ATLANTIS PRESS

Advances in Intelligent Systems Research, volume 143

2nd International Conference on Applied Mathematics, Modelling and Statistics Application (AMMSA 2018)

Analysis of Magnetoencephalography in Depression Based on DFA

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***Abstract*—In this paper, we used the method of detrended fluctuation analysis (DFA) to study the self-similarity of MEG signals in the healthy subjects and the patients with depression. In the same negative emotional image stimulation, the DFA algorithm was used to calculate the scaling exponent of MEG signals in the patients with depression and the healthy subjects, respectively. The result show: Under the same stimulation, the scaling exponent of the patients with depression is higher than that of the healthy subjects. As a general phenomenon, the scaling exponent is used as a discriminant basis for identifying MEG signals in the healthy subjects and the patients with depression, and in the experiment obtained a more satisfactory results, this is an important indication of clinical diagnosis.**

Keywords—DFA; MEG signals; depression; scaling exponent

I. INTRODUCTION

Depression, also known as depressive disorder, it is characterized by significant and persistent depression, and it is the major type of mood disorder. According to the WHO survey, about 300 million people in the world suffer from depression, and this number is also increasing year by year. However, only 10% of the total number of the patients with depression treated with systemic therapy [1], because of the difference in science and technology and development, the patients with depression often receive no timely and accurate treatment, and even many non-depressed patients are misdiagnosed. Therefore, it seems particularly important to make better diagnosis and treatment of depression.

Although there are many methods and means for the diagnosis and treatment of depression at home and abroad, these methods have brought some limitations to actual work, such as real-time monitoring, traumatic, resolution, and anti-interference factors. So how to make a more scientific and rational diagnosis and treatment of depression is extremely urgent.

Magnetoencephalography [2], or MEG, is an electromagnetic signal used to study brain tissue, and it is widely used in scientific research [3-7]. It can detect brain electromagnetic physiological signals without trauma. Positron emission tomography (PET) and functional magnetic resonance imaging (fMRI) are the most commonly used methods for the diagnosis of depression in traditional medicine [8], however, the traditional method is to measure brain metabolism and hemodynamic changes, and there are many interference factors, so traditional methods have limitations in scientific research. In this paper, the electrophysiological changes of the brain are measured directly by magnetoencephalography with high temporal and spatial resolution, and data obtained from negative emotional picture stimulation related to cortical nerve activity characteristics are used to make analysis of long_range dependence of time series using DFA analysis method, and it has important reference meaning in scientific research.

The DFA method can effectively detect long range correlations with noise and superimposed polynomial trend signals when filtering the order components of the sequence, which is suitable for long-range power law correlation analysis of non-stationary time series. Detrended fluctuation theory uses the whole time series to calculate and scale free, so it can provide useful information to distinguish physiological signals. Long-term correlation is ubiquitous in the natural world, and the scaling exponent (α) greater than 1 indicates the loss of long time correlation and the pathological changes of the body itself. The technique was initially applied to the exploration of long time correlations of DNA sequences, and was widely used in the analysis of physiological time series [9-11].

II. THE PRINCIPLE OF DETRENDED FLUCTUATION ANALYSIS

In 1994, Detrended Fluctuation Analysis (DFA) was proposed by Peng [12] et al. based on the DNA mechanism, which was used to analyze the long-range dependence of time series.

DFA, compared to traditional methods (such as spectrum analysis and Hurst analysis), it can detect the non-stationary time series of internal self similarity, but also can effectively filter out the order of trend component in the sequence, with long range correlation analysis of nonstationary time series in the important role. Specific algorithms are as follows :

For the time series $\{x(k)\}(1 \le k \le N)$ with the specified length of N, the sum of the following formulas is calculated as follows:

$$y(k) = \sum_{j=1}^{k} [x(j) - x_{ave}] \quad (1)$$

Wherein, $x(j)$ is j data, and x_{ave} is the mean value of time series of brain magnetic signals analyzed. This summation procedure can map the original time series to a self similar process.

The time series $y(k)$ of the upper type is divided into equal intervals of the first child according to the length of the window n, the last remaining tail sequence with insufficient length is moved. Draw the least squares and straight lines of each small segment of length n (which represents the trend in the fragment). The Y coordinates of the line segments are marked as $y_n(k)$.

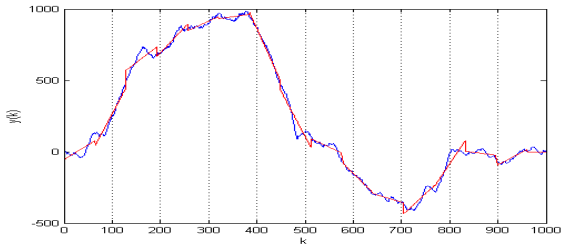

FIGURE I. LOCAL DETRENDED GRAPH (n = 64)

After the sum of the time series, the trend is removed, that is to subtract the local trend in each segment. For a given length of a fragment, the characteristic size of the summation and the fluctuation of the time series after the trend can be calculated by the lower formula:

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

Repeat the above calculation on all windows n (8,16,32,64,128), then we can gain the relation curve between $F(n)$ and segment n.The α is calculated according to the slope of $\log F(n)$ divided by $\log n$.

$$\mathrm{F}(n) \propto n^{\alpha} \quad (3)$$

The α shows that the time series is uncorrelated, and there is no long-term memory in the sequence, such as white noise. If $0.5 < \alpha < 1$, it It shows that the time series has long-range power-law correlation, and the time series has the same trend in a certain period of time and the next time. The closer the value of a is to 1, the stronger the sequence correlation is. If $\alpha = 1$, the long-range dependence of time series is similar to that of noise $1/f$. When $\alpha = 1.5$, the long-range dependence of time series is similar to Brown noise.

III. DETRENDED FLUCTUATION ANALYSIS OF MEG

A. *Experimental Background*

In order to study the healthy subjects and patients with depression in the negative emotional stumuli, difference of MEG signal, MEG data used in this paper is obtained from the center of magnetoencephalography Affiliated Brain Hospital of Nanjing Medical University. All subjects had normal hearing and visual acuity, underwent magnetoence-phalography, no somatic disease, excluded history of schizophrenia, affective disorder, neurosis, and had not taken psychotropic drugs recently, and had no history of addiction and psychoactive substance dependence.

The emotional pictures used in the experimental data were selected from the International Affective Picture Library (International Affective Pictures System), a total of 80. Negative pictures contain fear, depression, despair and so on. The subjects were asked to sit on the bed and gaze at the center of the screen to relax their body and experience the emotional meaning of each picture.

B. *Data Acquisition and Analysis*

The experimental data are collected by CTF275 head type MEG system, and the acquisition mode is set to successive acquisition, that is to collect only 4 seconds of MEG data around each keystroke movement. When the press button is pressed, the initial time of 0 seconds is 0 recorded, and the interval of MEG data acquisition is from 1 second to 2 seconds. The data sampling rate is set to 1200Hz, and the bandwidth is set to 0-300Hz. The emotional picture stimulation time was 1000ms, and the interval was from 1500 to 2000ms to eliminate the expected reaction time of the negative emotion picture. Due to the inevitable mixing of endogenous signals such as eye rotation, blinking, heart beating and so on, the interference of magnetic field and a small amount of exogenous noise, such as power frequency power grid magnetic signals, are inevitable in the experiment. Therefore, in order to reduce the impact of these noise signals on subsequent data analysis, data preprocessing was carried out on 9 healthy subjects and 6 depressed patients by preprocessing, such as artifact removal, baseline correction, and filtering.

Data acquisition is finished by using Canada CTF275 Magnetoencephalography System, each data collected will be a suffix for the.Meg file, the file is a 3D data structure of 275*161*80, 275 of which represent the 275 channels, 132 channels on the left, 132 on the right and 11 in the middle. 161 represents each picture 161 keystrokes trigger signal value. 80 represents 80 emotional pictures.

TABLE I. CHANNELS OF CTF275 MEG SYSTEM

	Frontal	**Central**	**Parietal**	**Occipital**	**Temporal**	**total**
Z	3	4	1	3	0	11
L	33	24	22	19	34	11
R	33	24	22	19	34	132
Total	69	52	45	41	68	275

The CTF275 MEG system will be roughly divided into three parts from left to right, each part is divided into 5 regions, F (Frontal), C (Central), P (Parietal), O (Oecipital) and T (Temporal) on behalf of the forehead, the central area, neck area, occipital and temporal region. Wherein, Temporal region and occipital areas correspond to the temporal lobe and occipital lobe of the cerebral cortex. The area centralis is located before neck area, roughly corresponding to the posterior portion of the frontal lobe. Frontal area is located before area centralis, and roughly corresponding to the frontal lobe. The corresponding location of the specific channel and brain region is shown in the figure below:

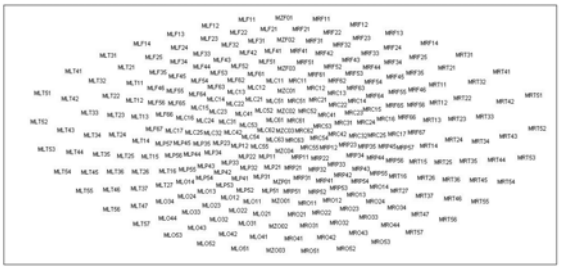

FIGURE II. THE ACQUISITION CHANNEL AND ITS POSITION OF MEG

C. Experimental Results and Analysis

DFA was used to analyze the physiological time series of the healthy subjects and the patients with depression. We collected MEG data from 9 healthy subjects and 6 major depressive disorder.

The data are processed by spm8, such as artifact removal, baseline correction, filtering and so on. The processed data is a three-dimensional matrix of 275*161*80, and then the time series of 161*80 points are taken out under the same channel, totaling 12880 points, and then the of the time series is calculated.

In this paper, MATLAB tools are used to preprocess the data by spm8 data processing tools, and the processed data are analyzed by detrended fluctuation analysis of DFA:

The α of 275 channels in 9 healthy subjects and 6 depressive patients was calculated, it was found that there were significant differences in the α between the patients with depression and the healthy subjects when the channel of MLF62 was used. Table 2 gives the numerical values of the α of 15 subjects. Figure 2 and Figure 3 shows the healthy subjects and the patients with depression log10(F(n)) and log10(n) diagram. In Figure 4, the average α of the depression patients is higher than the healthy subjects, and the average α of the depression patients is $\alpha = 1.1075$, which is close to 1.5. The average α of the healthy subjects is $\alpha = 0.9368$, these results can indicate that the loss long of

Long-time correlation and the pathological changes of the body itself as the depression deepens. In Figure 5, we can clearly see that the mean of the α of the patients with depression are higher than that of the healthy subjects, and we also can see the standard deviation of the patients with depression is larger than that of the healthy subjects.

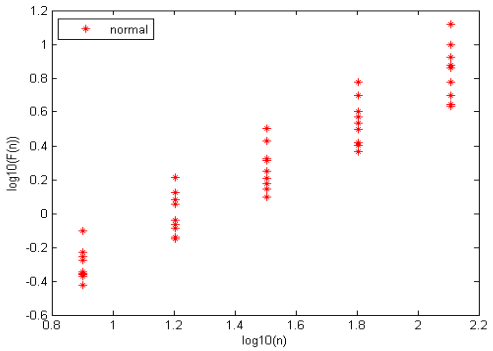

FIGURE III. THE SCALE INDEX OF NORMAL

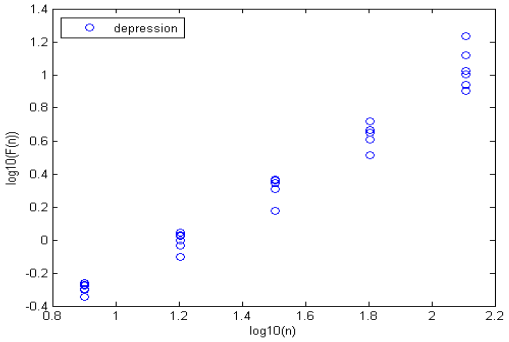

FIGURE IV. THE SCALE INDEX OF DEPRESSION

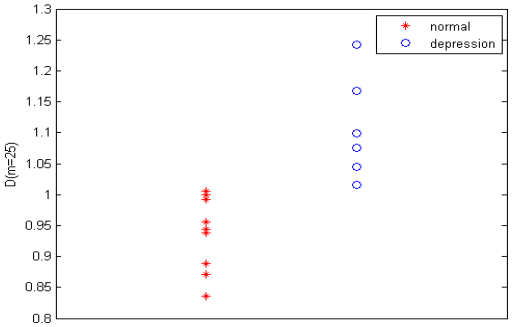

FIGURE V. THE DETAIL COMPARISON OF α

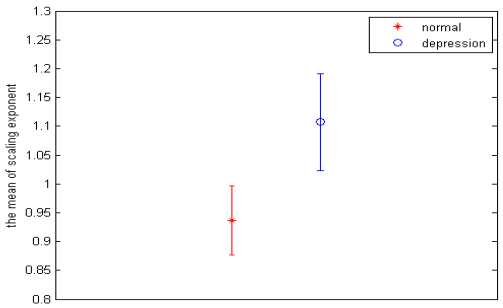

FIGURE VI. THE MEAN AND STANDARD DEVIATION OF α

TABLE II. THE α OF 15 SUBJECTS

count	1	2	3	4	5	6	7	8	9
healthy people	0.8352	1.0055	0.9564	0.9992	0.9925	0.9446	0.9379	0.889	0.8708
patient	1.0455	1.2419	1.0989	1.0152	1.0752	1.1683			

It can be seen from the diagram that the α of the channel of MLF62 is significantly different between the patients with depression and the healthy subjects. The channel of MLF62 is distributed in the frontal lobe, which is associated with advanced cognitive abilities in humans, such as memory, attention, and executive function [13]. Studies have shown that the left frontal lobe is associated with emotional regulation [14-16]. Therefore, under negative emotion picture stimulation, there are differences in one or some channels of the frontal lobe in the healthy subjects and the patients with depression.

In order to further verify the reliability of the above conclusions, we used SPSS statistical software to conduct independent sample t test for the DFA analysis results of two sets, and the results were shown that the first sig value is greater than 0.05, which shows that the homogeneity of variance is satisfied, and the second sig of the first row is less than 0.05, which shows that there is significant difference between the two groups of data. Therefore, we can determine the scale index of depression patients and healthy people in the MLF62 channel, which can distinguish the normal sample and the case sample well.

IV. THE CONCLUSIONS

The DFA method was used to analyze two MEG signals in the healthy subjects and the patients with depression. By changing the scale of time series signals, the results showed that the healthy subjects and the patients with depression presented two power law intervals, and showed different in different intervals. By comparison, it can be seen that the of MEG signal in the healthy subjects and the patients with depression is significantly different in the MLF62 channel, it can clearly distinguish the self similar characteristics in different magnetoencephalography under physiological and patholog-ical conditions, the results indicate that the depression evolution trend, DFA is a good methods. It has important reference value in the process of medical assistant diagnosis of disease.

ACKNOWLEDGMENTS

Project is supported by the National Natural Science Foundation of China (Grant Nos. 31671006, 61771251), Jiangsu Provincial Key R & D Program (Social Development) (Grant No.BE2015700, BE2016773), Natural Science Research Major Program in Universities of Jiangsu Province (Grant No.16KJA310002).

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