Interpretation of the Implementation Principle and Prospect of Brain-computer Interface

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Abstract: Since the advent of computer technology, many science fiction movies have added the technology fantasy of connecting human brain with computer. In movies, the protagonist connects his thinking with computer and Internet through corresponding computer access equipment, and then realizes the communication with others and the control of mechanical devices in the virtual world. With the development of science and technology, these video plots are no longer fantasy. Brain-computer Interface (BCI) technology realizes the connection between human brain and computer. The mature BCI technology in the future, with a wide application space, will change people's living environment and mode subversively, as well as help paralyzed patients recover their ability to move. This paper makes a technical analysis of the implementation principle of BCI technology and elaborates the specific application fields and future prospects combined for reference.

1. Introduction

BCI is a new technology realizing the connection between human brain and computer. It is not only a technical concept, but also an achievable technology in current research experiments. By applying a receiver that can receive signals from human brain, instructions from human brain will be received, information will be converted into computer language that can be recognized by the computer through a special encoding processor, and then related equipment and electrical appliances will be controlled with the assistance of computer, which can avoid the manual control of human beings. It not only speeds up the reaction speed of mechanical equipment and electrical appliances, but also provide assistant action tools for disabled or paralyzed patients. Therefore, the emergence of BCI technology is conducive to improving people's quality of life and work efficiency. It can be applied in entertainment, industry, medicine and other fields, with great research and application prospects.

2. Overview of BCI Technology

2.1 Specific Concept of BCI Technology

BCI technology is the abbreviation of Brain-computer Interface technology. In its technical name, "brain" refers to the brain and nervous system of human beings and other organisms. "Computer" refers to any equipment with the ability of data processing, such as computer, mechanical and electrical equipment equipped with micro-processors. "Interface" refers to the medium of converting brain signals to computer signals. The connection between human brain and computer is different from the signal feedback of human body itself. Take human touching objects as an example. The brain needs to feel the temperature of objects when touching objects. The hand transmits the sensory signals of overheating or overcooling to the brain, and to the nervous system in the muscle of hand as well. The nervous system drives the muscle to complete the contraction of hand and then feed it back to the brain. By connecting brain with computer, the computer conveys the brain's action instructions to the manipulator arm, which reduces the repeated transmission of intermediate signals and just require the brain to send instructions and receive feedback.

BCI technology is a comprehensive technology involving various fields, including computer

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technology and neuroengineering technology, etc. It has accumulated a lot of application experience in animal experiments and formed a practical basis for being implanted into human body. At present, BCI technology can complete the restoration of auditory system, visual system and limb movement. In study, it has also been found that the cerebral cortex of mammals has a good plasticity, which can be effectively connected with BCI so as to achieve the same control of mechanical prosthesis as the control of their own limbs.

2.2 Specific Implementation Steps of BCI Technology

The specific implementation steps of BCI technology are divided into three steps, namely, the acquisition of brain signals, information coding processing and signal feedback. Brain signal acquisition mainly collects the information of instructions sent by brain, converts the collected brain signals into digital formats, then sends brain instructions to special signal processing equipment, and completes signal coding processing by signal processing equipment. The main instructions in the signal are extracted and sent to the control equipment through a special coding format and then the control equipment completes the control of the manipulator, wheelchair and other devices (as shown in Figure 1).

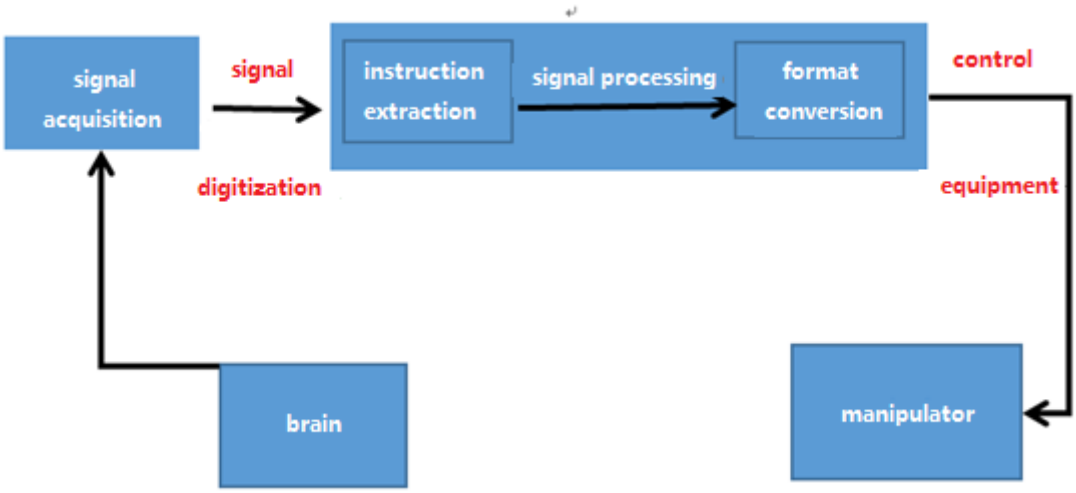

Figure 1 Working Principle Block Diagram for Brain-computer Interface Technology

3. Brain Signal Acquisition Method of BCI Technology

Brain signal acquisition is the technical core of BCI technology. Only by ensuring the accurate and complete brain signals, can follow-up signal processing and control of mechanical equipment be realized. Now, there are three ways of brain signal acquisition in BCI technology, which are the invasive, semi-invasive and non-invasive.

3.1 Intrusive Signal Acquisition

Invasive signal acquisition method refers to the direct connection to the gray matter of the brain through electrodes. Since it can reduce the interference of external factors on the signal, it has the characteristics of good signal quality. However, it is difficult to operate the implantation of electrodes into the human body and connect them with the gray matter of the brain. The whole process will not only leave scars in the body due to the reaction of the immune system of human body, but also lead to poor signal because of the aging of electrodes. The chemical substances produced by the aging of electrodes causes inflammation, thus affecting human health. Moreover, the operation of invasive signal acquisition method is relatively experience, with higher requirements for the technical level of doctors and some problems in popularization. At present, this method is only applied in the medical field, mainly in order to restore patients' special sensory ability and help paralysed patients restore their mobility.

3.2 Semi-intrusive Signal Acquisition

Semi-invasive signal acquisition interface is located in the intracranial cavity, but does not touch the gray matter of the brain. Therefore, it is inferior to the invasive BCI in the transmission quality of brain signals. The advantage of semi-invasive method is that it has less chance of triggering immune system reaction and is beneficial to wound healing. If the intrusive brain signal acquisition mode is compared to the direct USB connection mode, then the semi-intrusive mode to the wireless signal connection, of course, with certainly weaker signal transmission quality than the direct connection mode. At present, in the semi-intrusive signal acquisition method, some technical deficiencies still exist. The main reason is that it can not achieve complex signal transmission, so it fails to achieve more than one-dimensional action control.

3.3 Non-intrusive Signal Acquisition

Non-invasive signal acquisition method is that the signal interface does not enter the brain, but usually receives the signal of the human brain by wearing a motor cap. Because the skull in the human body will block the brain signal, and the signal will be attenuated in the process of transmission, the final received signal quality is often poor, which also causes the difficulty of signal resolution. Compared with the semi-intrusive signal acquisition, it seems to add a signal interference area in the process of wireless signal transmission. It outputs normal information and receives random code. Therefore, it is of great difficulty to achieve high control capability through non-invasive BCI. Now, it can only simply control the driving direction and acceleration and deceleration of wheelchair equipment, which is still in the initial stage of research.

4. Information Decoding, Coding Processing and Feedback of BCI Technology

4.1 Information Decoding of BCI Technology

When enough brain signals are collected through the receiving end of the brain receiver, they need to be decoded and processed, mainly to be translated, and at the same time to remove the superfluous interference information and useless information, so that only important instruction information can be retained. When the brain signal is decoded, instruction information is converted into the electronic data information that can be recognized by the computer through the encoding system. Finally, the control of machinery and electronic equipment will be realized. In the decoding and processing of brain signals, the technical difficulty is relatively high. Take human visual nerve signals as an example. When the visual system is disturbed by limb movements and external environment, the amount of information generated will increase, which further increases the difficulty of signal decoding. Meanwhile, because the bioelectrical signals of brain signals are relatively weak, it is difficult to collect and decode them.

4.2 Information Coding of BCI Technology

Moreover, after decoding the brain signal, the accuracy of control instructions encoding again can not be guaranteed. The main reason is that the control instructions often conduct inaccurate action control in three-dimensional environment mainly due to the lack of relevant algorithms. The low accuracy of the algorithm for converting electrical signals into computer language will affect the control effect. Therefore, one of the factors that restrict the development of BCI technology is the inadequate accuracy of information conversion algorithm, which needs further research by scientific researchers.

4.3 Feedback of BCI Technology

In BCI technology, how to realize information feedback to the brain is also one technical difficulty. Human and animal behavior is realized through instructions issued by the brain, and some of the brain’s judgments and command information adjustment are completed based on visual, taste, tactile and other perceptual feedback to the brain. Therefore, now, BCI technology still can not be applied to feedback complex perceptual information by the current technology. In addition,

the mixing of multiple perceptual information also makes it more difficult to analyze the feedback information.

5. Application Fields and Future Development Directions

5.1 Application Fields of BCI

The application of BCI technology in medical field is helpful to help patients recover their action function or part of their perception function. By using this technology, patients' thinking state is monitored in real time, and the data supporting for patients' treatment can be provided. BCI technology is conducive to assisting the treatment of limb movement disorders. For example, in the rehabilitation treatment of stroke patients, BCI device detects the action signals conveyed by the brain of stroke patients, identifies the corresponding action instructions, and then controls the functional muscle through electrical stimulation or mechanical rehabilitation equipment, so as to complete the rehabilitation exercise training of patients' limbs. In this method, patients become more initiative in rehabilitation training, which is conducive to improving the efficiency of rehabilitation. Therefore, the application of BCI technology to the medical field has attracted more and more attention.

5.2 Development of BCI Technology in the Future

In the future, as scientific researchers gradually overcome the difficulties of brain signal reception, decoding and encoding technology, the application level of BCI technology will be greatly improved, the convenience of non-invasive BCI technology will be highlighted, and BCI technology will become a popular civil device like smartphones. BCI device not only helps patients with motor and perceptual impairment to recover their normal living ability, but also can be used in other fields. For example, in the field of education, by monitoring students' attention through BCI technology, teachers are able to set up better teaching plans. In business applications, more accurate market research can be achieved and more information such as the viewing experience of consumers, advertising focus and so on can be collected, so as to better formulate sales plans, enhance the mode of interpersonal interaction and effectively improve consumers' shopping experience.

6. Conclusion

To sum up, enhancing BCI technology research and solving various technical difficulties in BCI technology are conducive to strengthening the performance of BCI equipment and realizing the application and promotion of BCI technology. It can not only improve people's quality of life and let more patients return to normal life, but also change the existing life mode and work. It is conducive to improving work efficiency and achieving the goal of promoting the development of human civilization.

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