BRAIN –COMPUTER INTERFACE

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ABSTRACT

As the power of modern computers grows alongside our understanding of the human brain, we move ever closer to making some pretty spectacular science fiction into reality. Imagine transmitting signals directly to someone's brain that would allow them to see, hear or feel specific sensory inputs. Consider the potential to manipulate computers or machinery with nothing more than a thought. It isn't about convenience, for severely disabled people, development of a **brain-computer interface** (BCI) could be the most important technological breakthrough in decades.

A Brain-computer interface, sometimes called a **direct neural interface** or a **brain-machine interface**, is a direct communication pathway between a brain and an external device. It is the ultimate in development of human-computer interfaces or HCI. BCIs being the recent development in HCI there are many realms to be explored. After experimentation three types of BCIs have been developed namely Invasive BCIs, Partially-invasive BCIs, Non-invasive BCIs.

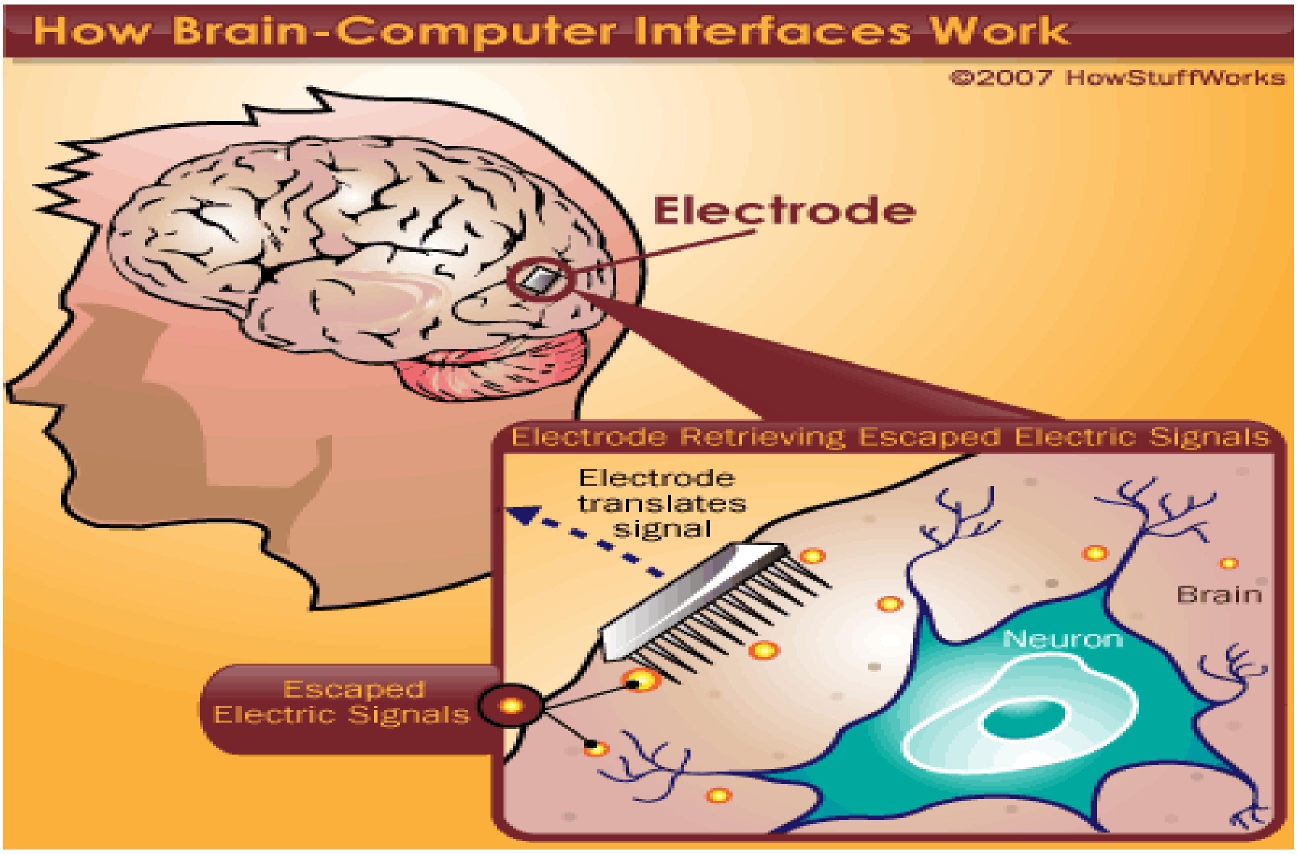
1.INTRODUCTION

Systems capable of understanding the different facets of human communication and interaction with computers are among trends in Human-Computer Interfaces (HCI). An HCI which is built on the guiding principle (GP): "think and make it happen without any physical effort" is called a brain-computer interface (BCI). Indeed, the "think" part of the GP involves the human brain, "make it happen" implies that an executor is needed (here the executor is a computer) and "without any physical effort" means that a direct interface between the human brain and the computer is required. To make the computer interpret what the brain intends to communicate necessitates monitoring of the brain activity.

2. TYPES OF BCIs

2.1. INVASIVE BCI

Invasive BCI research has targeted repairing damaged sight and providing new functionality to paralysed people. Invasive BCIs are implanted directly into the grey matter of the brain during neurosurgery. Using chips implanted against the brain that have hundreds of pins less than the width of a human hair protruding from them and penetrating the cerebral cortex, scientists are able to read the firings of hundreds of neurons in the brain. The language of the neural firings is then sent to a computer translator that uses special algorithms to decode the neural language into computer language. This is then sent to another computer that receives the translated information and tells the machine what to do. 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.

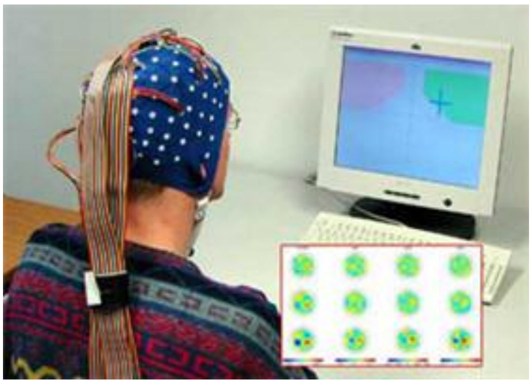


2.2. PARTIALLY-INVASIVE BCI

Partially invasive BCI devices are implanted inside the skull but rest outside the brain rather than within the grey matter. They produce better resolution signals than non-invasive BCIs where the bone tissue of the cranium deflects and deforms signals and have a lower risk of forming scar-tissue in the brain than fully-invasive BCIs.Electrocorticography (ECoG) measures the electrical activity of the brain taken from beneath the skull in a similar way to non-invasive electroencephalography, but the electrodes are embedded in a thin plastic pad that is placed above the cortex, beneath the dura materECoG is a very promising intermediate BCI modality because it has higher spatial resolution, better signal-to-noise ratio, wider frequency range, and lesser training requirements than scalp-recorded EEG, and at the same time has lower technical difficulty, lower clinical risk, and probably superior long-term stability than intracortical single-neuron recording. This feature profile and recent evidence of the high level of control with minimal training requirements shows potential for real world application for people with motor disabilities.

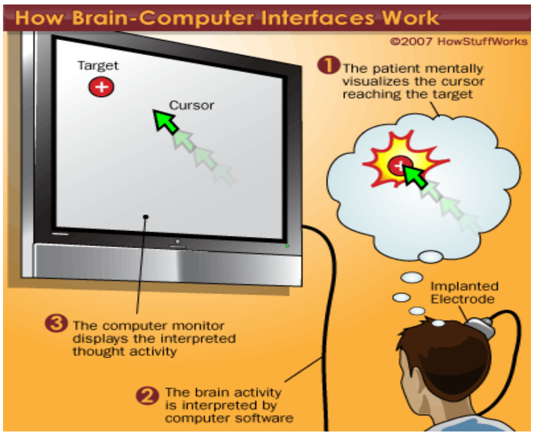
2.3. NON-INVASIVE BCI

The easiest and least invasive method is a set of electrodes,this device known as an **electroencephalograph** (EEG) -- attached to the scalp. The electrodes can read brain signals. Regardless of the location of the electrodes, the basic mechanism is the same: The electrodes measure minute differences in the voltage between neurons. The signal is then amplified and filtered. In current BCI systems, it is then interpreted by a computer program, which displayed the signals via pens that automatically wrote out the patterns on a continuous sheet of paper. Even though the skull blocks a lot of the electrical signal, and it distorts what does get through it is more accepted than the other types because of their respective disadvantages.

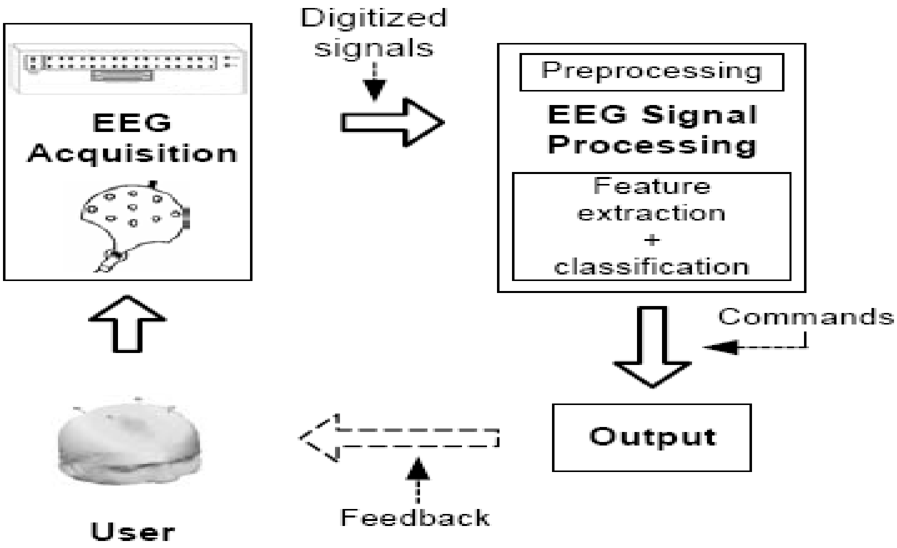


3. ELECTROENCEPHALOGRAM BASED BCI

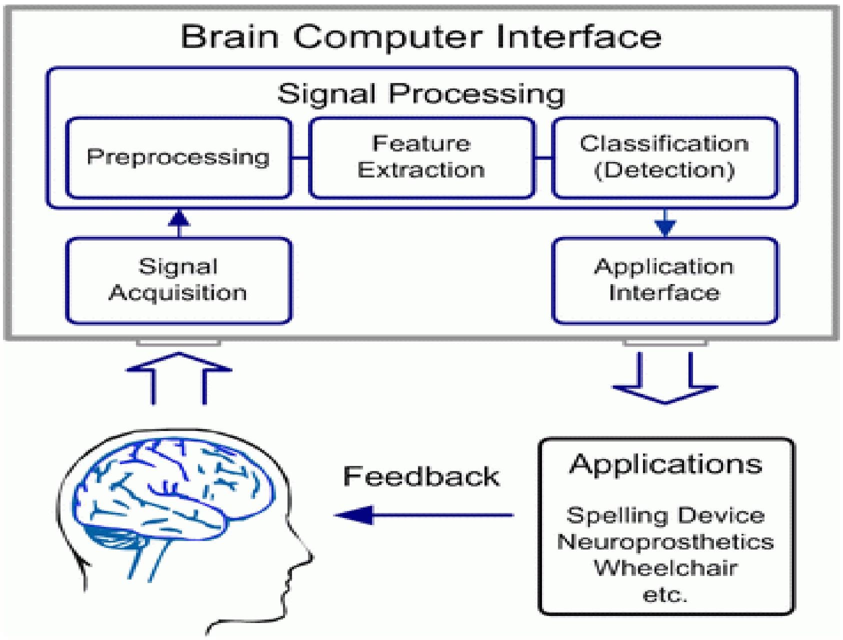
Electroencephalography (EEG) is the recording of electrical activity along the scalp produced by the firing of neurons within the brain.



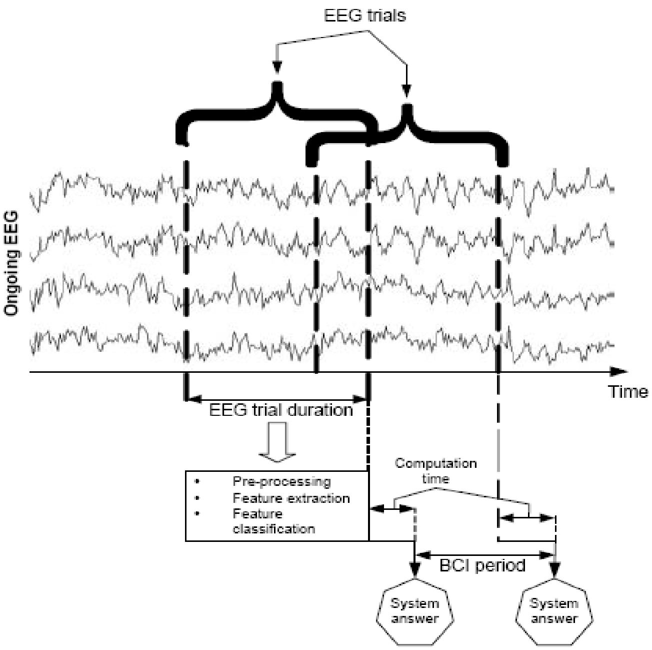
Among the possible choices the scalp recorded electroencephalogram (EEG) appears to be an adequate alternative because of its good time resolution and relative simplicity. Furthermore, there is clear evidence that observable changes in EEG result from performing given mental activities. The BCI system is subdivided into three subsystems, namely EEG acquisition, EEG signal processing and output generation.



General BCI architecture



The EEG acquisition subsystem is composed of an electrode array arranged according to the 10-20 international system and a digitization device. The acquired signals are often noisy and may contain artefacts due to muscular and ocular movements.The EEG signal processing subsystem is subdivided into a preprocessing unit, responsible for artefact detection, and a feature extraction and recognition unit that determines the command sent by the user to the BCI. This command is in turn sent to the output subsystem which generates a "system answer" that constitutes a feedback to the user who can modulate his mental activities so as to produce those EEG patterns that make the BCI accomplish his intents. Figure 5 illustrates the basic scheduling of our BCI. The BCI period is the average time between two consecutive answers and the EEG trial duration is the duration of EEG that the BCI needs to analyze in order to generate an answer. We assume that every EEG trial elicits a system answer.



BCI scheduling

We call “neutral state” when nothing happens (the BCI provides a neutral answer), the “active state” when the BCI executes something, the “neutral EEG set” as composed of those EEG trials that elicit the neutral answer and the “active EEG set” the complement of the neutral EEG set. The ideal BCI is a two-state machine whose state changes occur at a rate defined by the BCI period and are determined by a Boolean variable B1 (activation) which becomes true when the BCI detects an element of the active EEG set and false otherwise (Figure 6).

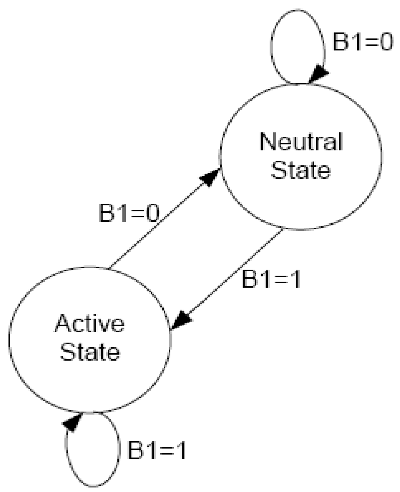


Figure 6: Ideal BCI

The ideal BCI behave properly when the recognition error rate is near zero.

In a real application, the false positive error (the system switches to the active state while the corresponding EEG trial belongs to the neutral EEG set) and the false negative error (the system switches to the neutral state while the corresponding EEG trial belongs to the active set) are not zero. Depending on the application, these errors are differently penalized.

We propose a less ideal BCI by introducing a transition state so that the BCI cannot switch from the neutral to the active state immediately. The BCI remains in the transition state as long as a second Boolean variable B2 (confirmation) is false (Figure 7).

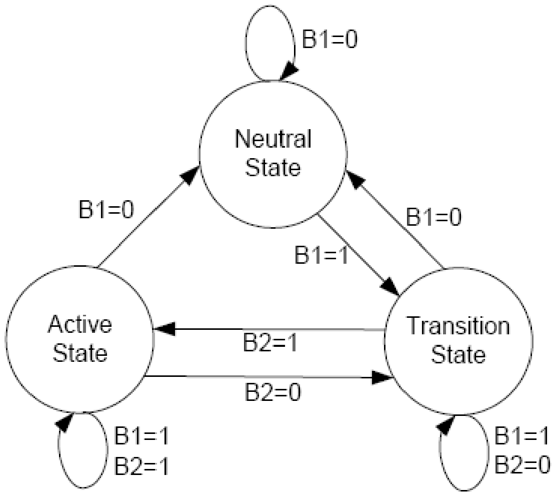


Figure 7: Less ideal BCI

B2 is true if the **L** (latency parameter) previous EEG trials are equally recognized as the current EEG trial. In practice, for the sake of user comfort the value of **L** multiplied by the BCI period should not exceed two seconds.

The BCI parameters are summarized in the following table:

BCI period
EEG trial duration
Latency
Signal processing parameters

Table 1

The optimal values for the BCI parameters are determined in the training phase. However, they should be continuously updated in order to take into account possible variations in the EEG caused by different brain's background activities over time. Thus, BCI operation requires constant training and adaptation from both, the user and the computer.

4.HOW BCI WORKS

Present BCI’s use EEG activity recorded at the scalp to control cursor movement, select letters or icons, or operate a neuroprosthesis. The central element in each BCI is a translation algorithm that converts electrophysiological input from the user into output that controls external devices. BCI operation depends on effective interaction between two adaptive controllers: the user who encodes his or her commands in the electrophysiological input provided to the BCI, and the computer which recognizes the command contained in the input and expresses them in the device control.

Current BCI’s have maximum information transfer rates of 5-25 bits/min.

The common structure of a Brain Computer Interface is the following :

1) Signal Acquisition:

the EEG signals are obtained from the brain through invasive or non-invasive methods (for example, electrodes). After, the signal is amplified and sampled.

2) Signal Pre-Processing:

once the signals are acquired, it is necessary to clean them.

3) Signal Classification:

once the signals are cleaned, they will be processed and classified to find out which kind of mental task the subject is performing.

4) Computer Interaction:

once the signals are classified, they will be used by an appropriate algorithm for the development of a certain application.

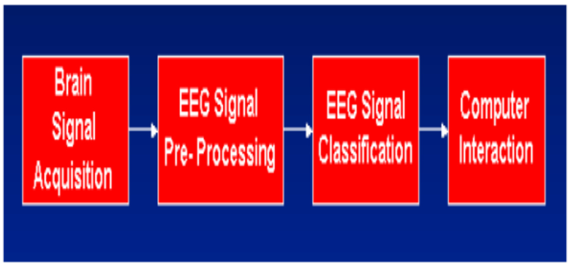


Figure 8:BCI common structure

In the case of a sensory input BCI, the function happens in reverse. A computer converts a signal, such as one from a video camera, into the voltages necessary to trigger neurons. The signals are sent to an implant in the proper area of the brain, and if everything works correctly, the neurons fire and the subject receives a visual image corresponding to what the camera sees.

Achievement of greater speed and accuracy depends on improvements in:

• **Signal acquisition:**

Methods for increasing signal-to-noise ratio (SNR), signal-tointerference ratio (S/I)) as well as optimally combining spatial and temporal information.

• **Single trial analysis:**

Overcoming noise and interference in order to avoid averaging and maximize bit rate.

• **Co-learning:**

Jointly optimizing combined man-machine system and taking advantage of feedback.

• **Experimental paradigms for interpretable readable signals:**

Mapping the task to the brain state of the user (or vice versa).

• **Understanding algorithms and models within the context of the neurobiology:**

Building predictive models having neurophysiologically meaningful parameters and incorporating physically and biologically meaningful priors.

5. LIMITATIONS

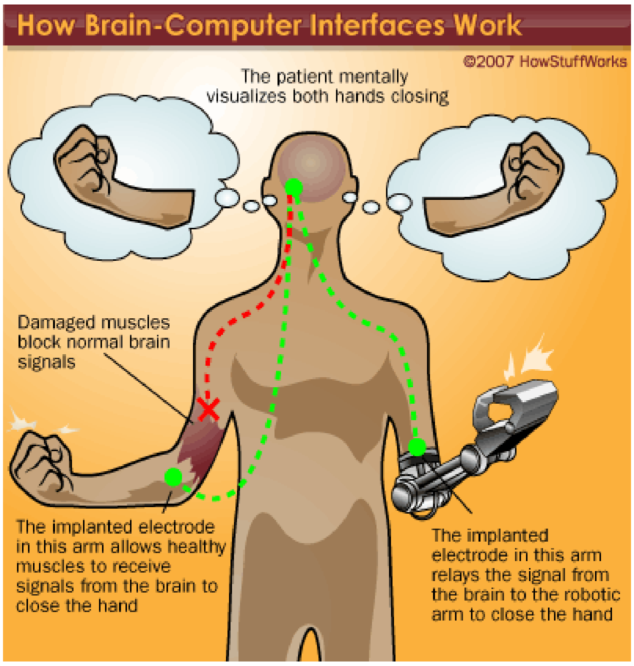
1. The brain is incredibly complex. To say that all thoughts or actions are the result of simple electric signals in the brain is a gross understatement. There are about 100 billion neurons in a human brain. Each neuron is constantly sending and receiving signals through a complex web of connections. There are chemical processes involved as well, which EEGs can't pick up on.
2. 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.

3. 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 BCIs 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. Like all technology, this will surely become lighter and more wireless in the future.

6. APPLICATIONS OF BCI

6.1. Bioengineering applications

Brain-computer interfaces have a great potential for allowing patients with severe neurological disabilities to return to interaction with society through communication and prosthetic devices that control the environment as well as the ability to move within that environment..



6.2. Human subject monitoring

Sleep disorders, neurological diseases, attention, monitoring, and/or overall "mental state".

6.3. Neuroscience research

Real-time methods for correlating observable behavior with recorded neural signals.

6.4. Man – Machine Interaction

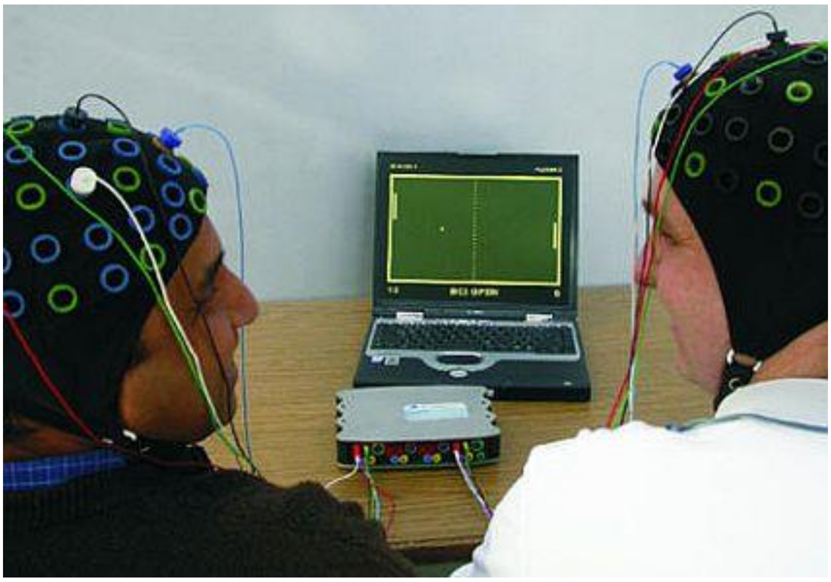
Interface devices between human and computers, Machines.

6.5. Military Applications

The United States military has begun to explore possible applications of BCIs beginning in 2008 to enhance troop performance as well as a possible development by adversaries.

6.6. Gaming

Computer game have gone hands-off because of development in BCI.



People playing ping-pong using BCI

6.7. Counter terrorism

A possible application is in Counter terrorism where a customs official can scan photos of many hundreds of faces.

7. PRESENT AND FUTURE

The practical use of BCI technology depends on an interdisciplinary cooperation between neuroscientists, engineers, computer programmers, psychologists, andrehabilitation specialists, in order to develop appropriate applications, to identify appropriate users groups, and to pay careful attention to the needs and desires of individual users. The prospects for controlling computers through neural signals are indeed difficult to judge because the field of research is still in its infancy. Much progress has
been made in taking advantage of the power of personal computers to perform the operations needed to recognize patterns in biological impulses, but the search for new and more useful signals still continues. If the advances of the 21st century match the strides of the past few decades, direct neural communication between humans and computers may ultimately mature and find widespread use. Perhaps newly purchased computers will one day arrive with biological signal sensors and thought-recognition software built in, just as keyboard and mouse are commonly found on today's units.

CONCLUSION

BCI being the considered the ultimate development in the world of HCI there is lot expections from it. Thus this field has been developed keeping in mind the extensive use of BCI in various applications mainly enabling the disabled survive independently. The boundaries of BCI applications are being extended rapidly and many experiments are being conducted in this concern.

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