Brain computer interface
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ABSTRACT
A brain-computer interface (BCI) sometimes called a direct neural interface or a brain-machine interface, is a
direct communication pathway between a brain and an external device. Recent advances in computer hardware
and signal processing have made it feasible to use human EEG signals or “brain waves” to communicate with a
computer. Locked in patients now have a means to communicate with the outside world. Even with modern
advances, such systems still suffer from communication rates on the order of 2-3 items/minute. In addition,
existing systems are not likely to be designed with flexibility in mind, leading to slow systems that are difficult to
improve. This dissertation presents a flexible brain-computer interface that is designed to facilitate changes in
signal processing methods and user applications. In order to show the flexibility of the system, several
applications, ranging from a brain-body actuated video game played with eye movements to a brain-computer
interface for environmental control in a virtual apartment, are shown.

INTRODUCTION
A Brain-Computer Interface (BCI) provides a new communication channel between the human brain and the
computer. The 100 billion neurons communicate via minute electrochemical impulses, shifting patterns sparking
like fireflies on a summer evening that produce movement, expression, words. Mental activity leads to changes
of electrophysiological signals. The BCI system detects such changes and transforms it into a control signal. In the case of cursor control, for example, the signal is transmitted directly from the brain to the mechanism directing the cursor, rather than
taking the normal route through the body’s neuromuscular system from the brain to the finger on a mouse.

HOW BRAIN COMPUTER INTERFACE
The reason a BCI works at all is because of the way our brains function. Our brains are filled with neurons,
individual nerve cells connected to one another by dendrites and axons. Every time we think, move, feel or
remember something, our neurons are at work. That work is carried out by small electric signals that zip from
neuron to neuron as fast as 250 mph. The signals are generated by differences in electric potential carried by
ions on the membrane of each neuron. Although the paths the signals take are insulated by something called
myelin, some of the electric signal escapes. Scientists can detect those signals, interpret what they mean and use
them to direct a device of some kind.

Fig: The Wonder Machine – Human Brain

Cortical Plasticity
The brain actually remains flexible even into old age. This concept, known as cortical plasticity, means that the
brain is able to adapt in amazing ways to new circumstances. Learning something new or partaking in novel
activities forms new connections between neurons and reduces the onset of age-related neurological problems. If
an adult suffers a brain injury, other parts of the brain are able to take over the functions of the damaged portion
Approaches:
Invasive BCIs are implanted directly into the grey matter of the brain during neurosurgery. As they rest in the
grey matter, invasive devices produce the highest quality signals of BCI devices but are prone to scar-tissue
build-up, causing the signal to become weaker or even lost as the body reacts to a foreign object in the brain The
easiest and least invasive method is a set of electrodes a device known as electroencephalograph (EEG) --
attached to the scalp. The electrodes can read brain signals. However, the skull blocks a lot of the electrical
signal, and it distorts what does get through.
To get a higher-resolution signal, scientists can implant electrodes directly into the gray matter of the brain
itself, or on the surface of the brain, beneath the skull. This allows for much more direct reception of electric
signals and allows electrode placement in the specific area of the brain where the appropriate signals are
generated. This approach has many problems, however. It requires invasive surgery to implant the electrodes, and devices left in the brain long-term tend to cause the formation of scar tissue in the gray matter. This scar tissue ultimately blocks signals. Regardless of the location of the electrodes, the basic mechanism is the same: The electrodes measure minute differences in the voltage between neurons. For example, if researchers are attempting to implant electrodes that will allow someone to control a robotic arm with their thoughts, they might first put the subject into an MRI and ask him or her to think about moving their actual arm or her to think about moving their actual arm. The MRI will show which area of the brain is active during arm movement, giving them a clearer target for electrode placement. Real life example Dobell’s first prototype was implanted into “Jerry,” a man blinded in adulthood, in 1978. A single-array BCI containing 68 electrodes was implanted onto Jerry’s visual cortex and succeeded in producing phosphine’s, the sensation of seeing light. The system included cameras mounted on glasses to send signals to the implant.

**BCI Applications:**

One of the most exciting areas of BCI research is the development of devices that can be controlled by thoughts. Some of the applications of this technology may seem frivolous, such as the ability to control a video game by thought. If you think a remote control is convenient, imagine changing channels with your mind. However, there’s a bigger picture -- devices that would allow severely disabled people to function independently. For a quadriplegic, something as basic as controlling a cursor via mental commands would represent a revolutionary improvement in quality of life. But how do we turn those tiny voltage measurements into the movement of a robotic arm.

A more difficult task is interpreting the brain signals for movement in someone who can’t physically move their own arm. With a task like that, the subject must “train” to use the device. With an EEG or implant in place, the subject would visualize closing his or her right hand. After many trials, the can learn the signals associated with the thought of hand-closing. Software connected to a robotic hand is programmed to receive the “close hand” signal and interpret it to mean that the robotic hand should close. At that point, when the subject thinks about closing the hand, the signals are sent and the robotic hand closes.

Once the basic mechanism of converting thoughts to computerized or robotic action is perfected, the potential uses for the technology are almost limitless. Instead of a robotic hand, disabled users could have robotic braces attached to their own limbs, allowing them to move and directly interact with the environment. This could even be accomplished without the “robotic” part of the device. Signals could be sent to the appropriate motor control in the hands, bypassing a damaged section of the spinal cord and allowing actual movement of the subject’s own hands.

**BCI Research and IBCI System:**

A schematic of a BCI system is shown in Figure. Brain electrical activity is acquired using electrodes (either implanted inside the brain or externally on the scalp). From the recorded signals, features (e.g., amplitudes of evoked potentials, or sensory motor cortex rhythms) that reflect user’s intent are extracted using signal processing methods. These features are then translated into device commands (e.g., using neural networks) which are then issued to systems like, virtual-keyboards, mobile robots, robotic wheelchairs and computer games. Feedback from these systems is given to the user using various modalities (e.g., visual, auditory etc.).

BCI is broadly classified into three categories based on invasiveness of the recording technique as

1) Invasive
2) Partially invasive
3) Non-invasive BCI.

For an invasive BCI, the electrodes are implanted directly into the grey matter of the brain during neurosurgery. As they rest in the grey matter, it can produce the highest quality signals of BCI devices but are prone to scar-tissue build-up, causing the signal to become weaker or even lost as the body reacts to a foreign object in the brain. Partially invasive BCI uses electrodes implanted inside the skull but resting outside the brain rather than amidst the grey matter (e.g., Electrocorticography, ECoG).

**EEG Processing:**

The brain activity was acquired via 16 EEG channels over the motor cortex with reference on the left and ground on the right mastoid. Machine learning techniques based on canonical variety analysis (CVA) were used to select subject-specific spatiofrequency features that maximize the separability between the different mental tasks Only features which appear to be stable across the whole training set were used to train a Gaussian classifier rejection threshold was set on the probability distribution over the mental classes emitted by the classifier, thus filtering out decisions with low confidence. Furthermore temporary evidence about the executed task was accumulated using an exponential smoothing probability integration framework.

**EMG Processing:**

Four EMG channels were bipolar recorded over the flexor and extensor of the left and right forearm (see Figure). The prehensile EMG activities were rectified and averaged over 0.3 s to get the envelopes. The resulting features were subject-specific threshold per channel, normalized and classified based on maximum
distance. For estimating the EMG thresholds the ongoing activity during the non-execution time was averaged. The thresholds were finally set to twice the mean plus standard deviation (SD) per channel. Therefore only activities larger than these thresholds were further used. **Fusion principle of muscular and brain activities**

Fig: Operation of a brain computer interfacing (BCI) system

**To Operate only with Brain:**

Advanced Telecommunications Research Institute International (ATR) and Honda Research Institute Japan Co., Ltd. have jointly developed base technology for a new BMI (brain machine interface) to operate robots based on the human brain’s activity patterns.

By measuring brain activity, the technology judges the subject person’s action from an image pattern and makes a robot take the same action almost in real time (about 7 seconds). This is a breakthrough technology that changes the relation between the human and machine.

Brain Gate is being developed by Massachusetts-based Neuron technology Company Cyber kinetics offers the possibility of hitherto unimaginable levels of independence for the severely disabled. Since the insertion of the tiny device in June, the 25-year-old has been able to check email and play computer games simply using thoughts. He can also turn lights on and off and control a television, all while talking and moving his head. User has an EEG cap on. By thinking about left and right hand movement the user controls the virtual keyboard with her brain activity.

Early research used monkeys with implanted electrodes. The monkeys used a joystick to control a robotic arm. Scientists measured the signals coming from the electrodes. Eventually, they changed the controls so that the robotic arm was being controlled only by the signals coming from the electrodes, not the joystick.

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Once the basic mechanism of converting thoughts to computerized or robotic action is perfected, the potential uses for the technology are almost limitless. Instead of a robotic hand, disabled users could have robotic braces attached to their own limbs, allowing them to move and directly interact with the environment. This could even be accomplished without the "robotic" part of the device. Signals could be sent to the appropriate motor control nerves in the hands, bypassing a damaged section of the spinal cord and allowing actual movement of the subject’s own hands.

Playing with the cursor:

A similar method is used to manipulate a computer cursor, with the subject thinking about forward, left, right and back movements of the cursor. With enough practice, users can gain enough control over a cursor to draw a circle, access computer programs and control a TV. It could theoretically be expanded to allow users to "type" with their thoughts.
RESEARCH

A new brain-computer-interface technology could turn our brains into automatic image-identifying machines that operate faster than human consciousness. Darpa, or the Defense Advanced Research Projects Agency, is funding research into the system with hopes of making federal agents' jobs easier. The technology would allow hours of footage to be very quickly processed, so security officers could identify terrorists or other criminals caught on surveillance video much more efficiently. The system harnesses the brain's well-known ability to recognize an image much faster than the person can identify it. Our human visual system is the ultimate visual processor" Coupling that with computer vision techniques to make searching through large volumes of imagery more efficient.

The brain emits a signal as soon as it sees something interesting, and that "aha" signal can be detected by an electroencephalogram, or EEG cap. While users sift through streaming images or video footage, the technology tags the images that elicit a signal, and ranks them in order of the strength of the neural signatures. Afterwards, the user can examine only the information that their brains identified as important, instead of wading through thousands of images.

The major weakness of computer vision systems today is their narrow range of purpose, a system that is intended to recognize faces and apply it to recognizing handwriting or identifying whether one object in a photo is behind another. The human user, who is more likely to easily spot oddities, can then look only at the parts of the image that matter. This could allow time-sensitive searches to be performed in real time.

DRAWBACKS

a. The brain is incredibly complex. To say that all thoughts or actions are the result of simple electric signals in the brain is a gross understatement. There are about 100 billion neurons in a human brain .Each neuron is constantly sending and receiving signals through a complex web of connections. There are chemical processes involved as well, which EEGs can't pick up on.

b. The signal is weak and prone to interference. EEGs measure tiny voltage potentials. Something as simple as the blinking eyelids of the subject can generate much stronger signals. Refinements in EEGs and implants will probably overcome this problem to some extent in the future, but for now, reading brain signals is like listening to a bad phone connection. There's lots of static.

c. The equipment is less than portable. It's far better than it used to be early systems were hardwired to massive mainframe computers. But some BCI's still require a wired connection to the equipment, and those that are wireless require the subject to carry a computer that can weigh around 10 pounds.

CONCLUSION

As we can see there are many useful applications of brain computer interface. It can be very helpful for people with moving disabilities as human - machine interface. But it can be also used for control of human body muscles. There are also many possibilities in military domain. Last are the applications for making our lives easier. So one day maybe all people are wearing bci-caps and using hands only for eating. Or even without caps with implants right in CNS. To bring this in reality it has to been developed more adaptable BCI system and foremost avoid all risks.

REFERENCES


AUTHOR BIOGRAPHY

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