**ABSTRACT**

A brain-computer interface (BCI), sometimes called a direct neural interface or a brain-machine interface, is a direct communication pathway between a human or animal brain and an external device. In one-way BCIs, computers either accept commands from the brain or send signals to it (for example, to restore vision) but not both. Two-way BCIs would allow brains and external devices to exchange information in both directions but have yet to be successfully implanted in animals or humans.

In this definition, the word brain means the brain or nervous system of an organic life form rather than the mind. Computer means any processing or computational device, from simple circuits to silicon chips. Research on BCIs began in the 1970s, but it wasn't until the mid-1990s that the first working experimental implants in humans appeared. Following years of animal experimentation, early working implants in humans now exist, designed to restore damaged hearing, sight and movement. With recent advances in technology and knowledge, pioneering researchers could now conceivably attempt to produce BCIs that augment human functions rather than simply restoring them, previously only a possibility in science fiction.

*Computer Interface*

**1. Introduction**

Man machine interface has been one of the growing fields of research and

development in recent years. Most of the effort has been dedicated to the design of user-

friendly or ergonomic systems by means of innovative interfaces such as voice recognition, virtual reality. A direct brain-computer interface would add a new dimension to man-machine interaction.

A brain-computer interface, sometimes called a direct neural interface or a brain machine interface, is a direct communication pathway between a human or animal brain(or brain cell culture) and an external device. In one BCIs, computers either accept commands from the brain or send signals to it but not both. Two way BCIs will allow brains and external devices to exchange information in both directions but have yet to be successfully implanted in animals or humans.

Brain-Computer interface is a staple of science fiction writing. In its earliest incarnations no mechanism was thought necessary, as the technology seemed so far fetched that no explanation was likely. As more became known about the brain however, the possibility has become more real and the science fiction more technically sophisticated. Recently, the cyberpunk movement has adopted the idea of 'jacking in', sliding 'biosoft' chips into slots implanted in the skull(Gibson, W.1984).Although such biosofts are still science fiction, there have been several recent steps toward interfacing the brain and computers.

In this definition, the word brain means the brain or nervous system of an organic life form rather than the mind. Computer means any processing or computational device, from simple circuits to silicon chips (including hypothetical future technologies like quantum computing).

Research on BCIs has been going on for more than 30 years but from the mid 1990’s there has been dramatic increase working experimental implants. The common thread throughout the research is the remarkable cortical-plasticity of thebrain, which often adapts to BCIs treating prostheses controlled by implants and natural limbs. With recent advances in technology and knowledge, pioneering researches could now conceivably attempt to produce BCIs that augment human functions rather than simply restoring them, previously only the realm of science fiction.



Fig. 1.1: Schematic diagram of a BCI system

**Chapter 2. Working architecture**

**2.1. Introduction:**

Before moving to real implications of BCI and its application let us first discuss the three types of BCI. These types are decided on the basis of the technique used for the interface. Each of these techniques has some advantages as well as some disadvantages. The three types of BCI are as follows with there features:

**2.2. Invasive BCI:**

Invasive BCI are directly implanted into the grey matter of the brain during neurosurgery. They produce the highest quality signals of BCI devices . Invasive BCIs has targeted repairing damaged sight and providing new functionality to paralyzed people. But these BCIs are prone to building up of scar-tissue which causes the signal to become weaker and even lost as body reacts to a foreign object in the brain.

fig.2.2.1: Jens Naumann, a man with acquired blindness, being interviewed about his vision BCI on CBS's The Early Show

In vision science, direct brain implants have been used to treat non-congenital i.e. acquired blindness. One of the first scientists to come up with a working brain interface to restore sight as private researcher, William Dobelle.

Dobelle’s first prototype was implanted into Jerry, a man blinded in adulthood, in1978. A single-array BCI containing 68 electrodes was implanted onto Jerry’s visual cortex and succeeded in producing phosphenes, the sensation of seeing light. The system included TV cameras mounted on glasses to send signals to the implant. Initially the implant allowed Jerry to see shades of grey in a limited field of vision and at a low frame-rate also requiring him to be hooked up to a two-ton mainframe. Shrinking electronics and faster computers made his artificial eye more portable and allowed him to perform simple tasks unassisted.

In 2002, Jens Naumann, also blinded in adulthood, became the first in a series of 16 paying patients to receive Dobelle’s second generation implant, marking one of the earliest commercial uses of BCIs. The second generation device used a more sophisticated implant enabling better mapping of phosphenes into coherent vision. Phosphenes are spread out across the visual field in what researchers call the starry-night effect. Immediately after his implant, Jens was able to use imperfectly restored vision to drive slowly around the parking area of the research institute.

BCIs focusing on motor Neuroprosthetics aim to either restore movement in paralyzed individuals or provide devices to assist them, such as interfaces with computers or robot arms.

Researchers at Emory University in Atlanta led by Philip Kennedy and Roy Bakay were first to install a brain implant in a human that produced signals of high enough quality to stimulate movement. Their patient, Johnny Ray, suffered from ‘locked-in syndrome’ after suffering a brain-stem stroke. Ray’s implant was installed in 1998 and he lived long enough to start working with the implant, eventually learning to control a computer cursor.

Tetraplegic Matt Nagle became the first person to control an artificial hand using a BCI in 2005 as part of the nine-month human trail of cyber kinetics Neurotechnology’s Braingate chip-implant. Implanted in Nagle’s right precentral

gyrus(area of the motor cortex for arm movement), the 96 electrode Braingate implant allowed Nagle to control a robotic arm by thinking about moving his hand as well as a computer cursor, lights and TV.

**2.3. Partially Invasive BCI:**

Partially invasive BCI devices are implanted inside the skull but rest outside the brain rather than amidst 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) uses the same technology as non-invasive electroencephalography, but the electrodes are embedded in a thin plastic pad that is placed above the cortex, beneath the dura mater. ECoG technologies were first traled in humans in 2004 by Eric Leuthardt and Daniel Moran from Washington University in St Louis. In a later trial, the researchers enabled a teenage boy to play Space Invaders using his ECoG implant. This research indicates that it is difficult to produce kinematic BCI devices with more than one dimension of control using ECoG.

Light Reactive Imaging BCI devices are still in the realm of theory. These would involve implanting laser inside the skull. The laser would be trained on a single neuron and the neuron’s reflectance measured by a separate sensor. When neuron fires, The laser light pattern and wavelengths it reflects would change slightly. This would allow researchers to monitor single neurons but require less contact with tissue and reduce the risk of scar-tissue build up.

**2.4. Non-Invasive BCI :**

As well as invasive experiments, there have also been experiments in humans using non-invasive neuroimaging technologies as interfaces. Signals recorded in this way have been used to power muscle implants and restore partial movement in an experimental volunteer. Although they are easy to wear, non-invasive implants produce poor signal resolution because the skull dampens signals, dispersing and blurring the electromagnetic waves created by the neurons. Although the waves can still be detected it is more difficult to determine the area of the brain that created them or the actions of individual neurons.



fig.2.4.1: Recordings of brainwaves produced by an electroencephalogram

*Electroencephalography*(EEG) is the most studied potential non-invasive interface, mainly due to its fine temporal resolutions, ease of use, portability and low set-up cost. But as well as the technology's susceptibility to noise, another substantial barrier to using EEG as a brain-computer interface is the extensive training required before users can work the technology. For example, in experiments beginning in the mid-1990s, Niels Birbaumer of the University of Tübingen in Germany used EEG recordings of *slow cortical potential* to give paralysed patients limited control over a computer cursor.(Birbaumer had earlier trained epileptics to prevent impending fits by controlling this low voltage wave.) The experiment saw ten patients trained to move a computer cursor by controlling their brainwaves. The process was slow, requiring more than an hour for patients to write 100 characters with the cursor, while training often took many months.

Another research parameter is the type of waves measured. Birbaumer's later research with Jonathan Wolpaw at New York State University has focused on developing technology that would allow users to choose the brain signals they found easiest to operate a BCI, including mu and beta waves.

A further parameter is the method of feedback used and this is shown in studies of P300 signals. Patterns of P300 waves are generated involuntarily (stimulus-feedback) when people see something they recognise and may allow BCIs to decode categories of thoughts without training patients first. By contrast, the biofeedback methods described above require learning to control brainwaves so the resulting brain activity can be detected. In 2000, for example, research by Jessica Bayliss at the University of Rochester showed that volunteers wearing virtual reality helmets could

control elements in a virtual world using their P300 EEG readings, including turning lights on and off and bringing a mock-up car to a stop.

In 1999, researchers at Case Western Reserve University led by Hunter Peckham, used 64-electrode EEG skullcap to return limited hand movements to quadriplegic Jim Jatich. As Jatich concentrated on simple but opposite concepts like up and down, his beta-rhythm EEG output was analysed using software to identify patterns in the noise. A basic pattern was identified and used to control a switch: Above average activity was set to on, below average off. As well as enabling Jatich to control a computer cursor the signals were also used to drive the nerve controllers embedded in his hands, restoring some movement.

Electronic neural-networks have been deployed which shift the learning phase from the user to the computer. Experiments by scientists at the Fraunhofer Society in 2004 using neural networks led to noticeable improvements within 30 minutes of training.

Experiments by Edurado Miranda aim to use EEG recordings of mental activity associated with music to allow the disabled to express themselves musically through an encephalophone.

*Magnetoencephalography* (MEG) and *functional magnetic resonance imaging* (fMRI) have both been used successfully as non-invasive BCIs. In a widely reported experiment, fMRI allowed two users being scanned to play Pong in real-time by altering their haemodynamic response or brain blood flow through biofeedback techniques. fMRI measurements of haemodynamic responses in real time have also been used to control robot arms with a seven second delay between thought and movement.

**2.5. Animal BCI research:**



fig.2.5.1: Rats implanted with BCIs in Theodore Berger's experiments

Several laboratories have managed to record signals from monkey and rat cerebral cortexes in order to operate BCIs to carry out movement. Monkeys have navigated computer cursors on screen and commanded robotic arms to perform simple tasks simply by thinking about the task and without any motor output. Other research on cats has decoded visual signals.

**2.5.2. Prominent research successes**

Phillip Kennedy and colleagues built the first intracortical brain-computer interface by implanting neurotrophic-cone electrodes into monkeys



fig.2.5.2: Garrett Stanley's recordings of cat vision using a BCI implanted in the lateral geniculate nucleus (top row: original image; bottom row: recording)

In 1999, researchers led by Garrett Stanley at Harvard University decoded neuronal firings to reproduce images seen by cats. The team used an array of electrodes embedded in the thalamus (which integrates all of the brain’s sensory input) of sharp-eyed cats. Researchers targeted 177 brain cells in the thalamus lateral geniculate nucleus area, which decodes signals from the retina. The cats were shown eight short movies, and their neuron firings were recorded. Using mathematical filters, the researchers decoded the signals to generate movies of what the cats saw and were able to reconstruct recognisable scenes and moving objects.

Miguel Nicolelis has been a prominent proponent of using multiple electrodes spread over a greater area of the brain to obtain neuronal signals to drive a BCI. Such neural ensembles are said to reduce the variability in output produced by single electrodes, which could make it difficult to operate a BCI.

After conducting initial studies in rats during the 1990s, Nicolelis and his colleagues developed BCIs that decoded brain activity in owl monkeys and used the devices to reproduce monkey movements in robotic arms. Monkeys have advanced reaching and grasping abilities and good hand manipulation skills, making them ideal test subjects for this kind of work.

By 2000, the group succeeded in building a BCI that reproduced owl monkey movements while the monkey operated a joystick or reached for food.The BCI operated in real time and could also control a separate robot remotely over Internet protocol. But the monkeys could not see the arm moving and did not receive any feedback, a so-called open-loop BCI.



fig.2.5.3: Diagram of the BCI developed by Miguel Nicolelis and collegues for use on Rhesus monkeys.

Later experiments by Nicolelis using rhesus monkeys, succeeded in closing the feedback loop and reproduced monkey reaching and grasping movements in a robot arm. With their deeply cleft and furrowed brains, rhesus monkeys are considered to be better models for human neurophysiology than owl monkeys. The monkeys were trained to reach and grasp objects on a computer screen by manipulating a joystick while corresponding movements by a robot arm were hidden. The monkeys were later shown the robot directly and learned to control it by viewing its movements. The BCI used velocity predictions to control reaching movements and simultaneously predicted hand gripping force.

Other labs that develop BCIs and algorithms that decode neuron signals include John Donoghue from Brown University, Andrew Schwartz from the University of Pittsburgh and Richard Andersen from Caltech. These researchers were able to produce working BCIs even though they recorded signals from far fewer neurons than Nicolelis (15–30 neurons versus 50–200 neurons).

Donoghue's group reported training rhesus monkeys to use a BCI to track visual targets on a computer screen with or without assistance of a joystick (closed-loop BCI).Schwartz's group created a BCI for three-dimensional tracking in virtual reality and also reproduced BCI control in a robotic arm. The group created headlines when they demonstrated that a monkey could feed itself pieces of zucchini using a robotic arm powered by the animal's own brain signals.

Andersen's group used recordings of premovement activity from the posterior parietal cortex in their BCI, including signals created when experimental animals anticipated receiving a reward.

In addition to predicting kinematic and kinetic parameters of limb movements, BCIs that predict electromyographic or electrical activity of muscles are being developed.Such BCIs could be used to restore mobility in paralysed limbs by electrically stimulating muscles.

**2.6.Cell-culture BCIs**

Researchers have also built devices to interface with neural cells and entire neural networks in cultures outside animals. As well as furthering research on animal implantable devices, experiments on cultured neural tissue have focused on building problem-solving networks, constructing basic computers and manipulating robotic devices. Research into techniques for stimulating and recording from individual neurons grown on semiconductor chips is sometimes referred to as neuroelectronics or neurochips.



fig.2.6.1: World first: Neurochip developed by Caltech researchers Jerome Pine and Michael Maher

Development of the first working neurochip was claimed by a Caltech team led by Jerome Pine and Michael Maher in 1997. The Caltech chip had room for 16 neurons.

In 2003, a team led by Theodore Berger at the University of Southern California started work on a neurochip designed to function as an artificial or prosthetic hippocampus. The neurochip was designed to function in rat brains and is intended as a prototype for the eventual development of higher-brain prosthesis. The hippocampus was chosen because it is thought to be the most ordered and structured part of the brain and is the most studied area. Its function is to encode experiences for storage as long-term memories elsewhere in the brain.

Thomas DeMarse at the University of Florida used a culture of 25,000 neurons taken from a rat's brain to fly a F-22 fighter jet aircraft simulator.After collection, the cortical neurons were cultured in a petri dish and rapidly begin to reconnect themselves to form a living neural network. The cells were arranged over a grid of 60 electrodes and trained to control the pitch and yaw functions of the simulator. The study's focus was on understanding how the human brain performs and learns computational tasks at a cellular level.

**Detecting lateral hemisphere differences:**

Drake [Drake 1993] studied induced lateral differences in relative brain hemisphere activation after subjects heard arguments through left, right or both earphones which they either strongly agreed with or strongly disagreed with, as determined by prior

interviews. Subjects exhibited greater discounting of arguments they disagreed with during left hemisphere activation as measured by ratings of truth. Results supported previous work indicating asymmetries in lateral activation potential during processing

pursuasive arguments, however the study did not include measuring directly either activation levels or potentials in the cortex.

**Brain Gate**



fig.4.1:Dummy unit illustrating the design of a BrainGate interface

**BrainGate** is a brain implant system developed by the bio-tech company Cyberkinetics in 2003 in conjunction with the Department of Neuroscience at Brown University. The device was designed to help those who have lost control of their limbs, or other bodily functions, such as patients with amyotrophic lateral sclerosis (ALS) or spinal cord injury. The computer chip, which is implanted into the brain, monitors brain activity in the patient and converts the intention of the user into computer commands.

Currently the chip uses 100 hair-thin electrodes that sense the electro-magnetic signature of neurons firing in specific areas of the brain, for example, the area that controls arm movement. The activity is translated into electrically charged signals and are then sent and decoded using a program, which can move either a robotic arm or a computer cursor. According to the Cyberkinetics' website, three patients have been implanted with the BrainGate system. The company has confirmed that one patient (Matt Nagle) has a spinal cord injury, whilst another has advanced ALS.

In addition to real-time analysis of neuron patterns to relay movement, the Braingate array is also capable of recording electrical data for later analysis. A potential use of this feature would be for a neurologist to study seizure patterns in a patient with epilepsy.

Cyberkinetics has a vision, CEO Tim Surgenor explained to Gizmag, but it is not promising "miracle cures", or that quadriplegic people will be able to walk again - yet. Their primary goal is to help restore many activities of daily living that are impossible for paralysed people and to provide a platform for the development of a wide range of other assistive devices.

"Today quadriplegic people are satisfied if they get a rudimentary connection to the outside world. What we're trying to give them is a connection that is as good and fast as using their hands. We're going to teach them to think about moving the cursor using the part of the brain that usually controls the arms to push keys and create, if you will, a mental device that can input information into a computer. That is the first application, a kind of prosthetic, if you will. Then it is possible to use the computer to control a robot arm or their own arm, but that would be down the road."

Existing technology stimulates muscle groups that can make an arm move. The problem Surgenor and his team faced was in creating an input or control signal. With the right control signal they found they could stimulate the right muscle groups to make arm movement.

"Another application would be for somebody to handle a tricycle or exercise machine to help patients who have a lot of trouble with their skeletal muscles. But walking, I have to say, would be very complex. There's a lot of issues with balance and that's not going to be an easy thing to do, but it is a goal."

Cyberkinetics hopes to refine the BrainGate in the next two years to develop a wireless device that is completely implantable and doesn't have a plug, making it safer and less visible. And once the basics of brain mapping are worked out there is potential for a wide variety of further applications, Surgenor explains.

"If you could detect or predict the onset of epilepsy, that would be a huge therapeutic application for people who have seizures, which leads to the idea of a 'pacemaker for the brain'. So eventually people may have this technology in their brains and if something starts to go wrong it will take a therapeutic action.

Surgenor also sees a time not too far off where normal humans are interfacing with BrainGate technology to enhance their relationship with the digital world - if they're willing to be implanted.

"If we can figure out how to make this device cheaper, there might be applications for people to control machines, write software or perform intensive actions. But that's a good distance away. Right now the only way to get that level of detail from these signals is to actually have surgery to place this on the surface of the brain. It's not possible to do this with a non-invasive approach. For example, you can have an EEG and if you concentrate really hard you can think about and move a cursor on a screen, but if someone makes a loud noise or you get interrupted, you lose that ability. What we're trying to make here is a direct connection. The [BrainGate] is going to be right there and you won't have to think about it."

APPLICATIONS

**5.2. The Mental Typewriter:**

March 14, 2006 Scientists demonstrated a brain-computer interface that translates brain signals into computer control signals this week at CeBIT in Berlin. The initial project demonstrates how a paralysed patient could communicate by using a mental typewriter alone – without touching the keyboard. In the case of serious accident or illness, a patient’s limbs can be paralyzed, severely restricting communication with the outside world. The interface is already showing how it can help these patients to write texts and thus communicate with their environment. There’s also a PONG game (computer tennis) used to demonstrate how the interface can be used. Brain Pong involves two BBCI users playing a game of teletennis in which the “rackets” are controlled by imagining movements and predictably the general media has focussed the majority of its attention on computer gaming applications but BCCI could equally be used in safety technologies (e.g. in automobiles for monitoring cognitive driver stress), in controlling prostheses, wheelchairs, instruments and even machinery.

On the first day of the 2006 CeBIT Computer Fair, Fraunhofer FIRST and the Berlin Charité demonstrated how the mental typewriter could be used for this purpose. On the other days of the CeBIT Fair, a simulated test setup using a shop-window dummy will be on display.

Cooperation between Fraunhofer FIRST and the Charité to develop an interface between the human brain and the computer began some years ago. The result was the Berlin Brain-Computer Interface (BBCI which uses the electrical activity of the brain in the form of an electroencephalogram (EEG). Electrodes attached to the scalp measure the brain’s electrical signals. These are then amplified and transmitted to the computer, which converts them into technical control signals. The principle behind the BBCI is that the activity of the brain already reflects the purely mental conception of a particular behaviour, e.g. the idea of moving a hand or foot.

The BBCI recognizes the corresponding changes in brain activity and uses them, say, to choose between two alternatives: one involves imagining that the left hand is moved, the other that the right hand is moved. This enables a cursor, for example, to be moved to the left or right. The person operating the mental typewriter uses the cursor to select a letters field. The next step reduces the choice, and after a few more steps we arrive at the individual letters, which can be used to write words. This process enables simple sentences to be constructed within minutes. A first prototype of the mental typewriter is currently available. In a series of experiments, different spelling methods are tested in terms of their usability and are adapted to the BBCI. It will be some years, though, before the mental typewriter can be used in everyday applications. Further research is needed, in particular to refine the EEG sensors.

**5.3. BCI offers paralyzed patients improved quality of life:**

Tuebingen, Germany. A brain–computer interface installed early enough in patients with neuron-destroying diseases can enable them to be taught to communicate through an electronic device and slow destruction of the nervous system.

Fundamental theories regarding consciousness, emotion and quality of life in sufferers of paralysis from Amyotrophic Lateral Sclerosis (ALS, also known as 'Lou Gerhig's

*Division of Computer Science and Engineering, SOE, CUSAT* 23*Brain Computer Interface* disease') are being challenged based on new research on brain-computer interaction. ALS is a progressive disease that destroys neurons affecting movement.

The study appears in the latest issue of *Psychophysiology*. The article reviews the usefulness of currently available brain-computer –interfaces (BCI), which use brain activity to communicate through external devices, such as computers.

The research focuses on a condition called the completely locked-in state (CLIS, a total lack of muscle control). In a CLIS situation, intentional thoughts and imagery can rarely be acted upon physically and, therefore, are rarely followed by a stimulus. The research suggests that as the disease progresses and the probability for an external event to function as a link between response and consequence becomes progressively smaller it may eventually vanish altogether.

Researchers have found that by implementing a brain-computer –interface before the completely locked-in state occurs, a patient can be taught to communicate through an electronic device with great regularity. The continued interaction between thought, response and consequence is believed to slow the destruction of the nervous system.

The findings are also raising a number of new questions about the quality of life amongst paralysis sufferers. Patients surveyed were found to be much healthier mentally than psychiatrically depressed patients without any life-threatening bodily disease. Only 9% of ALS patients showed long episodes of depression and most were during the period following diagnosis and a period of weeks after tracheotomy.

“Most instruments measuring depression and quality of life are invalid for paralyzed people living in protected environments because most of the questions do not apply to the life of a paralyzed person. Special instruments had to be developed,” says

Niels Birbaumer, PhD., Author of the study.

*Division of Computer Science and Engineering, SOE, CUSAT* 24*Brain Computer Interface*

This contrasts previously accepted notions as many doctors believe that the quality of life in total paralysis is extremely low and continuation of life is a burden for the patient. The study challenges the myth of helplessness, depression and poor quality of life in paralyzed persons that lead to hastened decisions on euthanasia.

## **6.2. Work of the software:**

The ABI is a BCI based on trials. A trial is a time interval where the user generates brainwaves to perform an action. The BCI tries to process this signal and to associate it to a given class. The association is done by feeding a neural net with the preprocessed EEG data. The neural net's output is then further processed and this final output corresponds to the given class. The neural net should be trained in order to learn the association.

The classifier's idea is heavily based on Christin Schäfer's design (winner of the BCI Competition II, Motor Imaginery Trials).

The ABI software allows you to

1. Do simple Biofeedback. You can display raw EEG channels, narrow band frequency amplitudes and classes.
2. Simulate trials.
3. Record trials for a number of choice of different classes.
4. Train the interface.

**6.3. The classification achieved by this software:**

The method has been previously applied to the data provided by the BCI Competition II data (dataset III, Graz University, Motor Imaginary) and compared against the results obtained by the contributors. The method has **outperformed** the results achieved by them, obtaining a higher Mutual Information (which was the criterion used in the competition) of 0.67 bits (the winner of the competition obtained 0.61 bits).

Of course, it is very important that more people test the software and report its results to improve the method. Statistical stability can only be guaranteed if more people try it out.

**6.4. Instructions:**

By executing ABI, it reads a configuration file called "abi.txt" (which you can edit with a simple text editor), where the way the BCI should act is specified. ABI tries to load the trial file defined in the configuration file. The trial file is a text database containing trials for different classes. Then, the main screen is displayed:

1. a) The EEG channels. The ModularEEG should be turned on. You can choose the amount of channels by setting the variable **NChannels** to desired value.
2. b) The extracted features. Each color strip indicates the intensity of a given frequency band. The variable **NFeatures** indicates the number of features you want to use. **Channels** indicates the source channels for the feature extraction. **Frequencies** tells ABI what frequencies should be used (in Hertz). Example: **NFeatures = 4**, **Channels = 0 0 1** 1, **Frequencies = 10 20 10 20**, tells ABI to

use 2 EEG channels, and to extract frequencies 10 Hz and 20 Hz from channel 0 and channel 1.

1. c) Class bar. The variable **NClasses** tells ABI how many classes it should be able to discriminate. Each class has an associated bar, and its size (and color) shows how good the given class has been recognized by the system.

ABI has three operating modes: **SIMULATION**, **RECORDING** and **TRAINING**. You can switch between operating modes by pressing **F1**, **F2** or **F3** respectively (the software doesn't change its mode instantly, because a trial shouldn't be interrupted in the middle).

The operation is quite simple. The user records several trials for the different classes (**RECORDING** mode). Each class is associated to a different mental task. After recording a reasonable amount of trials (more than 50 trials for each class), the user can train the system to learn a way to discriminate between the different classes (**TRAINING** mode). This process can be repeated in order to improve the quality of the recognition. The system can be tested under the **SIMULATION** mode.

An explanation of the different modes follows.

### 6.4.1.SIMULATION and RECORDING

These two modes perform single trials. The **SIMULATION** mode is used to test the BCI. **RECORDING** is the same as SIMULATION, with the difference that the EEG data is recorded and used as training examples. A trial has the following structure:

**6.4.7. Considerations**

First of all, be patient! The system tries, by using a trainable classification method, to adapt the BCI to the user, and in this way, to simplify the learning process required by the user. Nevertheless, as any other instrument, it requires a considerable amount of time to use the BCI in order to get nice results.

BCI technology is still in its infancy, so little is known about which mental tasks are better than others for BCIs. Also, the electrode placing is important. If your electrode setting isn't appropiate, then it can happen that they even aren't recording the cortical areas related to the mental task!

Research has discovered the following changes in electrical activity during mental tasks (this list isn't complete, I hope that the OpenEEG community will discover some more):

1. **Motor Imaginery:** Imagination of physical movement produces changes in the sensorymotor cortex. In example, imagination of left and right middle finger imagination produces changes, namely (de-)synchronization on electrode positions around C3 and C4. Good features are around 10 and 20 Hz.
2. **Rotation of 3D objects:** Literature stated that during imagination of rotation of 3d objects involves frontal and temporal lobe activity. They seem to sinchronize. Good features are around 10 Hz.
3. **Mental Letter Composition**.
4. Others (please report!)

Do not use too many features at the same time, 4-10 features are reasonable. If you want to change the used features, restart the BCI with the appropiate change in the configuration file.

**CONCLUSION**

Brain-Computer Interface (BCI) is a method of communication based on voluntary neural activity generated by the brain and independent of its normal output pathways of peripheral nerves and muscles.

The neural activity used in BCI can be recorded using invasive or noninvasive techniques.

We can say as detection techniques and experimental designs improve, the BCI will improve as well and would provide wealth alternatives for individuals to interact with their environment.

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