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Development of BCI Application in Gaming

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Abstract
BCI (brain-computer interface) is a current frontier technology with implementations ranging from non-invasive and partially invasive to invasive and applications in many fields. In the field of games, the application of BCI technology has seen some new developments. From the Neuralink conference showcasing a monkey playing games with its mind to Valve's BCI game applications, game streamers using brainwave devices to defeat bosses in games, and the invention of BCI games in recent years, these developments have shown us the capabilities and limitations of the current BCI technology, and that BCI game applications are still far from maturity.

Keywords: *Brain-computer interface，BCI game.*

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I. INTRODUCTION

1.1 Technical

A BCI (brain-computer interface) is the technology that sends and receives signals between the human or animal brain (or a culture of brain cells) and an external device. It gives rise to a new type of control feedback relationship in which real machines can be directly controlled solely by thinking. The concept of BCI was first introduced by American scientist J. Vidal in 1973, but it never saw a real development boom until the end of the 20th century when the rapid development, popularization of computers and computing power increase made it possible to decode complex EEG signals in real-time.

1.2 Equipment

Depending on how close electrodes get to brain tissue, current implementations of BCIs range from non-invasive and partially invasive to invasive.

"Invasive" BCI generally refers to the surgical implantation of signal acquisition electrodes into the gray matter of the brain, which allows high-quality EEG signal acquisition and more accurate and immediate external device control. Due to the need for complex implantation procedures, which may easily trigger immune responses, tissue damage and signal attenuation, "invasive" BCIs are currently still in the human trial stage.

"Non-invasive" BCI refers to the placement of signal acquisition electrodes directly outside the skull to collect neural information. By eliminating the need for surgical intervention, this method has advantages in terms of safety and convenience of disassembly and assembly. However, due to the signal attenuation effect of the skull as well as that it can cause dispersion and blurring of the electromagnetic waves emitted by the neurons, “non-invasive" BCIs often suffer from poor signal stability and low signal quality.

The "partially invasive" BCI refers to the implantation of signal acquisition electrodes between the cranial cavity and gray matter for information analysis mainly based on cortical electroencephalogram (ECoG). In terms of signal acquisition quality and safety, this method is in the middle of the other two technologies.

BCI is still a cutting-edge technology. With the development of relevant theories, experience accumulation and in-depth technical research, it will be applied to more fields that mainly include medical healthcare, military, education and training, game entertainment, aerospace, smart home, etc.

II. Sstatus Quo

2.1 "Mind control"

In recent years, Musk founded Neuralink and introduced an "invasive" device developed by the company, which is a chip that is only the size of a coin but has 1,024 transmission channels and can receive information about brain nerve activity after being implanted inside the skull, and wirelessly transmit brain wave data in real-time. Three piglets that underwent BCI surgery were also displayed during the above presentation. After receiving brain-implanted BCI systems each capable of monitoring more than a thousand neurons with more than three thousand electrodes, these piglets walked on the stage with their brain wave signals transmitted by the BCI systems to the big screen in an easily perceivable audio-visual format. By once again putting BCI technology on display to the public, this press conference sparked another great upsurge in this technology.

In this upsurge, more innovative ideas have been brought into the field of BCI gaming applications. Neuralink posted a demo video showing "a monkey playing game with its mind", which caused widespread discussion on social networks. The monkey in the video is playing Pong! a very simple ancient game (about using a joystick to control a board to move up and down). However, the video shows the monkey remotely controlling the game with chips implanted in its skull, which indicates true "mind control" and is the reason why Neuralink named the experiment "MindPong". The video shows the monkey learning to control a computer with his brain activity. At first, the monkey uses a joystick to interact with the computer for a "tasty banana smoothie, delivered through a straw." The monkey had two Neuralink devices put on each side of his brain about six weeks ago, learned how to use a joystick to move a cursor to targets on a screen in exchange for a banana smoothie delivered through a straw. To get to the stage where the monkey can play Pong with its brain, it must successfully complete a series of maneuvers with a joystick, moving a ball across the screen and landing it in a square. This rewards the monkey with a drink of the reportedly "tasty" smoothie, but the Neuralink device also records the electric signals sent out by the brain. Not only is the monkey being trained to move things around a screen, but the device itself is being trained to understand what the brain signals mean in the context of Pong. Once the joystick is disconnected, the monkey's brain keeps sending the same signals out, as if the monkey was moving the joystick. In addition to providing a new direction for the innovation of game operation methods, the aforementioned experiment also provides new possibilities for helping people with disabilities enjoy more entertainment.

Picture1: Monkey can play Pong with its brain

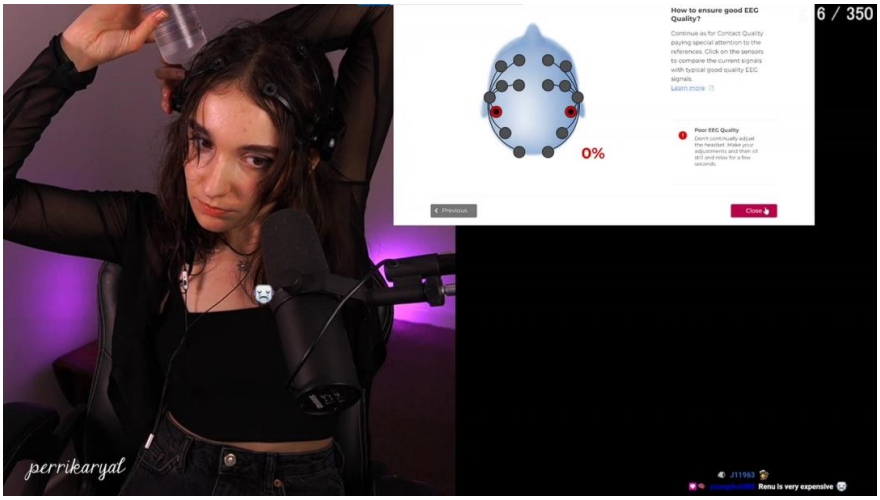
2.2 Apply BCI to games

Another gaming giant, Gabe Newell from Valve, also expressed his views on BCI technology in an interview and talked about how Valve will apply BCI to games. In his opinion, ideas about BCI gaming at this stage are mostly hypothetical, but he also said that as a technology that can be used to widely collect data user experience data from brains, BCI will become an important tool for the development and production of software and games in the future. A device called Galea, developed by Valve in partnership with OpenBCI, is designed to be used with Valve's VR device to read and analyze all kinds of emotional signals generated by the human brain during gaming sessions, and these data can be a very useful reference for future efforts to improve player immersion, optimize game level design or dynamic difficulty settings. When it comes to imagining the future, Newell believes that BCI can give players a gaming experience that far exceeds the current audio-visual

experience, saying that the player's real world will seem calm, boring, and even lifeless compared to the possible brain-based experience. Other than reading brain signals to provide support data for games and realize a gaming experience superior to the audio-visual one, BCIs can be more widely used in medical treatment, using the plasticity of the human nervous system to cure and even enhance the human body. In this regard, Newell gave a simple example to the media: BCI technology can now be used to artificially suppress vertigo that some people feel when using VR equipment.

2.3 Brainwave control

In January, game streamer Perrikaryal showed viewers a surreal game session: playing Elden Ring with brainwave control. Perrikaryal is a Twitch game streamer and a Master of Psychology. At first, she used the brainwave monitoring device just to observe the activity of her brain during gaming, but after a while, she suddenly had the idea of using brainwaves to control the game character. She quickly put this idea into practice and chose Elden Ring as the game for the experiment. After using a brainwave monitoring device to record data on brain activity that processes game commands, she bound specific types of brain activity to game keys, allowing her to control the in-game character through thinking. The EEG collector she uses during the game is "Emotiv Epoic+" developed by an American neurotechnology company. Since the device uses wet electrodes, she had to repeatedly adjust the device during the game and constantly wet her scalp with saline to improve conductivity. Despite the best efforts to ensure acquisition accuracy, the sensors were still susceptible to interference as every slight physical movement of Perrikaryal can disrupt bioelectric currents, causing the EEG collector to miss certain brain signals. Therefore, she not only needed to be mentally focused but also physically stable for a long time during the game. "There's often a delay between when I have the idea to launch an attack and when it actually happens." She said on the live stream, "However, it's not all the equipment's fault as our understanding of our own brains is also limited. My reaction can be improved through concentration and intensive training. " After a week of adjustment and training, Perrikaryal finally defeated the boss during a live gaming session, the news of which attracted many viewers, and the atmosphere in her game streaming room also changed from initial disapproval to highly congratulatory and encouraging. Perrikaryal admits that so far, she has not been able to fully control the game using brain waves. She has only trained a few simple commands which allowed her to do things such as dodging, attacking and casting spells, but still needs a gamepad for more complex operations such as moving around and organizing backpacks.



Picture2: Monkey can play Pong with its brain

2.4 BCI game

In 2013, Congedo developed a BCI game "Brain Invaders" (inspired by Space Invaders, a famous retro game) which runs on Visual P300. The P300's potential acquisition and motion imaging capabilities have led to the invention of many BCI games. But this does not mean that BCI technology has been fully applied to gaming, as most of these BCI games only involve very simple gameplays that are similar to those of the earliest video games. The BCI devices used for gaming today are all "non-intrusive". Since players cannot be mentally

concentrated forever in gaming sessions, these BCI devices cannot achieve high precision. In addition, because the transmission rate is not high enough, these BCI devices cannot be used to complete complex game operations, so they cannot replace game operation devices such as keyboards and mice. It can be said that low transmission rate is a major difficulty in the development of BCI game applications.

III. CONCLUSION

The current BCI game application is still a far cry from the sci-fi imaginations in various films and TV shows. The development of such applications is facing certain obvious problems including low transfer rates, high material costs, limited market investment, and a lack of BCI game-related content developers and art designers. In addition, the acceptance of BCI games is also an issue, because BCI-based game input is not reliable enough, which can easily lead to insurmountable frustration due to operational errors unrelated to game skills. A subjective study of BCI gaming applications also reported a lack of feedback from participants on error quantification, which coincided with the fact that about 20% of users were not proficient with using typical BCI devices.

As a cutting-edge technology, BCI's development will have a non-negligible impact on the world. In healthcare, for example, cochlear implants, the most widely used BCI implementation, are benefiting people around the world. The use of this technology in gaming is still in its infancy. From Musk's "intrusive" chips to Gabe Newell's BCI-aided devices, directions for development are being explored; from magical boss battles using brain waves to the booming of BCI games, the technical capabilities and bottlenecks at this stage have been demonstrated. One thing is for sure, BCI technology in its infancy enjoys countless possibilities for future development.

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