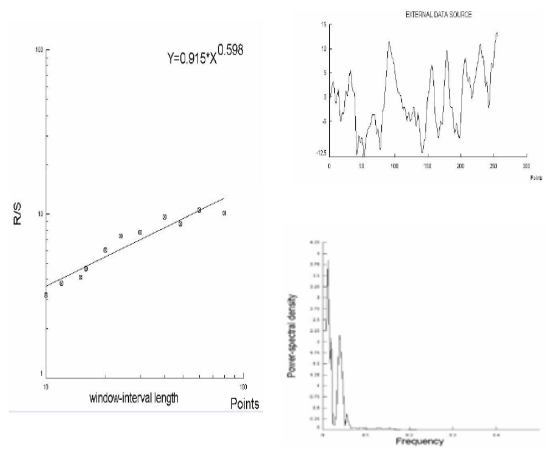

Fig. 8: Control Subject Co2c0000338 Channel 36

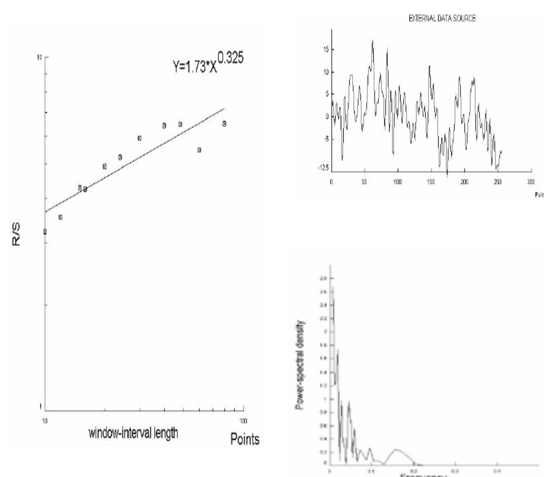

Fig. 9: Alcoholic Subject Co2c0000365 Channel 36

Figure 11 shows the fractal dimension, raw data, and power spectral density from channel 51 probe for the control subject Co2c0000338. The comparison is done with Figures 11 and 12, obtained from the channel 51 probes of alcoholic subjects Co2a0000365 and Co2a0000368. The dimension trends can be shown in a plot for ease for understanding. Fig. 14 below shows all three subjects used in the analysis.

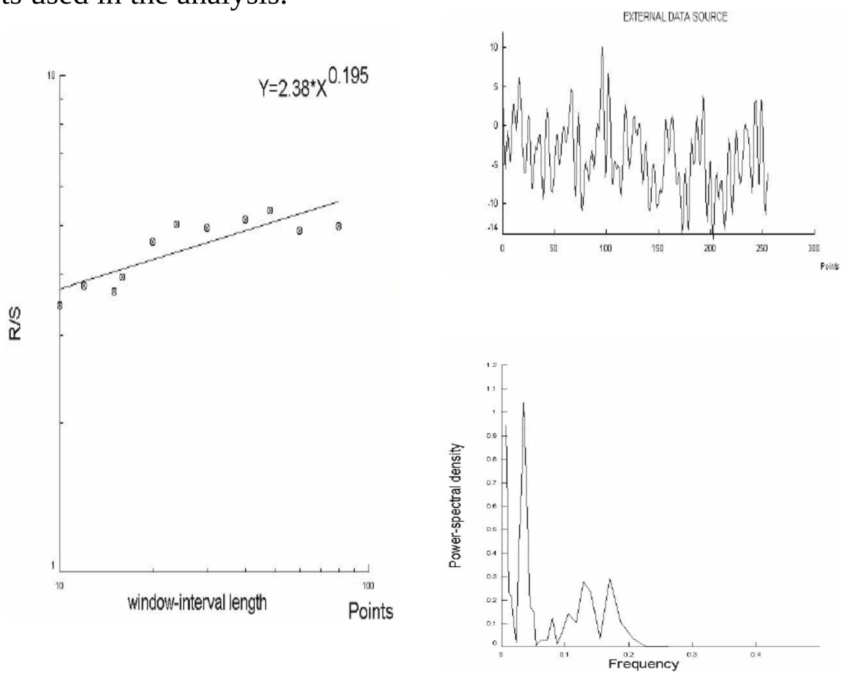

Fig. 10: Alcoholic Subject Co2c0000368 Channel 36

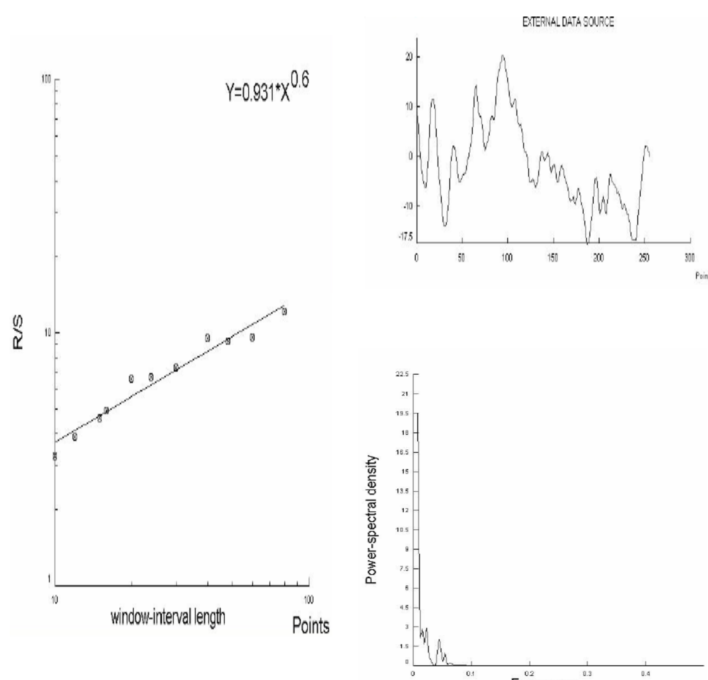

Fig. 11: Control Subject Co2c0000338 Channel 51

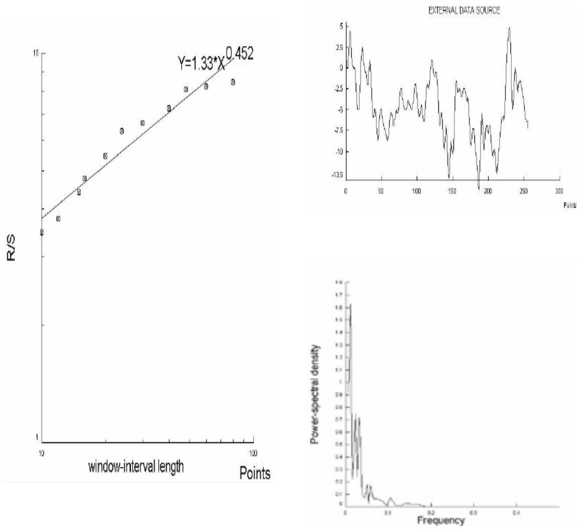

Fig. 12: Alcoholic subject Co2c0000368 channel 51

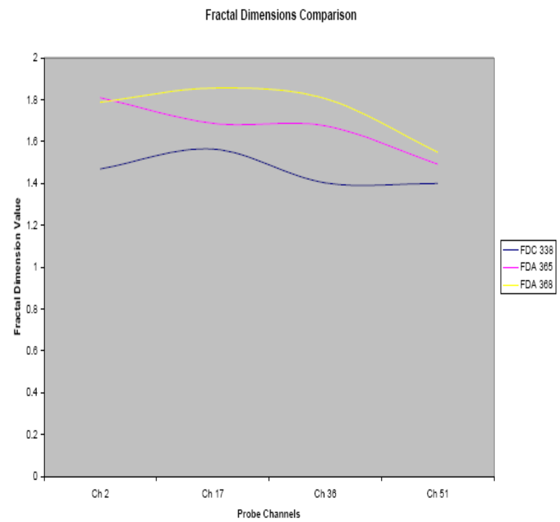

Fig. 13: Comparison of all three subjects

Comparison of all three subjects is presented in Fig. 13. The fractal dimensions are higher in the alcoholic subjects. The fractal comparisons indicate that there are significant differences between the EEG signals from the alcoholic than a non-alcoholic subject. The brain patterns in the alcoholics are much rougher than that of the non-alcoholic. This may equate to a sporadic brainwave patterns versus the smother more uniform one in a non-alcoholic. There are many factors that needed to be taken into considerations. Factors like age, weight, and gender may affect the subjects in various ways. It is also difficult to determine whether these EEG characteristics were caused by excessive drinking over a period of time. It can also be true that subjects with this type of pattern may be more prone to become alcoholics.

5. Conclusions

This indicates frequency of the particular signal occurrence. There are enough self-affine artifacts in the waveforms that the fractal method is suitable for such usage. The fractal dimension method seems to be able to detect condition change in the signals and may be very useful in biomedical applications. Further research is needed on more cases in order to establish a good base line on different brain conditions. There may also be interests in seeing the differences between violence drunk and calm mellow drunk via EEG analysis. More research may be suitable in collecting data from these subjects.

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