A DISTINGUISH METHOD OF EPILEPTIC EEG AND DEGLUTITION EEG BASED ON CHAOTIC NOISE-REDUCTION*

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Abstract-**A new method for recovering epileptic EEG and deglutition EEG's nonnoise trajectory and distinguishing these two waveforms is presented. The main aim of this paper is to introduce the theory and establish math model of a simple recovering EEG's nonnoise trajectory. This method is finally used to experiments. Our results prove that chaotic dynamics does exist in EEG and signal-noise of EEG marked improves. Furthermore, it is also successful to recover structural characteristic of strange attractor destroyed by noise. The paper obtains the real chaotic trajectory of EEG with which it can calculate dipole of EEG. According to the different parameters of dipole, a method of distinguishing epileptic EEG and deglutition EEG using the measurement of nonlinear dynamics is obtained.**

Key Word- **Epilepsy, Deglutition, EEG, Chaos**

Ⅰ.INTRODUCTION

Epilepsy is a sort of familiar chaotic syndrome, which clinic characteristic is epileptic outbreak. Traditional diagnose of epilepsy mainly depends on inquiring clinic illness history and checking-up electroencephalogram. Though people have rather deeply understand to brain microstructure and enginery from neuroanatomy and neurophysiology, cerebral high-ranking activity is still difficult to explain, because cerebra are the most complicated apparatus in body. It is very difficult to diagnose and forecast epilepsy.

People find that there is usually a sort of high-amplitude epileptiform discharge in EEG of typical epileptic in experiment. This high-amplitude wave can be emitted by epileptic focus, so searching and analyzing epileptiform discharge are likely to become a kind of groping task, checking epilepsy and determining epileptic focus. However, people also find that the high-amplitude epileptiform wave resembles with deglutition EEG of normal people. There aren't simple distinguishing methods to them in time series. This brings difficulty for diagnosing epilepsy.

Along with the increasing theoretical understanding of complex dynamical system, people have recognized that cerebral activity is entirely nonlinear which is a sort of broad band signal[1]. Some foreign scholars have brought chaotic theory in study of cerebral activity from 1980's. They consider that normal EEG is chaotic state[2]. When cerebra occurs epileptic pathological changes, part nerve cells present exorbitant repetitive discharge and occur epileptic wave, which can reduce cerebral chaotic state[3]. It is very significant to distinguish epileptic EEG and deglutition EEG with nonlinear dynamics theory.

However, time series of epileptic EEG and deglutition EEG contain obvious noise that usually hides dynamics information of cerebral activity. It is necessary for irregular EEG to reduce noise in order to get rid of disadvantage effect of noise. Furthermore, confirmed dynamics mechanism of irregular discharge is obtained. The main aim of paper is to seek the method that can reduce EEG noise and recover EEG dynamics trajectory.

Ⅱ. PRINCIPLE AND METHOD

A. Establish Math Model

Base of chaotic time series noise-reduction is the

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Abstract

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reconstruction theory of phase space. Let us assume that chaotic time series studied is x(t), then $X_i=(x(t),x(t+\tau),\cdots,x(t+(d-1)\tau)^T$ can denote a point in the phase space in which d represents phase space's dimension and τ represents delay time. Dynamics system of chaotic attractor satisfies projection relation:

f: $R^d \longrightarrow R^d$

In order to express clearly, x_p is looked as a reference point in time series, $x_1,x_2,\cdots,x_n$. x_p, with its delay points and "advance" points($x_{p+1},\cdots,x_{p+m}$), consists of $X_p=(x_p,x_{p+1},\cdots,x_{p+m})^T$, which is a point in (m+1)-dimensional phase space. $X_1,X_2,X_3,\cdots,X_N$ are points of X_p's neighborhood M. The data x_p can be obtained by taking a linear average of its delay points and "advance" points in a small local neighborhood. The relation is[4]:

$$x_p = a_0 x_p + a_1 x_{p+1} + \cdots + a_m x_{p+m} + b$$
$$= \sum_{i=0}^{m} a_i x_{p+i} + b \qquad (1)$$

In order to obtain the optimal values the coefficients, a_i $(i=1,2,\cdots m)$ and b, the paper uses the least squares fits method. $X_1,X_2,X_3,\cdots,X_N$ of X_p's neighborhood also satisfy extremal condition in a small local neighborhood :

$$Q=\left(\sum_{i=0}^{m} a_i x_{1+i} + b - x_p\right)^2 + \left(\sum_{i=0}^{m} a_i x_{2+i} + b - x_p\right)^2 + \left(\sum_{i=0}^{m} a_i x_{3+i} + b - x_p\right)^2 + \cdots$$
$$= \sum_{j=1}^{N}\left(\sum_{i=0}^{m} a_i x_{j+i} + b - x_p\right)^2 = \min \qquad (2)$$

Note that if one tries to fit the optimal value for a_0 from the least squares, one would get the trivial solution $a_i=\delta_{i0}$ and b=0. Thus, a_0 has to be fixed. Usually choose a_0 =0.5 or 0.7. Apart from a_0, there remain essentially two parameters that can be varied in our procedure. The first is the order m of the local linear model (eq. (1)), the proper value of m depends on the number of frequencies involved. The second is the size N of the neighborhoods. Larger neighborhoods give more stable fits, but if they are chosen too large the locality required for the linear approximation is violated.

After obtaining coefficients, it can calculate x_p' point, which is closer to real chaotic trajectory y_p than x_p. Do it continually to every point in time series, then we can obtain a clearer chaotic trajectory than original one, $x_1',x_2',\cdots,x_n'$. After finishing a time noise reduction, the procedure is repeated several times (with x_n replaced each time by the last x_n') until the result seems optimal.

B. Physical Signification of Math Model

Let us assume that that time series x_p measured is dynamics system that comes from noise-free y_p. Bowen proves that there must be an only accurate trajectory beside inaccurate noise trajectory in dynamics system, what is well-known Shadowing Theorem of dynamics system[5].

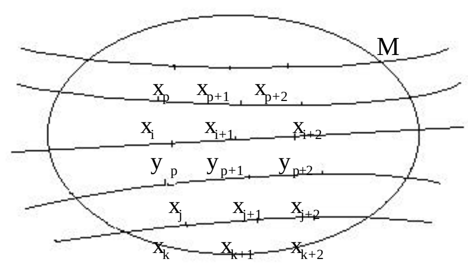

Fig.1 Sketch of nonlinear chaotic noise-reduction

In fig.1, L_x, consisted by x_p, x_{p+1} and x_{p+2} ,denotes a measured noise trajectory. According to Shadowing Theorem, there is a noise-free trajectory L_y, consisted by y_p, y_{p+1} and y_{p+2}, beside L_x. There are also other else noise trajectories, such as x_i, x_{i+1}, x_{i+2}; x_j, x_{j+1}, x_{j+2}; x_k, x_{k+1}, x_{k+2}; $\cdots$, in neighborhood M. All these noise trajectories satisfy the eq.(1). Because L_x affected by noise usually doesn't overlap with L_y, but lumps with the other else trajectories. An optimal method of approaching real noise-free trajectory is to compute minimizes distance square to each noise trajectory. This is the least square fit, such as eq. (2).

III. RESULT

A. EEG Data Collection

In this paper, it collects EEG signals by 32-channel electroencephalogram instrument EE2514 of Japan NEC Medical System Ltd. . The position of electrodes is the same to the position marks of MRI, and it use 32-channel electrodes. We collect the sleep EEG of epileptic with high-amplitude discharge in fig.2 and deglutition EEG of normal people in fig.3.

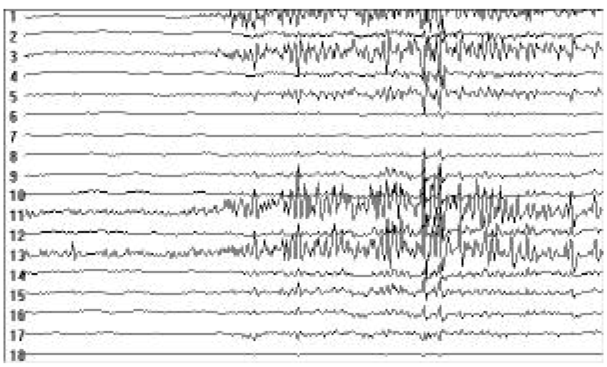

Fig.2 Epileptic EEG wave of patient

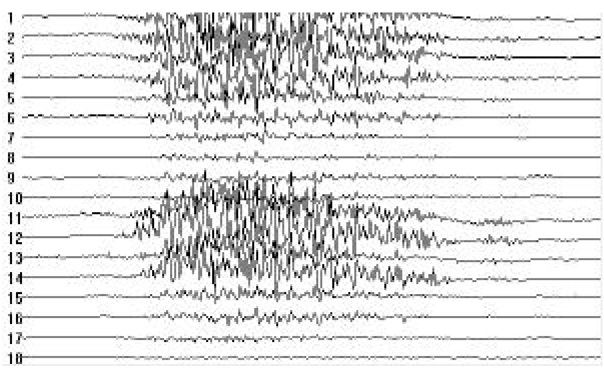

Fig.3 Deglutition EEG of normal people

B. Handle Experiment Data

Respectively take a length wave with 400 points form epileptic EEG and deglutition EEG measured, and make a backtracking projection map to measuring waves of the NO. 11 electrode. Results are shown in fig.4 and gfig.5.

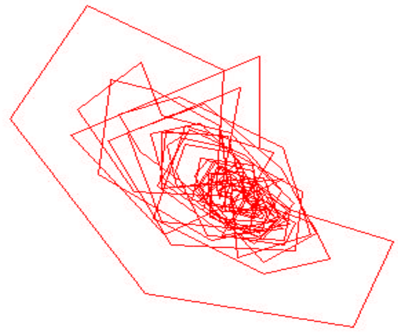

Fig.4 Chaotic trajectory of epileptic EEG with noise

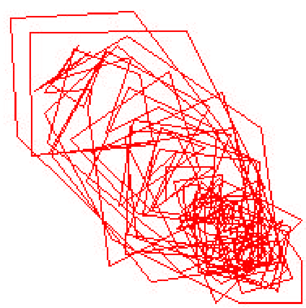

Fig.5 Chaotic trajectory of deglutition EEG with noise

It can be seen that data series have marked noise interfere, structural characters of strong attractor isn't clear and real chaotic trajectories are hided by noise from fig.4 and fig.5. So, we should not distinguish between epileptic EEG and deglutition EEG. Only deal with these data with nonlinear noise-reduction method. In our case, the paper chooses parameter values a_0=0.5, m=3, N=10. After the procedure is repeated 30 times, results are shown in fig.6 and fig.7.

Through comparing fig.4 with fig.6 and fig.5 with fig.7, it is easily found that signal-to-noise of EEG measured marked increases and structural characters of projection function are clearly revealed. From fig.6 and fig.7, it is seen that real chaotic trajectory of epileptic EEG differs from one of deglutition EEG. We can calculate dipole of EEG with the real chaotic trajectory of EEG. According to the different parameters of dipole, a method of distinguishing epileptic EEG and deglutition EEG using the measurement of nonlinear dynamics is obtained. Furthermore, abnormally discharging field of cerebra and diagnose epileptic focus of patient be obtained according to the different parameters of dipole[6].

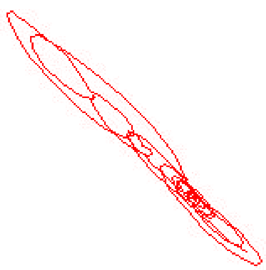

Fig.6 Denoised chaotic trajectory of epileptic EEG

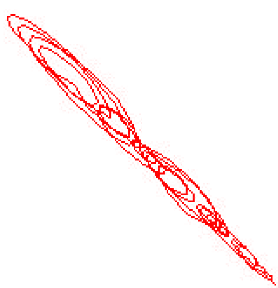

Fig.7 Denoised chaotic trajectory of deglutition EEG

Ⅳ. DISCUSSION AND CONCLUSION

The data of epileptic EEG and deglutition EEG measured are usually irregular and include marked noise, what brings a lot of difficulties to distinguish EEG signal in experiment. Some people try to obtain noise-free wave by improving experimental conditions or using linear noise-reduction method, for example average piling up or frequency chart analysis [7], but results are not good.

With the method mentioned in paper, it only need simply deal with EEG signal measured, and then obtains the real chaotic trajectory of EEG with which the paper calculates dipole of EEG. According to the different parameters of dipole, a method of distinguishing epileptic EEG and deglutition EEG using the measurement of nonlinear dynamics is obtained. This method maybe also prove a new tool of analyzing EEG signal and a new clue of picking-up EEG and diagnosing cerebral illness.

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