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Application of brain-computer interface in rehabilitation medicine

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Abstract. A brain-computer interface (BCI) can realize the communication and control between the human brain and computers or other electrical equipment by electroencephalography. It is a novel kind of human2computer interface. BCIs will be applied in rehabilitation, control, and other fields. This paper introduces the working principle of BCIs. Some key techniques to design BCIs are discussed from these aspects: signal processing, device control methods, and signal feedback. Besides, the application of BCI in rehabilitation medicine is also discussed. Finally, some main problems and future trends are pointed out. The discussions have guiding values to the design and research of BCI.

Keywords: BCI, computer science, electromechanical prosthesis, bioengineering, non-invasive.

1. Introduction

Brain-computer interfaces are technologies that establish entirely new communication and control between the brain and computers or other electronic devices that do not rely on conventional brain information output pathways. Brain-machine interface technology in the field of rehabilitation can be done directly through the manipulation of the output device, through the acquisition of the human brain's electric signal, to realize the function disorder of communication with the outside world, to provide a possible way for improving the quality of the impairment of survival. The brain control interface is a new kind of robot interface technology, is a brain-machine interface(also called brain-computer interface (BCI)) important application and the research direction in the field of robot control. Brain-computer connection is the core module of the BCRI system [1].

This article introduces the concept of the brain-computer interface, describes how the brain-computer interface can be used to compensate for lost function or promote rehabilitation therapy, and discusses the application of the brain-computer interface in motor and sensory recovery [2].

2. How brain-computer interfaces work

BCI are direct connections between the human or animal brain (or cultures of brain cells) and external devices. In the case of a one-way brain-computer interface, the computer either receives commands from the brain or sends signals to the brain (such as video reconstruction), but cannot send and receive signals at the same time. Two-way brain-computer interfaces, which allow two-way information

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exchange between the brain and external devices, are being integrated with prosthetics to develop electromechanical prosthetics for people with disabilities [3].

According to the different ways of obtaining EEG signals, BCI systems can be divided into non-invasive BCI and invasive BCI. Non-invasive BCI involves measuring electrodes attached to the scalp of the brain to record electrical signals. Invasive BCI involves inserting electrodes into specific areas of the cerebral cortex to obtain the electrical activity signals of a single neuron or a small group of neurons... These two methods have advantages and disadvantages: non-invasive BCI has no damage to the user, but the collected signal is fuzzy, the ophthalmoelectric and myoelectric interference is large, and the signal-to-noise ratio is low. Invasive BC1 requires surgical implantation of electrodes into the brain, and the resulting brain signal has a high signal-to-noise ratio and good localization [4]. However, due to some unsolved social issues and user psychological problems, as well as technical limitations, invasive BC1 is only used for specific patients and occasions, and currently, it is mainly tested on animals.

2.1. Signal processing

For the feature extraction of two wavelet packet decomposition tasks in brain-computer interface (BCI), a novel Wavelet packet Decomposition (WPD) and common spatial decomposition is proposed EEG feature extraction method is combined with pattern and CSP. This method first chooses to lead seven important electricals (electroencephalograph, EEG) signals, with 'hear wavelet base third-order WPD decomposition. Then, the five sub-bands of each lead were reconstructed to obtain the relevant frequency domain information. Finally, the reconstructed signal is extracted by the CSP feature to obtain six – a dimensional feature vector. The combination of CSP and WPD can make full use of the time-frequency characteristics of WPD and effectively avoid the defects of CSP requiring too many input leads and a lack of frequency-domain information. The probabilistic neural network (PNN) was used to classify the data from the 2008 International BCI Competition and the experimental data from our laboratory [5]. The classification accuracy of the two data sources was 92% and 80%, respectively, which was 5% and 20% higher than that of simple CSP feature extraction. The experimental results show that the feature extraction algorithm combined with WPD and CSP can extract obvious features and improve the recognition accuracy of BCI.

2.2. Device control

From the perspective of control science, the brain is the control center of all movement and language functions of the human body and sends instructions to the body through the medium of external nerves. Neuroscience research has found that even if the external nerves and limbs lose their function due to injury, the brain function is still normal, and the command information sent by the brain can be transmitted by electrical signals. The study also found that when people are engaged in some thinking activities or induced by some external stimuli, the EEG signal will show a corresponding and regular pattern of change. Thus, people's wishes expressed by abstract and virtual brain activities can be "represented" by real and physical EEG signals, which serve as a bridge between the human brain and the outside world. The above research results provide a scientific basis and working principle for the research of brain control [7]. Electroencephalogram is the basis for realizing such control. Currently, electroencephalogram mainly used for brain-computer interface is as follows: Cortical potential (SCP), P300 potential, Motor imagery (MI) and Steady-state visual evoked potential (Steady-state visual evoked potential) etc. Both SCP and Event-related(de)synchronization (ER(D)S) are independent of external stimuli. And it's generated, it's generated spontaneously. Event-related potential (P300) and steady-state visual evoked potential are evoked modes [8].

2.3. Signal feedback

To train subjects to adjust their status to generate EEG signals suitable for recognition algorithms, a brain-computer interactive feedback system based on virtual reality feedback was designed. The system combines brain-computer interface technology with virtual reality technology. Firstly, the

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virtual human model is built in 3DMAX, then the designed actions are added to the character model in virtual reality. Finally, the system controls the actions of the character model by calling the database in real-time. The simulation results show that the subjects can compare the feedback movement of the virtual person with their imaginary movement in real-time and adjust themselves in time to achieve the consistency of the imaginary movement and the feedback movement. The research results preliminarily prove the feasibility of the feedback system and provide a good idea for the design of the BCI feedback system [9].

3. Application of brain-computer interface in rehabilitation medicine

Brain-computer interface (BCI) technology provides new neuro-engineering solutions for rehabilitation problems caused by amputation or nerve injury. As a result, neural interface technology is being incorporated into rehabilitation strategies for patient populations. After the onset of stroke, patients in the acute phase of the brain-damaged functional areas can have a partial spontaneous recovery, while patients in the sequel stage of the possibility of spontaneously recovering of the cerebral-damage functional regions significantly reduced the traditional rehabilitation treatment methods are not obvious. Especially in the upper limb motor function and hand function recovery and other aspects can only be promoted through some special rehabilitation treatment means to restore the function of stroke often leads to movement, balance, walking, and another aspect of the patient, seriously affecting the patient's daily life activities BCI technology can be collected brain signal processing into executive instructions, and transmitted to the limb through the spinal cord, peripheral nerve. At the same time, the transformed brain control information is presented to the patient through external devices, and the purpose of controlling brain signals is achieved through repeated training, gradually forming a normal cerebral cortex activation state.

3.1. The application of BCI technology in the rehabilitation of upper limb

Application of BCI technology in rehabilitation of upper limb and hand function of stroke patients. Existing studies have preliminarily confirmed BCI in chronic brain clinical effect of upper limb functional rehabilitation in apoplexy patients and its influence on brain functional plasticity. A study of patients with subacute stroke showed BCI training-induced changes in the electro-sensorimotor spectrum of the brain. Improvements in upper limb function in patients were associated with enhanced internal connections in the ipsilateral hemisphere. Li Mingfen et al. believed that electrical stimulation technology based on BCIs has a significant effect on promoting the recovery of upper limb function in stroke patients, and its therapeutic mechanism may be related to promoting the activation of motor-related brain regions on the affected side. Motor imagination can not only improve the upper limb motor function of elderly stroke patients but also significantly improve the cognitive function of elderly stroke patients and improve the quality of life of patients [10].

3.2. Application of BCI Technology in lower limb functional rehabilitation of stroke patients

Hemiplegia after stroke can cause muscle tone changes, often manifested as increased upper limb flexor muscle tension, lower limb extensor muscle tension, limb movement is not coordinated, and then affect the balance and gait, resulting in patients with limited social participation ability, quality of life seriously decreased, traditional rehabilitation therapy training has a certain therapeutic effect, but there is a single treatment method, boring, low active participation rate of patients shortcomings. In recent years, many rehabilitation equipment which can improve balance and gait function have been developed at home and abroad [9].

3.3. Application of BCI technology in stroke speech rehabilitation

Language is an important communication tool for human beings, and it is the main way of expression for people to communicate. Stroke often leads to patients' speech dysfunction, which leads to their limited ability to participate in society. For those with severe language communication disabilities, BCI is the most appropriate and valuable technology at present. It decodes information from the

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patient's brain and converts it into peripheral control instructions. Thus, peripheral control can replace the patient's expression or action. BCI speller is a typical application in this field. It can help people with speech disorders to realize external communication and control through visual or auditory paradigms.

3.4. Application of BCI technology in rehabilitation of stroke consciousness disorder

Brain diseases such as stroke and cerebration injury often lead to varying degrees of disturbance of consciousness in patients. In severe cases, patients even appear unconscious or vegetated. The other person's name is the standard stimulus and your name is the deviant stimulus. The results showed that P300 potential appeared in 5 minimally conscious patients when they heard their name (P300 is a positive wave occurring about 300ms after the deviated stimulus, which can be divided into P3a and P3b components. The classic P300, also known as P3b4 MCS patients had a more pronounced P300 potential when they heard someone else name. No task-related P300 potential was found in the other 5 patients with MCS and all patients with PVS, indicating that the conscious state of the MCS group was significantly better than that of the PVS group The application of brain-computer interface in consciousness rehabilitation of cerebral apoplexy will achieve certain results [7].

3.5. Application of BCI Technology in stroke psychological rehabilitation

After the occurrence of a stroke, most patients' psychologically adverse state is aggravated. Negative and avoidant attitude towards rehabilitation training. At present, most rehabilitation training based on BCI technology, especially VR technology, has added virtual scene videos related to life and physical activities. It can greatly avoid the conflict of patients in the rehabilitation treatment, and improve the enthusiasm and initiative of patients to participate in the treatment, to improve the rehabilitation effect. In terms of limb rehabilitation, two significant roles of BCIs in rehabilitation are replacement and restoration of lost neurological function. When BCI systems are used to replace lost neurological function, the technology restores the user's ability to interact with and control various environments and activities, including computer-based tasks (word processing, Internet browsing, etc.), environmental control units (light, heat, television, etc), mobility devices (power wheelchair drive, or neuroprosthetic limbs) [10].

4. The outlook and challenges of brain-computer interfaces

In recent years, with the rapid development of computer technology and signal processing technology, with the deepening of basic and clinical research on human brain function and EEG, as well as the continuous recognition and attention to the needs and potential of the disabled, the research of BCI has been rapidly developed. In 1995, there were fewer than 20 research groups. In 2000, there are now nearly 100 research groups around the world. A variety of BCI systems are developed in these laboratories. Different BCIs choose different control signals, adopt different signal processing methods, different conversion algorithms from EEG signal to operation control command, and different realization ways of the command output.

After many years of effort, the research of BCI has achieved a lot of exciting results, but it is undeniable that the research is still in the early stage of development. Currently, the maximum communication rate that can be achieved by BCIs is about 25 bits/minl3 J. Most BCIs are still in the laboratory stage, with most testing conducted in normal people and less testing in people with disabilities. There are still a lot of problems to be solved. The research and development of BCI depend on the development and integration of computer science, neurobiology, mathematics, materials science, psychology, clinical rehabilitation, and other disciplines [10].

On this basis, more in-depth research and exploration should be carried out in the following aspects. They are: to improve the information transmission rate of BCI system, reduce the error rate; to eliminate noise more effectively, obtain clear EEG signal, seek effective signal features, the best feature extraction and conversion algorithm, to improve the degree of automation when users use; to explore a more reasonable learning and training method is designed to enable users to control their

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EEG characteristics in the shortest possible time, to reduce the dependence of BCI on conventional motor and sensory output channels; to enhance the mutual adaptability of users and BCI system; to reduce the number of electrodes, reduce the complexity of the use, enhance the stability and compatibility of the BCI system, to develop discipline specifications, accurately and objectively evaluate the performance of BCI.

The development of BCI should pay attention to individual and diversification, in order to meet the differences of individual users and the needs of the extensive application of BCI. Besides, As for the development of innovative BCI, attention should be paid to solving patients' psychological and social-ethical problems while breaking through technological limitations. With the full understanding and gradual solution of these problems, BCI will eventually walk out of the laboratory and into people's lives [11].

5. Conclusion

In this study, the application and challenges of brain-computer interfaces in rehabilitation medicine were studied through a literature review. Brain-computer interface is widely used in rehabilitation therapy, prosthetics for disabled people, and so on. The challenges are inadequate computer power and incomplete signal acquisition. With the development of science and technology, there will be greater breakthroughs in brain-computer interface technology in the future.

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