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Communication Technologies Based on Brain Activity

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Abstract- In this article we present a description of communication systems based on brain activity, specifically the brain computer interfaces, principles, applications and recent advances in this field. The brain computer interfaces are designed to provide a communication and control system to people who suffer a severe loss of motor function resulting from various accidents and / or diseases, so they can to control and to interact better with their environment, also currently there is the possibility that healthy people can use this interfaces. To implement a brain computer interface is necessary to acquire electroencephalogram signals of brain activity, to process and interpret them to take appropriate action.

Keywords: Brain computer interface, EEG, ICC, thought control, rehabilitation

I. INTRODUCTION

There are a significant number of people suffering from severe motor disabilities due to various causes, high cervical injuries, cerebral palsy, multiple sclerosis or muscular dystrophy. In these cases the communication systems based on brain activity play an important role and provide a new form of communication and control, either to increase the integration into the society or to provide to these people a tools for interaction with their environment without a continued assistance. There are various techniques and paradigms in the implementation of brain-computer interfaces (BCI). A brain-computer interface is a communication system for generating a control signal from brain signals such as EEG and evoked potentials. The Communication between the two essential parts of BCI (brain and computer), is governed by the fact that the brain generates the command and the computer must to interpret [1]. The amyotrophic lateral sclerosis (ALS) is a progressive neurodegenerative disease and is characterized by the death of motor neurons, which turns in a loss of control over voluntary muscles [2] [3] [6]. A stroke or other accident can lead to degeneration of parts of the brain, which makes people unable to communicate more with the environment, they have the same cognitive abilities, this is what is known as Syndrome "Locked-In" in France there is approximately 500 patients with this syndrome and about 8000 and 9000 patients with ALS, data published in [4] [7]. To measure and study the brain activity signals, there are different methods such as: magnetic resonance imaging (MRI), computed tomography (CT), the ECOG scale, single photon emission computed tomography (SPECT), CT positron emission tomography (PET), magnetoencephalography

(MEG), functional MRI (fMRI), but these signals are not practical to implement a human-machine interface, because some are only anatomical information, other techniques are very invasive, others are a lot of exposure to radiation and another are very expensive [5] [7]. To work with electroencephalographic (EEG) is the most convenient and therefore the BCI is based on detecting the EEG signals associated with certain mental states.

The aim of this paper is to provide an introduction and the background in the field of BCI research. In the first part of this paper we present a conceptual review of EEG signals and how to position the electrodes to be measured. In the second part we show a brain-computer interface own mind that the different models and their various applications. Finally we end with a specific application of BCI as the control of a wheelchair and the respective conclusions

II. THE ELECTROENCEPHALOGRAM (EEG)

The electroencephalogram (EEG) is a study of brain function that reflects the brain's electrical activity. To collect brain electrical signal using electrodes placed on the scalp, which is added a conductive paste to enable the brain electrical signal, which is of a scale of microvolts, can be recorded and analyzed.

EEG signals have different rhythms within the frequency band with the following characteristics: [1] [7].

Rhythm Alfa or Mu: It is characteristic of the state of consciousness and physical and mental rest with the eyes closed.

- Low voltage (20-60 μV /3-4mm) with variable morphology.
- High frequency (8-13 Hz).
- Zones of origin: later.
- Visual blockade before palpebral opening and stimuli (reactivity).
- No differentiable childhood after the 8 years, 10 hertz, established after 12 years.

Rhythm Beta: It is characteristic of the state of consciousness in states of cortical activation (replace of α).

- Low voltage (10-15 μV /1-1.5 mm) with variable morphology.
- High frequency (13-25 δ + Hz) to greater predominant frequency in anxious and unstable subjects.
- Zones of origin: central frontals.

Rhythm Theta: It is characteristic of the state of deep and normal sleep in the childhood (10 years), abnormal during the state of consciousness.

- Preponderant before 2 years (emotional situations).
- Appearance in specific physiological conditions (hyperventilation and deep sleep).
- High voltage (50 $\mu\text{v}/7\text{mm}$).
- Low frequency (4-8 Hz).
- Zones of origin: thalamic zones, parietotemporal region.

Rhythm Delta: It is characteristic of indicative pathological states of neuronal difficulty (comma) and occurs during deep sleep.

- High voltage (70–100 $\mu\text{v}/9\text{-}14\text{ mm}$) with variable morphology.
- Low frequency (4 - 6 Hz).
- Subcortical origin (not defined).

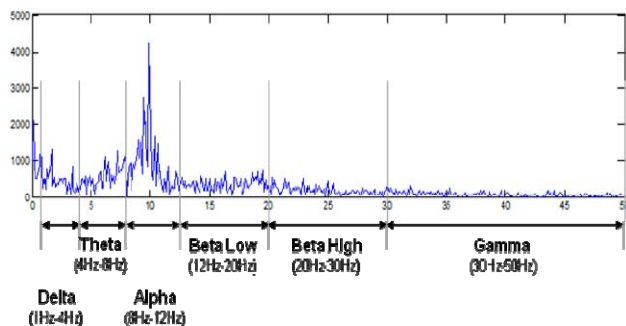
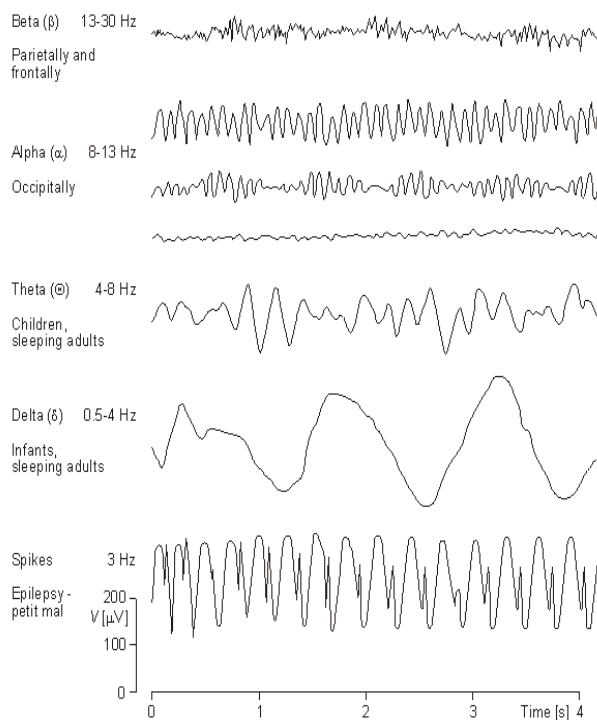


Fig. 2 EEG rhythms in time and frequency domain [6] [7]

In the EEG signals, can be observed what is called evoked potentials, these evoked potentials is a neurophysiologic examination that assesses the role of acoustic sensory

system, visual, and somatosensory pathways through evoked responses to a stimulus known and standardized. There are several types of event-related evoked potentials (ERP) and visual evoked potential (VEP) evoked potentials acoustic (PEA), motor evoked potentials (MRP), Steady State Visual Evoked Responses (SSVEP), etc. which are discussed in articles [2] [3] [4] [8] [9].

III. INTERNATIONAL SYSTEM OF POSITIONING ELECTRODES 10/20

Although, there are several different systems (Illinois, Montreal, Aird, Cohn, Lennox, Merlis, Oastaut, Schwab, Marshall, etc.), the 10/20 international system is the most widely used at present. To place the electrodes according to this system proceeds as follows:

The inactive or common electrode is placed remote of the skull (earlobe, nose, or chin). It is counted on data points such as: nasion and inion. Ten percent of the data points are the prefrontal and occipital planes. The rest is divided in four equal parts of 20% each.

Five cross-sectional planes exist:

- Prefrontal: Fpz
- Frontal: Fz
- Vertex: Cz
- Parietal: Pz
- Occipital: Oz

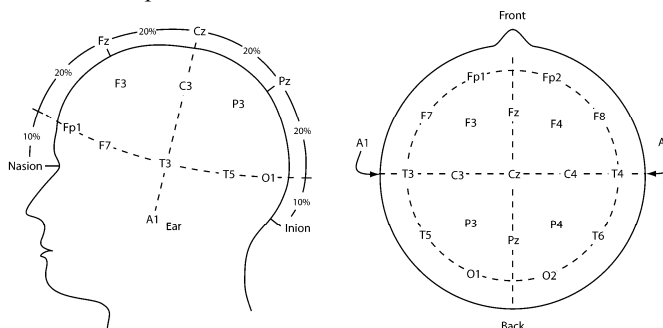


Fig. 2 Positioning of the Electrodes

The number of electrodes used and the position, depends on the particular signal that we want to analyze. The oscillation of the sensorimotor cortex, changes dynamically the execution of the movement of a member:

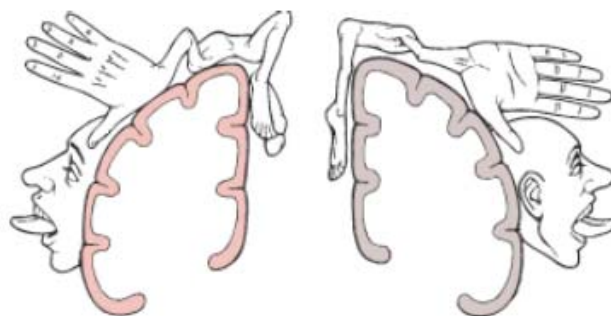


Fig. 3 Sensory and Motor Homunculus [10]

IV. THE BRAIN-COMPUTER INTERFACES

A brain-computer interface is a communication system that can generate control signals from brain signals, i.e. a BCI is a system that translates brain activity into commands for a computer or other device. A BCI allows users to interact with their environment using just brain activity, without using nerves and muscles.

A general block diagram for a brain-computer interface is shown below:

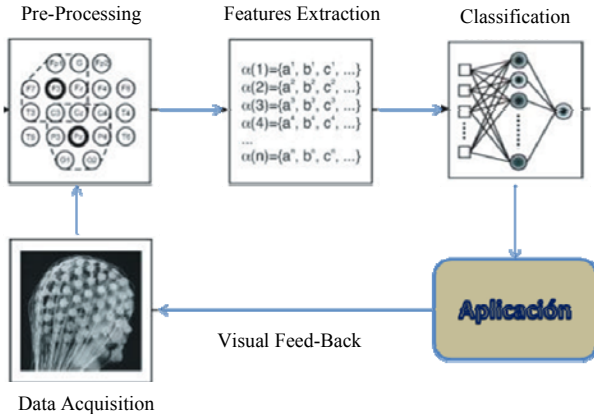


Fig. 4 General Block Diagram for a BCI

A. Data Acquisition

For data acquisition is used electrodes, signal amplifiers and analog filters, for example in [1] was used 8mm electrodes Ag/AgCl, the signal is amplified with an 8-channel EEG amplifier Procomp Infinity model. For the fixation of electrodes is necessary to use paste and/or conductive gel, is necessary to measure the impedance of the electrodes and to be sure that we have well established, since this impedance must be less than 5 K ohms [1].



Fig.5 Electrodes



Fig. 6 Gel and conductive grease



Fig. 7 Photographs with the fixed electrodes

B. Features Extraction

The feature extraction step is probably the most critical step in the EEG signal processing. The aim of this step is to create a manageable and meaningful representation of the original EEG signal, with a view to maximizing the potential success of the classification step and in turn the overall system performance. A second objective of the feature extraction step is to compress data without loss of relevant information in order to reduce the number of input variables in the qualifying round to make it operate in real time. For this step there are many feature extraction methods such as autoregressive parameters used in [1] [15], the average fast Fourier transform (FFT) used in [11], the average of the signal in time domain by windows used in [12], independent component analysis [13] [14] and others.

C. Classification

The classification is the final processing step. The entry to the classification algorithm is the set of features extracted in the previous step and the output is an indication of the user's mental state. As in the previous step, there are several methods to classify data, which are explained in each of the items listed in the references, especially in [16].

The following are some types of BCI:

A. Asynchronous Interfaces

This kind of interface analysis the user voluntary activity, this analysis retains at all times a communication link with the system, in this case the system continuously analyzes the signals from the user's brain activity and classify mental status periodically. In other cases, the interface can measure temporal variations in the rates associated with motor activity of the user, such amplitude variations can be detected and then transform them into commands, the analysis of motor activity requires lengthy training.

Spontaneous brain activity produces the following types of signals that are used in interfaces [4]:

- 1) Slow Cortical Potential Shifts (SCPS).
- 2) Oscillatory activity sensorimotriz.
- 3) Spontaneous EEG signals.

B. Synchronous Interfaces:

This type of interfaces analyzed EEG signals evoked potential stimuli received by the user from the system (can be visual, auditory or tactile), in this case is the

system that performs the task of communication, the user simply react or not to a series of stimuli. In this case do not work with spontaneous brain activity, if not rather with the brain's response to stimuli and then transform this response commands. For such interfaces requires a limited learning. The main types of signals that are used in these synchronous interfaces are [4]:

- 1) Steady State Visual Evoked Responses (SSVERs).
- 2) Event Related Potentials (ERPs).

C. Invasive or Noninvasive Interfaces

The signals of brain activity that can be measured can be signs at the scalp as the electroencephalogram (EEG) can be at the level of the cerebral cortex as the electrocorticogram (ECoG) or the need for implanting electrodes into the brain. Then we distinguish the invasive methods such as those that require the installation of electrodes inside the skull. Noninvasive methods are those that can measure signals only from the surface of the scalp [4] [17].

In the invasive methods, when an electrode is connected directly to a neuron, it measures its post-synaptic electrical activity and / or the potential cast for its axon [4].

The most used non-invasive technique is to work with the EEG signals collected from electrodes placed on the scalp.



Fig. 8 Invasive Method for Measuring Brain Activity [18]

D. BCI P300 Speller:

This kind of BCI was originally proposed by Farwell and Donchin [19] and is also studied in [4] and [20], is a non-invasive communication interface based on event-related evoked potentials ERPs P300 type. This interface allows the user to write a text on the computer, is a 6x6 matrix that is displayed on the screen and is made up of 26 letters of the alphabet, nine numbers and a symbol that enables the cancellation of the previous selection.

The P300 speller is based on a paradigm which consists of presenting stimuli in the form of lighting in each row or column. The user's task is to take attention to the character to select and count the times that is affected by lighting. The illuminations are done in a random and repeated several times for each character.



Fig. 9 P300 Speller Matrix

The applications of brain-computer interfaces can be different, starting with the movement control of a course on a screen [1], multimedia applications such as video games, applications in robotics and process control, and aerospace applications to help astronauts handling robots as explained in [21], control of a wheelchair which will be discussed in the next section, etc.

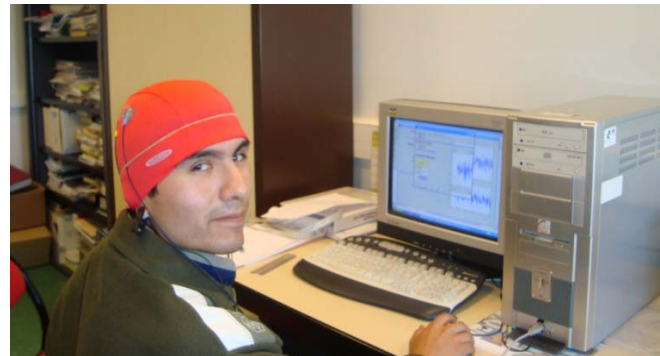


Fig. 10 To Control a Cursor on a Computer Screen [1]

V. CONTROL DE UNA SILLA DE RUEDAS CON BCI

Currently there are several research teams working to develop and improve the control system of a wheelchair based on measurements of the EEG signals of brain activity in patients with severe loss of motor activity. In this area, one of the first to submit a rough prototype wheelchair controlled by EEG signals was by Tanaka in [24] and is also studied in [4]. Tanaka used a noninvasive BCI asynchronous analyzing EEG signals between 0.5 and 30 Hz, in the training phase of the system the user must imagine the movement left and right for 20 seconds for each move, the acquisition is made at 1024 Hz and based on these signals the system learns to discriminate between both types of movement.

One of the latest studies in relation to control a wheelchair with EEG signals was introduced by Toyota in June 2009 [22]. This system has the capacity to analyze the EEG wave signal every 125 milliseconds and decide whether to turn left, turn right or forward. The analyzed waves are shown in real time on the computer screen to give visual feedback. This system uses a cheek movement to slow or stop the

wheelchair; this movement can be made by an accumulation of air in that area.



Fig. 11 Toyota Wheelchair Controlled by BCI [22]

Another work with wheelchair control based on EEG is done by the project OpenViBE [18] and [23] presented in 2009. OpenViBE is a free platform to develop BCI applications, within these different applications was a control of a wheelchair, for which uses electrodes at positions C3 and C4 of the international position of electrodes 10/20 to capture the signals of intention to move left or right hand and thus represent the rotation the wheelchair to the right or left respectively, for EEG signals representing the movement of feet, an electrode is placed in the front and thus represents the advancement of the wheelchair. In a first moment is perceived to be very difficult to handle the wheelchair with these premises, so in a second experiment using the signal from the feet to select from several target destinations, so once you select your destination, as Wheelchair uses other algorithms to get to your chosen destination and progress.

CONCLUSIONES

In this article we have tried to present the work done by different research groups studying brain-computer interface or BCI, each of these teams with different techniques, methods, approaches, but all of them aiming to develop a tool that can help people who suffer a severe loss of motor skills to be able to better interact with their environment, but not limited to those disabled people, today are also involved people who are healthy and can use this types of interfaces to perform complicated tasks or in complicated environments.

Through this article we provide the basis and foundation for developing a brain-computer interface, showing the different steps to implement a BCI, the different stages of processing and analyzing the different techniques currently used.

The most important aspects to be taken into account in order to have good results: A good fixation of the

electrodes on the scalp, which required a measure of the impedance of the electrodes on the scalp, which should be less than 5 K ohms. It is always necessary prior training stage. However there are investigations that seek to perform discrimination tasks without training, but the results are not encouraging. Each person has a different way of managing their brain activity [1].

The results so far are very encouraging, in some cases reaching rates of 93% effective, but even more must be done about it because it is necessary to increase the number of free degrees, a better definition of states, speed in the interpretation, to be able to have more complex applications

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