Design of Brain Computer Interface Based on Steady-State Visual Evoked Potential

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Abstract. This paper explains the concept of brain computer interface, and introduces the most popular steady-state visual evoked potential system. After that, the principle and basis of steady-state visual evoked potential （SSVEP） signal are emphatically introduced, and the considerations for obtaining SSVEP signal are discussed, and the brain computer interface is designed based on the steady-state visual evoked potential.

Keywords: Brain computer interface; Steady state visual evoked potential; EEG signal

1 Introduction

The coming information age with the progress of human science and technology, various disciplines are developing vigorously. For more than a century, although scientists have devoted themselves to brain science research, human beings still know little about it. The brain contains a large number of neurons, and its structure is extremely complex. It controls our individual daily life.

Since the 20th century, human beings have been studying brain activity for a long time. In the 1990s, many countries, led by Europe and the United States, defined the 21st century as the "era of brain science[1] ", and formulated long-term research plans for the brain, which can finally be summarized as "understanding the brain, protecting the brain, and creating the brain". "Understanding the brain" is the working process of learning the brain, including how the brain generates cognition, emotion, learning about external things, communication, etc; "Brain protection" is the content of the medical field, with the core of understanding the brain structure to prevent disease; "Creating brain" is to combine and sublimate the two, and its ultimate goal is to develop a micro controller similar to the brain.

Bioelectric activities occur in daily activities. With the signal extraction equipment, we can capture these electrical signals. It is generated because there are hundreds of millions of neurons in the human body, and the interaction feedback between each neuron finally produces this bioelectrical signal. As the only data at the input of BCI system, EEG signal is the foundation of the whole BCI system.

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Some people say that the BCI[2] system is built to read the brain's ideas and understand the real intention of users in real time, which is wrong. We get the feedback signals of different types of brain by giving a specific stimulus to the brain, and then use these EEG signals to identify the user's intention through a special extraction method, finally realizing the decryption of the user's EEG signals.

At present, there are many ways to distinguish BCI systems. According to the different types of evoked EEG signals, BCI systems are divided into three categories: P300-BCI, motor imagery (MI) - BCI and steady-state visual evoked potential (SSVEP) - BCI. Compared with the other two types, SSVEP-BCI [3] has the advantages of short training time, high signal-to-noise ratio, short response time and high ITR. Therefore, this paper mainly studies the SSVEP-BCI system.

2 Research status of SSVEP-BCI

Around 1978, Regan team created the first SSVEP-BCI system, which laid a solid foundation for the development of SSVEP . At the same time, Regan team published the relevant content of SSVEP signal in the form of a book, and also recorded the different responses of different experimenters (amblyopia, monocular blindness) to visual stimuli. In 1999, Gao Shangkai's team in China continued to carry forward Regan's idea of using Fast Fourier Transform (FFT) to recognize SSVEP signals, and built a four target two-dimensional cursor movement system, which was designed for disabled people, also made an important step in China's research in the field of BCI. Since then, more researchers have joined in the research of SSVEP-BCI.

In 2000, the US Air Force Research Laboratory developed that the flight simulator can roll left and right through SSVEP, and also applied the research results to exercise the disabled limbs, which is the earliest attempt in rehabilitation. In 2005, Professor Kelly passed theαThe study of the band proves thatαIn band The frequency of stimulation does not affect the recognition effect of SSVEP-BCI. In 2008, M ü ller Putz and others achieved success in SSVEP-BCI asynchronous control. In 2011, Tsinghua University in China discovered the phase characteristics of SSVEP signals, and combined the phase information with the stimulus frequency using a hybrid coding method, thus greatly increasing the number of effective coding targets.

In recent years, the research results of BCI technology have gradually increased. At the same time, many excellent algorithms have greatly improved the performance of SSVEP-BCI and expanded the scope of application. In the future, there will be more room for development in the field of BCI.

3 Steady-State Visual Evoked Potentials (SSVEP)

Generally, evoked potentials [4] have three ways: tactile, auditory and visual. The use of tactile and auditory evoked potentials requires high requirements for sensors, so visual triggering is generally selected in consideration of experimental conditions. This convenient method is used in EEG research. When the human visual pathway receives light stimulation, the cell potential in the brain will change, which is collectively called visual evoked potential (VEP). There are also three kinds of visual evoked potentials: transient visual evoked potential (TVEP); Steady state visual evoked potential (SSVEP); Pseudorandom code visual evoked potential.

3.1 Principle and Basis of SSVEP Signal

Principle of SSVEP signal: various neural networks distributed in the brain have their inherent resonant frequencies. Under normal conditions, these neural networks operate spontaneously without rules. When apply a constant frequency external visual stimulus, the neural network consistent with the stimulus frequency or harmonic frequency will generate resonance, resulting in significant changes in brain potential activity at the stimulus frequency or harmonic frequency, thus generating SSVEP signals.

The composition of the brain is very complex. From a physiological point of view, different parts have different division of labor, and the functions of different cortical regions are independent of each other. As shown in Figure 1, the frontal lobe is responsible for movement and understanding, the parietal lobe is responsible for tactile and spatial perception, the occipital lobe is responsible for vision, and the temporal lobe is responsible for hearing and language. Each organizational module is independent of each other, working in parallel, and forming an organic whole. Generally, we infer the thinking process of the brain by collecting EEG of occipital lobe area [5].

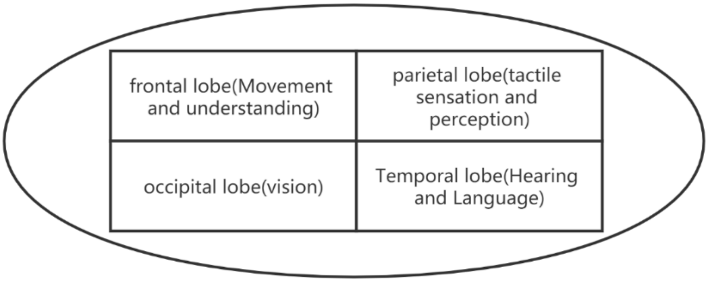

Fig. 1. Brain region and function [Owner draw]

When the eyes are subjected to a fixed frequency of visual stimulation, the potential activity of the cerebral cortex will be modulated to produce a continuous response related to the stimulation frequency. The response has a periodic rhythm similar to the visual stimulation, that is the steady-state visual evoked potential. In EEG, SSVEP signal can show a spectral peak in the power spectrum at the stimulation frequency or harmonic. By analyzing the frequency corresponding to the peak of the detection spectrum, the stimulus source of the visual gaze of the subject can be detected, so as to identify the intention of the subject.

3.2 Precautions for obtaining SSVEP signal

Table 1. Precautions for obtaining SSVEP signal Owner draw]

EEG	(Hz)	(μV)	Condition
δ	0.4-4	20-180	Unconscious deep sleep
θ	4-8	30-120	Consciousness is interrupted and bodies are deeply relaxed. It is a high-level mental state.
α	8-14	10-40	In this state, the physical and mental energy consumption is the least, and the energy obtained by the brain is relatively high.
β	14-40	4-18	Most of the brain wave states when people are awake β with the increase of waves, the body gradually becomes tense and ready to respond to the external environment at any time.
γ	40-100	4-8	Participating in healthy cognitive function and more complex tasks.

When SSVEP signal is obtained through stimulation, the following requirements are required:

(1) The stimulus intensity that can induce SSVEP can be roughly divided into three regions: low frequency region (4~15Hz), medium frequency region (15~30Hz), and high frequency region (30~60Hz). SSVEP requires stable frequency induction, and unstable frequency signals will be disordered and cannot be judged, so stability is the premise of all experimental operations.

(2) The amplitude of SSVEP signal is affected by many conditions, and each person has different responses to stimuli of the same frequency. At the same time, if one stimulus frequency is an integral multiple of the other, it will generate harmonics, so try to avoid it, otherwise it will cause identification errors.

(3) The individual's physical conditions are different, and the response to external stimuli cannot harm the body. Satisfy the comfort and friendliness. Too high frequency or intensity of stimulation will easily lead to visual fatigue, which will affect the visual health, and even induce epileptic EEG activity.

4 Design of brain computer interface based on steady-state visual evoked potential

Before analyzing SSVEP signals, it is necessary to create a good stimulation platform for SSVEP signals. A good stimulation interface and stimulation paradigm [6] can simplify a lot of work and improve efficiency. The performance of the SSVEP-BCI system is affected in many ways, In order to realize the real-time, compatibility and effectiveness of the system, the system is as follows.

4.1 Selection of stimulus design methods

At present, there are three common stimulus design methods used in SSVEP-BCI research: (1) using LED. In the early research, researchers chose to place a layer of paper in front of the LED lamp, and then control the microcontroller to change the frequency of the LED lamp. The advantages are high intensity and accurate control. The disadvantage is that the design is extremely inconvenient, requires more single chip computers, and must accurately consider the communication protocol between hardware. Now, researchers have designed two research interfaces that are suitable for them. (2) Simple flashing stimulus (such as single black and white square or circular stimulus) and (3) complex flip stimulus (such as square chessboard flip stimulus and circular contraction stimulus), as shown in Figure 2.

After many experiments, the SSVEP signal induced by method (3) is more obvious than that induced by method (2), but the number of graphics displayed by the computer is less. Therefore, in order to get more signal patterns, a simple flicker stimulus design method is generally used.

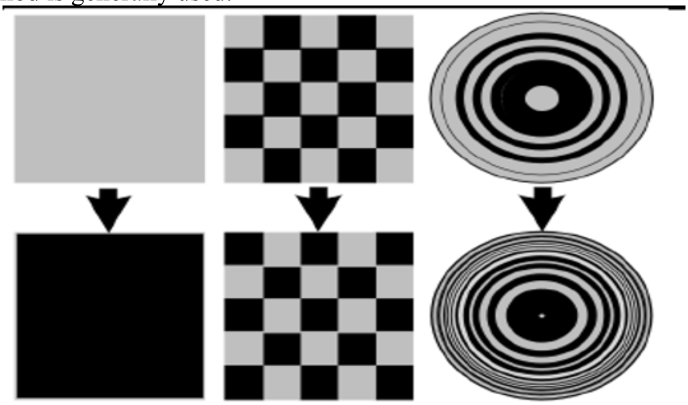

Fig. 2. Three commonly used stimulation methods [Owner draw]

To sum up, LCD display is selected to realize simple flicker stimulation, as shown in Figure 3. The two kinds of stimulation interfaces use the same stimulation freque, which is 8~16Hz, and the interval is 2Hz.

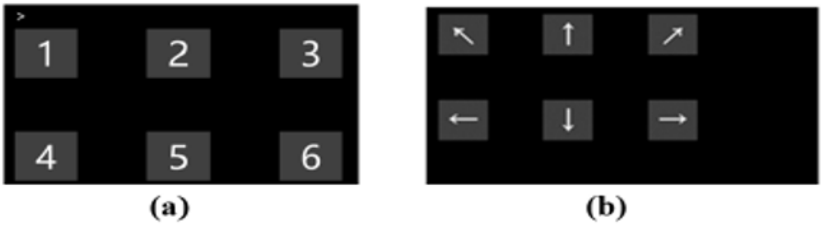

Fig. 3. The ssvep design interface designed [Owner draw]

4.2 Realization of stimulus frequency

The traditional gray white flip coding method can only achieve the stimulus frequency that can be divided by the screen refresh rate. In order to meet any stimulation frequency, this chapter uses the method of sine coding [7] to modulate the gray value of the target block, and the formula is as follows:

$$gray(i) = \frac{1+sin(2\pi f * \frac{i}{F})}{2} \quad (1)$$

Among them, the screen refresh rate is represented by F, the number of frames is represented by i, and gray (i) represents the gray value of the target area of the ith frame. The value range is [0, 1]. 0 represents gray, and 1 represents white. With this method, all stimulus frequencies below half of the screen refresh rate can be achieved.

4.3 Design of Online SSVEP-BCI System

The flow chart of SSVEP-BCI system is shown in Figure 4.

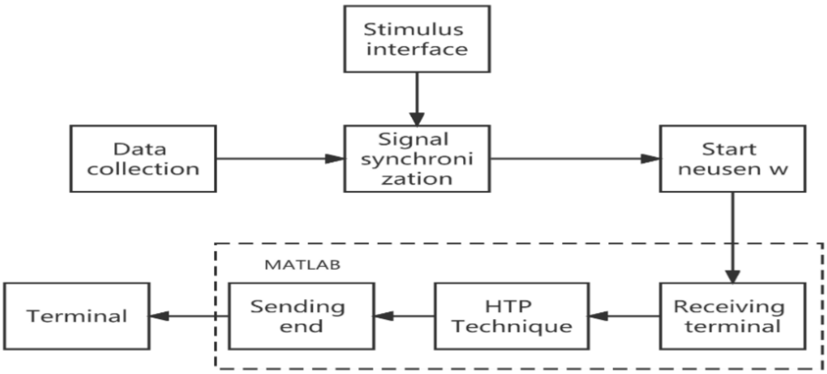

Fig. 4. Flow Chart of Online SSVEP-BCI System [Owner draw]

First, the information of the stimulation module and the EEG information of the data acquisition module are packaged and sent to the signal synchronizer, where the time information synchronization function is realized. Then the packaged information is transmitted to the supporting EEG signal acquisition and analysis software "Neusen w". Neusen W is a commonly used EEG analysis software. Under this software, you can select EEG information channels and send data, output IP, and the output port is the host IP and port by default. In the MATLAB platform shown in the box: according to the IP address, port address and receiving end sent by Neusen W, use TCP/IP protocol to receive EEG data and submit it to the algorithm processing module. The algorithm processing module collates the received data and identifies tags. Currently, the algorithms that can be implemented include MSI, CCA, FBCCA, IST-MSI and FBMSI. The sending end receives the data processed by the algorithm, then uses the IP and port address to send the identified label, and finally the terminal executes the instructions on the Label. In the above system process, all devices should be kept under the same LAN.

5 Conclusion

The paper introduces BCI technology and designs brain computer interface based on steady-state visual evoked potential. BCI is a new human-computer interaction discipline, which shows that human beings explored themselves. It has high scientific research value, and will also have its application value in various fields in the future. At present, BCI technology has attracted people's attention, and has been gradually developed in many research fields such as medical, military, genetic engineering. With the progress of scientific research, the simplification of algorithms, and the improvement of communication capabilities, BCI technology will have a broader development in the future, and the reform of the 21st century will soon arrive due to it.

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