

Analysis of alpha rhythm epileptic Electroencephalogram based on Inner composition alignment

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Abstract. The EEG signal is an important tool for the diagnosis and prediction of epilepsy due to EEG containing a large number of physiological and pathological information. Based on alpha rhythm multi-channel EEG (electroencephalogram), this paper applied inner composition alignment (IOTA) algorithm to construct brain functional network and visualize the network topology. It is to apply the algorithm to calculate and analyze IOTA coefficient, the node average degree and clustering coefficient of epileptic brain network for studying if epileptic brain network is significantly different from those of normal. The results show that IOTA coefficient of epileptic brain network obviously differs from the normal by calculating T testing with SPSS software, which proved that the effectiveness of the algorithm to distinguish IOTA coefficient of epileptic brain network.

Introduction

EEG can effectively reflect the physiology activities of brain nerve cells and it is important to analyze and diagnose epilepsy [1]. Currently, doctors predict and diagnose epilepsy through EEG pathological waves in clinical trials.

Inner composition alignment algorithm (IOTA) is a nonlinear algorithm [2] based on permutation to calculate the coupling relationship between the multi-channel EEG signals. The research shows that IOTA coefficient of epilepsy patients α rhythm (8 ~ 13 Hz) EEG significantly distinguishes with normal subjects. Finally, we give statistical analysis of the samples and come to relevant conclusions.

The basic principle of Inner composition alignment algorithm

Next, we define IOTA and analyze its properties. Given the time series y^l and y^k of the subsystems l and k over the same time domains, let π^l be the permutation which orders y^l in a non-decreasing order, i.e. , $\pi^l : \forall i \quad [y^l(\pi^l)]_i \leq [y^l(\pi^l)]_{i+1}$. The series $g^{l,k} = y^k(\pi^l)$ is the reordering of the time series y^k with respect to π^l . The definition of IOTA coefficient is as following:

$$\tau^{l-k} = 1 - \frac{\sum_{i=1}^{n-2} \sum_{j=i+1}^{n-1} w_{i,j} \Theta[(g_{j+1}^{l,k} - g_i^{l,k})(g_i^{l,k} - g_j^{l,k})]}{\Delta} \quad (1)$$

Where n is the length of the time series, Δ is a normalization constant which corresponds to the

maximum number of crossing, $w_{i,j}$ denotes weight coefficients..

$$\Delta = \frac{(n-1)(n-2)}{2} \quad (2)$$

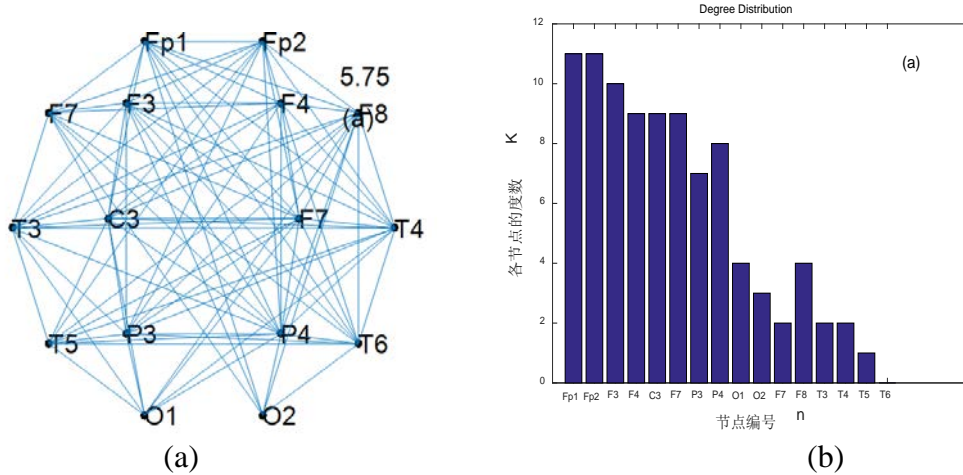
$\Theta[x]$ is the Heavyside step function,

$$\Theta(x) = \begin{cases} 1, & x > 0 \\ 0, & x \leq 0 \end{cases} \quad (3)$$

The paper calculates the coupling relationship between the multi-channel EEG signals with the inner composition alignment algorithm (IOTA). Each lead of EEG is a node of network, a total of 16 nodes. Select the first 50s data of the original data, a total of 25,600 samples. It will be divided into 256 segments, each has 100 sample points. After calculating the IOTA unidirectional coupling coefficient of each segment and averaging to obtain the IOTA unidirectional coupling coefficient of every two nodes, it was got the coefficient matrix. Through numerous experiments, the appropriate coefficient λ is 0.96. Thus, we can compute the threshold C_{thr} by $C_{thr} = \lambda \cdot C_{mean}$. Where C_{mean} is mean of the IOTA unidirectional coupling coefficient matrix. When the element $C_{i,j}$ of coefficient matrix C is greater than the threshold C_{thr} , it was thought that the two leads region i, j have functional connections, then adjacency matrix coefficient corresponding value was set to 1. On the contrary, the two leads region doesn't have functional connections, the adjacency matrix coefficient corresponding value was to 0.

The data processing and analysis

Nodes' coordinates in the network are the relative physical position between electrodes during EEG acquisition, which contribute to construct brain functional network and visualize via filter simulation with matlab software [3]. This paper only presents each sample of epilepsy and normal brain function network topology graph and its degree distribution due to limited space, as shown in Figure 1.



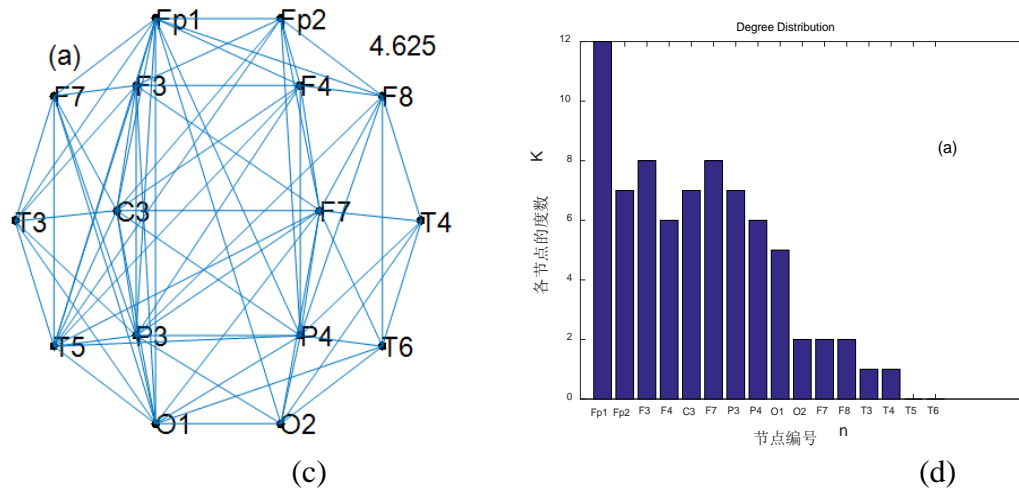


Figure 1 (a) Network topology graph of epileptic brain function; (b) Degree distribution of the epileptic patient;(c) Network topology graph of normal brain function; (d) Degree distribution of the normal subject.

For figure 1 (a) and (c), the figure in the upper right corner is the average degree of the network nodes. Node degree of epilepsy patient in (a) is 5.75, and that of the normal subject in(c) is 4.625, which shows that the brain function network of alpha rhythm epileptic electroencephalogram is more complex than the normal EEG. At the same time, it can be clearly seen the connections of each node of epileptic patient are mostly more than the normal subject from (a) and (c).

To compare accurately IOTA coefficient of epilepsy patients with the normal subjects, we analyze each 20 individuals of epileptic and Normal subjects. The results are shown in Table 1.

Table 1

The average IOTA coefficient Epileptic and Normal sample volunteer brain networks							
Epileptic	individual	1	2	3	4	5	mean
	IOTA coefficient	0.7457	0.7415	0.7354	0.7462	0.7598	0.7514
	individual	6	7	8	9	10	standard deviation
	IOTA coefficient	0.754	0.7706	0.7397	0.7451	0.7516	
	individual	11	12	13	14	15	0.014
	IOTA coefficient	0.7458	0.7625	0.7381	0.7453	0.7372	
	individual	16	17	18	19	20	
	IOTA coefficient	0.7895	0.7618	0.7616	0.7633	0.7329	
Normal	individual	1	2	3	4	5	mean
	IOTA coefficient	0.7557	0.7612	0.7517	0.7547	0.7721	0.7632
	individual	6	7	8	9	10	standard deviation
	IOTA coefficient	0.7485	0.7431	0.7711	0.7499	0.7911	
	individual	11	12	13	14	15	0.0171
	IOTA coefficient	0.7443	0.748	0.7547	0.771	0.7641	
	individual	16	17	18	19	20	
	IOTA coefficient	0.7946	0.7726	0.753	0.7587	0.8044	

The experiment selects each 20 groups epileptic and normal EEG. The average of the IOTA coefficient in epileptic group is 0.7514 and the normal group is 0.7632. The standard deviation of the IOTA coefficient in epileptic group is 0.014, and the normal group is 0.0171, which display the coupling degree of brain network of epileptic patients is more than normal peoples in the alpha rhythm.

Experimental data is alpha rhythm electroencephalogram filtered from original data after the data was de-noised and processed through wavelet transform [4]. After statistical analyzing and

hypothesis testing significant differences for two groups data, we obtained the results $p=0.022<0.05$. It can be concluded that, compared to normal peoples, the brain functional network characteristics of alpha band of brain network complexity of epilepsy patients is higher than the normal. It was shown that IOTA coefficients can distinguish between epilepsy and normal peoples.

Conclusions

This paper uses IOTA algorithm, through filtering program, obtaining alpha rhythm EEG data from 20 normal subjects group and 20 epilepsy patients group. Then we analyzed IOTA coefficients using independent-Samples T Test. The results showed that the IOTA coefficient of epileptic patients and normal person have significant difference. Simultaneously, this paper calculates unidirectional coupling coefficient of 16 leads based on EEG data. After selecting appropriate threshold, it was built brain function networks. Comparing epilepsy patients' brain network features with normal subjects', we also found a significant difference between them. Above all show that patients with epilepsy brain network have changes, thus verify the effectiveness of the algorithm in constructing and analyzing brain networks. At the same time, it also has certain reference significance for clinical research.

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References

- [1] Meng Qing-Fang, Zhou Wei-Dong, Chen Yue-Hui, Peng Yu-Hua. The feature extraction of epileptic EEG signals based on nonlinear prediction[J]. Acta physica sinica, 2010,59(01):0123.
- [2]S. Hempel, A. Koseska, J. Kurths, et al. Inner composition alignment for inferring directed networks from short time series[J]. Physical Review Letters, 2011, 107: 054101.
- [3]Wang Haowen, Qian Zhiyu, Li Hongjing et al. Analysis of FFT and wavelet processing effect of wave information from EEG signal[J], Journal of Biomedical Engineering, 2013, 30(4):704-709.
- [4]Xu Xin, Zhou Yun, Ma Qianli. Matlab filter design and Simulation of the EEG data signal analysis[J], Journal of Nanjing University of Posts and Telecommunications, 2011,31(6): 37-43