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Synchronization Method for EEG Signals of Body Movements in Patients with Parkinson's Disease*

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Abstract **- In this paper, a synchronization method of intracranial electroencephalogram (EEG) and body movements based on patients with Parkinson's disease (PD) is proposed. By using the EEG signals acquisition system provided by a medical company, we develop the external induction electric pulse generator, and realize the synchronization of intracranial EEG (iEEG) and patient's body movements in the video shot. The synchronization method proposed in this paper provides technical support for further analysis of the correlation between EEG and body movements of patients with PD and decoding of EEG, and it also establishes basic conditions for disease diagnosis and treatment by using EEG of body movements. If we can predict the coming symptoms of tremor, rigidity and bradykinesia through the changes of EEG before the onset of PD, even if the time is very short, it is possible for us to intervene and treat PD to a certain extent, which will greatly relieve the damage to patients during the onset of symptoms.**

Index Terms - Parkinson's disease; EEG signals; body movements; synchronization method; prediction

I. Introduction

PD is a common chronic neurodegenerative disease with the main symptoms of tremor, rigidity, bradykinesia, gait and balance disorders [1]. Long-term recurrent episodes and the progression of the disease will make patients suffer physical pain and even lead to mental and psychosocial disorders. Therefore, how to effectively predict, control and treat the onset of PD has become a hot issue in the world for research in recent decades. Among them, Deep brain stimulation (DBS), a major surgical intervention method for treating PD, is a new treatment method for PD developed in recent years, which can improve motor symptoms and non-motor symptoms of advanced PD and improve the quality of life of patients [2-4]. By implanting the stimulation electrodes into the nucleus of the human brain (the main targets are the subthalamic nucleus and the inner part of globus pallidus) [5-7], applying electrical stimulation of different frequencies, amplitudes and pulse widths to different nucleus to control abnormal discharge activities of nucleus, the symptoms of patients such as tremor, rigidity, bradykinesia can be effectively alleviated.

It should be noted that the PINS Medical Company of China has developed a new type of implanted electrode and EEG acquisition system for the treatment and research of PD. After patients receive deep brain stimulation, this type of electrode can not only provide electrical stimulation, but also realize the collection of iEEG signals. The correlation characteristics between EEG signals and body movements of patients with PD can be used as a kind of basis for assisting doctors to diagnose and treat patients in the later stage.

EEG signals originate from prominent posterior potentials caused by synchronization of a large number of neurons, reflecting the electrophysiological activities of brain neuron cells, which contain abundant biological information. Analysis of EEG signals can study the physiological state of the human body and different working mechanisms of the brain, which has important research and application values [8-9], especially can provide important basis for clinical diagnosis and treatment [10-11]. The epilepsy prediction using EEG signals has been applied, and typical spikes will appear in EEG signals before epileptic symptoms break out.

At present, only the equipment manufactured by Medtronic Medical Company of the United States and Pinch Medical Company of China can record local field potentials and iEEG signals， but the signals collected by these two companies have no time information. When doctors and other scientific researchers do some event-related action potentials or research, they cannot accurately match time and body movements, that is, they cannot synchronize EEG signals and body movements in time aspect. For this reason, further analysis of the recorded EEG signals and extraction of feature information are limited. Therefore, this paper proposes a synchronization method for EEG signals and body movements of patients with PD. The marker light in the video shot and the external induction pulse signal are used as synchronization signals to realize accurate synchronization of EEG signals and body movements of patients over time. This method provides technical support for further analysis of the correlation between EEG and body movements of patients with PD and decoding of EEG, and it is of great value in the study of EEG signals of patients with PD.

II. Methods

The schematic diagram of EEG signals collection and experiment process is shown in Fig. 1.

The G102RS stimulators were implanted under the left and right clavicle. Use a new type of implanted electrode to collect the EEG signals of patient, and the collected signals

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comprise EEG signals of patient and electrical pulse signals provided by an external induction electric pulse generator. The external induction electric pulse generator includes an electrical pulse trigger device and a marker light. The patient and the external induction electric pulse generator are photographed by a camera for each acquisition.

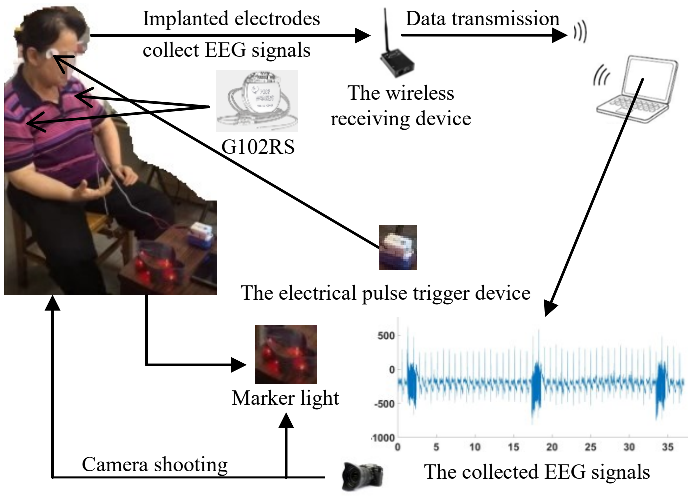


Fig. 1 The schematic diagram of EEG signals collection and experiment process

A. The Data Collection of EEG Signals

Using the new EEG acquisition system-G102RS to collect the iEEG signals of patients with PD, the wireless receiving device is connected to the computer through a USB interface, and the EEG signals data collected by the new electrode is transmitted to the computer through the receiving device-P402, which can realize real-time monitoring and acquisition of EEG signals.

Two pulse generators were implanted under the clavicles on the left and right sides of the patient to control two types of nuclei in the brain-the inner part of the globus pallidus and the subthalamic nucleus. There is a globus nucleus and a subthalamic nucleus on the left and right sides of the brain, so there are four nuclei in the patient's brain that are stimulated by the electrodes. Each nucleus corresponds to a stimulus electrode, which plays the role of stimulation and signal collection. Each pulse generator has two stimulating electrodes, each of which includes four platinum-rhodium alloy contacts of 1.5 mm length. The contacts are divided into stimulating contacts and non-stimulating contacts. The intracranial electrodes and contacts of the patient are distributed as shown in Fig. 2, with a total of 16 contacts.

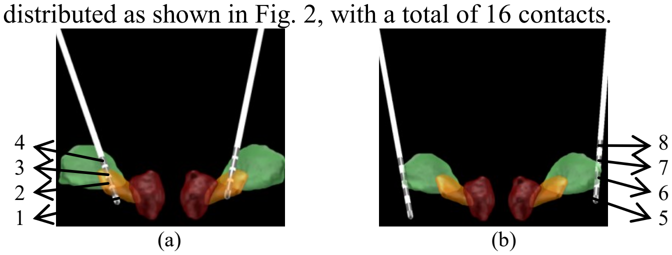


Fig. 2 Distribution of Intracranial Electrodes and Contacts in Patient

In the Fig. 2, the yellow nuclei represent the subthalamic nucleus (STN) and the green nuclei represent the inner part of globus pallidus (GPi). The gray parts represent the contacts. The left electrode from bottom to top corresponds to the contact number: 1,2,3,4, and the right electrode from bottom to top corresponds to the contact number: 5,6,7,8.

B. The External Induction Electric Pulse Generator and Video Shot

In this study, an external induction electric pulse generator was designed and constructed. Its main function is to output electric pulse signals with a certain time interval, frequency and amplitude through programme control, and the pulse triggers the red marker light to turn on at the same time. The time interval and frequency of the pulse are adjusted according to the two pulse generators of the patient so as to facilitate the subsequent pre-processing of the EEG signals.

Before the EEG signals collection, two wet electrode patches are attached to the left and right temples of the patient, and the two electrode clamps of the external induction electric pulse generator are respectively clamped on the two wet electrode patches. Turn on the EEG signals acquisition system and the pulse generator at the same time. After the red marker light flashes for a certain number of times, turn off the acquisition system and the pulse generator to end signal acquisition. During the whole collection process, a camera with a sampling rate of 30 frames /s is used for video shooting of the patient, and the state of the patient during the period of EEG collection is recorded. The video includes the patient performing the specified actions and the resting state and the marker light, and the EEG signals collected at the same time include the EEG signals of the patient in the resting state and EEG signals of body movements.

C. Synchronization Method

The iEEG signals collected by the experiment contains the electrical pulse signal provided by the external induction electric pulse generator, and the EEG signals is reproduced by using MATLAB software. After filtering the collected original EEG signals, the external induction electric pulse signals can be visually seen from the image. The electric pulse signal is time-marked on the image, and the time points at which each pulse starts and ends are recorded. Find the time when the red marker light flashes in the video and record the time when the flashing starts and stops. The time when the red marker light starts flashing corresponds to the time when the externally induced electric pulse signal starts, and the time when the flashing stops corresponds to the time when the electric pulse signal ends, thus realizing the synchronization of the EEG signal and body movements in time. Then the synchronized time axis is superimposed on the collected original EEG signals, so that the patient can be observed from the video to be in a certain state within a certain time interval. Furthermore, the iEEG signals of the patient during this period can be extracted through the time axis for further analysis.

D. EEG Signals Pre-processing

The purpose of pre-processing the collected EEG signals is to extract the synchronous induction triggered pulse signal from the original EEG signals of patients, which is convenient for synchronous operation. The parameters of the two pulse generators in the patient are shown in TABLE I, so set the frequency of external inductive electrical pulse signal at 100Hz. The characteristic of Butterworth filter is that the frequency response curve within the passband is as flat as possible without fluctuation, while in the stopband it gradually drops to zero. In this study, a fourth-order Butterworth filter is used for band-pass filtering, with a band-pass boundary of 80-110 Hz.

TABLE I
The parameters of the two pulse generators

Pulse generator for controlling STN			Pulse generator for controlling GPi		
	Left brain	Right brain		Left brain	Right brain
Amplitude	2.0V	2.0V	Amplitude	2.85V	2.6V
Pulse width	90μs	90μs	Pulse width	120μs	70μs
Frequency	60Hz	60Hz	Frequency	140Hz	140Hz

E. The Experimental Scheme

The pulse frequency of the external inductive electric pulse generator is set to 100 Hz, the number of pulses is 3 times, the pulse width is 5 ms per pulse, and the number of cycles is 100 times. Each pulse triggers the red marker light synchronously. The collection time of each EEG signals is about 1min, and the patient is required to perform two movements of raising her hand and clenching her fist in a natural state of emotional stability and remain stationary after the action ends. The experimental design is shown in Fig. 3.

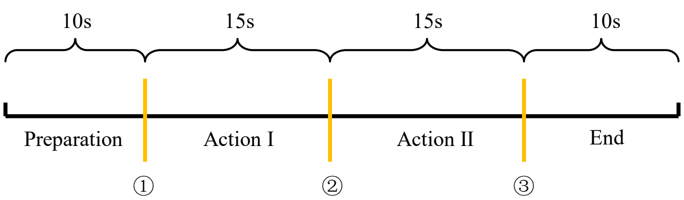


Fig. 3 The experimental scheme
①-First flash ②-Second flash ③-Third flash

In the preparation period, the EEG acquisition system and the external induction electric pulse generator are turned on, and the patient is reminded to start raising her hand. After the first flash, the patient will keep static after 1-2 times of raising her hand, and before the second flash, she will start to make a fist several times. After the second flash, the patient makes another 1-2 fist movements and remains at rest. The collection is completed after the third flash.

Video capture is performed during each acquisition, and the red light is illuminated as a marker. In the video, observing what actions the patient is taking when the light is on for three times and before and after the light is on respectively, and at the same time include two kinds of EEG signals when the patient performs actions and is at rest in the time interval of each pulse.

III. Results and Discussion

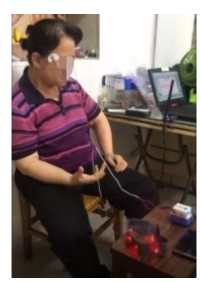
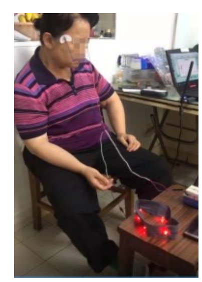
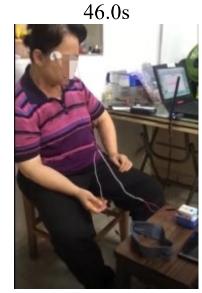
Four experiments were carried out in this study. EEG signals of the two nuclei were collected under the condition that both pulse generators of the patient were turned off.

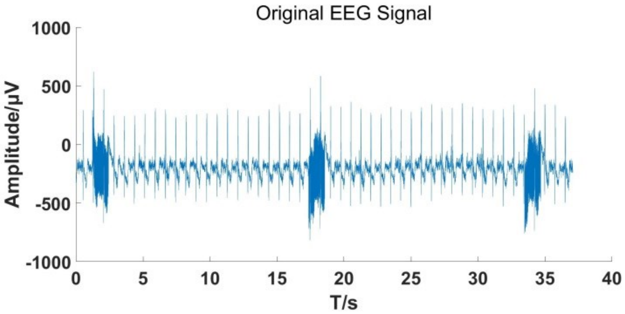
Butterworth bandpass filtering is performed on the four original EEG signals acquisitions. According to the time point when the red marker light flashes three times in the shot video, the three-time pulse signal provided by the external induction electric pulse generator can be clearly seen from Fig. 4-(a) and 4-(b). The filtering results of four EEG signals are shown in Fig. 5. After the filtering process, the three signal values apparent in Fig. 5-(a) are the synchronous inductive electric pulse signals, and the red marker light in the corresponding video of the pulse signal blinks once.

The filtered EEG signals are marked, and the time points at which the three pulses start and end are marked from the Fig. 5. Then mark the time point when the red light flashes in the video. Each time the pulse corresponds to one light in the video and the state of the patient at each time of the light flashing are recorded in the video. The marker records and patient status of the first experiment are shown in TABLE II.

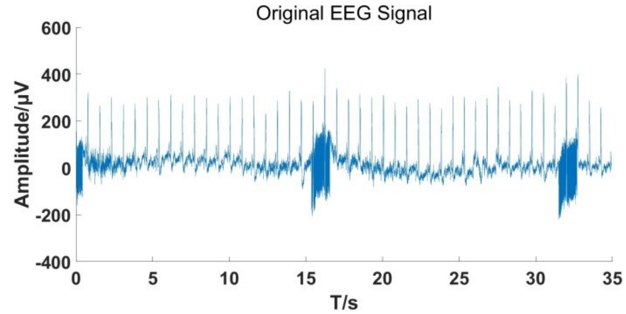
Video can be used to observe and record the patient's action when the red light is on to determine whether patient is in a static state or not. Meanwhile, the EEG signals between the pulses in the image can correspond to the patient's action between the two lights in the video, thus realizing the synchronization of EEG signals and body movements on the time axis.

TABLE II
Measure the inner part of the globus pallidus

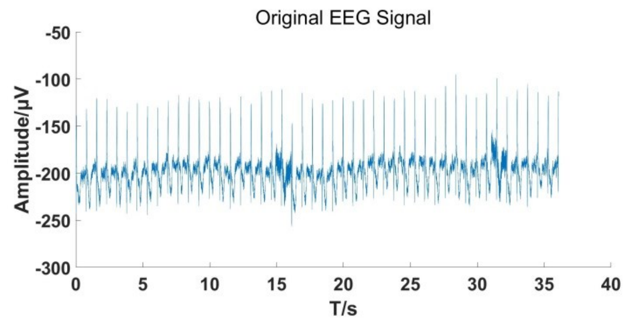
The time point of the pulse provided by the external induction electric pulse generator in the acquired EEG signals		
First pulse	Second pulse	Third pulse
1.23s-2.42s	17.36s-18.57s	33.43s-34.69s
The time when the red marker light flashes in the video		
First flash	Second flash	Third flash
14.0s-16.0s	30.0s-32.0s	46.0s-48.0s
The state of patient in the video shot		
Just finish a hand-raising movement	Finish one fist action	In a static state
 14.0s	 30.0s	 46.0s
 16.0s	 32.0s	 48.0s



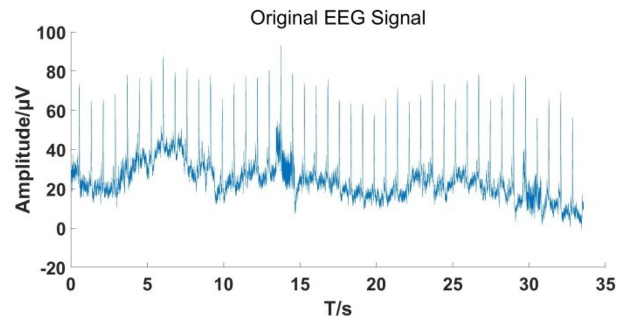
(a) Measure the inner part of the globus pallidus



(b) Measure the subthalamic nucleus

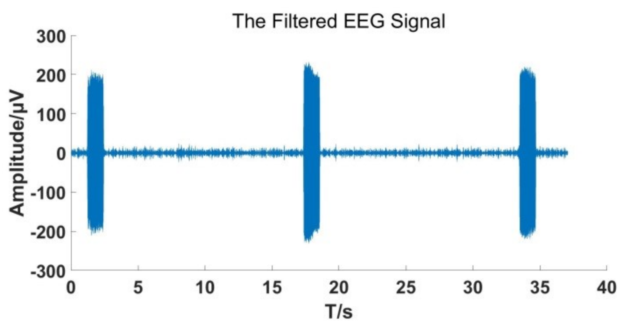


(c) Measure the inner part of the globus pallidus

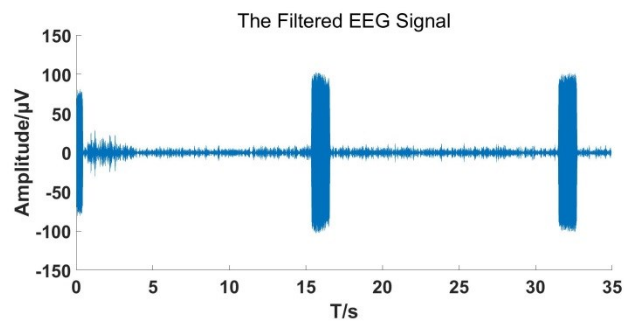


(d) Measure the subthalamic nucleus

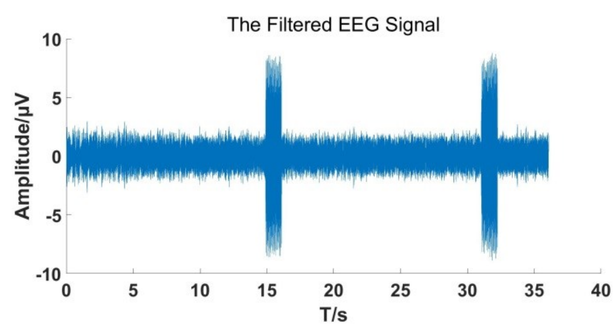
Fig. 4 The original EEG signal collected in four experiments



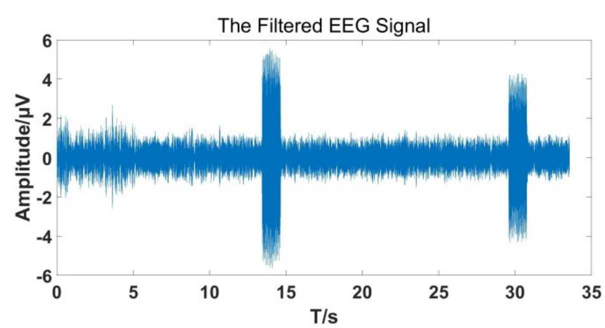
(a) Measure the inner part of the globus pallidus



(b) Measure the subthalamic nucleus



(c) Measure the inner part of the globus pallidus



(d) Measure the subthalamic nucleus

Fig. 5 The filtered EEG signal in four experiments

Although the synchronization of EEG signals and body movements is realized in the time aspect, there are still some registration errors due to the sampling frequency of EEG acquisition system, the frame rate of camera and the visual staying phenomenon of human eye. However, the synchronization method provides technical support and basic conditions for further analysis of EEG signals of patient with PD, which is of great significance in the study of EEG signals.

IV. Conclusions

The external induction electric pulse generator we designed and constructed in this research and the synchronization method proposed realize the synchronization of the EEG signals of patient with PD and body movements in the video shot, and establish the one-to-one correspondence between the EEG signals and body movements, which provides technical means for further diagnosis and treatment by analyzing the EEG signals of patients with PD. The next step is mainly to analyze the differences between the EEG signals corresponding to different actions, the differences between the EEG signals of patients with PD the two states of action and rest, and to extract the features of EEG signals in patients with PD, compare the EEG signals of the same actions with normal people to find the differences. If we can predict the coming symptoms of tremor, rigidity and bradykinesia through the changes of EEG before the onset of PD, even if the time is very short, it is possible for us to intervene and treat PD to a certain extent, which will greatly relieve the damage to patients during the onset of symptoms.

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References

[1] LE Liang, LI Shifeng, WANG Youqiong, et al. " A review on Parkinson's disease," *Journal of the Graduates Sun YAT-SEN University(Natural Science, Medicine)*, vol. 30, no. 4, pp. 1-6, 2009.

[2] Collomb-Clerc A and Welter M L, "Effects of deep brain stimulation on balance and gait in patients with Parkinson's disease: A systematic neurophysiological review," *Neurophysiologie Clinique / Clinical Neurophysiology*, vol. 45, no. 4-5, pp. 371-388, 2015.

[3] Adam Nassery, Christina A. Palmese, Harini Sarva, et al. "Psychiatric and cognitive effects of Deep Brain Stimulation for Parkinson's disease," *Current Neurology and Neuroscience Reports*, vol. 16, no. 10, pp. 87-87, 2016.

[4] Williams A, Gill S, Varma T, et al. "Deep brain stimulation plus best medical therapy versus best medical therapy alone for advanced Parkinson's disease(PD SURG trial): a randmised, open-label trial," *Lancet Neurol*, vol. 9, no. 6, pp. 581-591, 2010.

[5] Wong JK, Cauraugh JH, Ho K, et al. "STN vs GPi deep brain stimulation for tremor suppression in Parkinson's disease: A systematic review and meta-analysis," *Parkinsonism and Related Disorders*, vol. 58, pp. 56-62, 2019.

[6] Mirza Shazia, Yazdani Umar, et al. "Comparison of globus pallidus internal and subthalamic nucleus in deep brain stimulation for Parkinson's disease: an institutional experience review," *Parkinson's Disease*, vol. 2017, pp. 3410820, 2017.

[7] Xu F, Ma WB, Huang YM, et al. "Deep brain stimulation of pallidal versus subthalamic for patients with Parkinson's Disease: a meta-analysis of controlled clinical trials," vol. 12, pp.1435, 2016.

[8] Nabeel A. Khan and Sadiq Ali, "Classification of EEG signals using adaptive time-frequency distributions," *Metrology and Measurement Systems*, vol. 23, no. 2, pp. 251-260, 2016.

[9] Salai Selvam V and Shenbaga Devi S, "Analysis of spectral features of EEG signal in brain tumor condition," *Measurement Science Review*, vol. 15, no. 4, pp. 219-225, 2015.

[10] Dinesh Bhati, Manish Sharma, Ram Bilas Pachori, et al. "Time-frequency localized three-band biorthogonal wavelet filter bank using semidefinite relaxation and nonlinear least squares with epileptic seizure EEG signal classification," Digital Signal Processing, vol. 62, pp. 259-273, 2016.J.-G. Lu, "Title of paper with only the first word capitalized," J. Name Stand. Abbrev., in press.

[11] Shahidi AS, Tafreshi R, Javidan M, et al. "Predicting epileptic seizures in scalp EEG based on a variational bayesian gaussian mixture model of zero-crossing intervals," IEEE transactions on bio-medical engineering, vol. 60, pp. 1401-1413, 2013.