International Journal of Bio-Science and Bio-Technology
Vol.7, No.4 (2015), pp.223-228
http://dx.doi.org/10.14257/ijbsbt.2015.7.4.21

Neuroimaging Techniques for Brain Computer Interface

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Abstract

Brain-computer interface (BCI) is combination of hardware and software systems that allows the severely or partially disabled persons to communicate with their surroundings. The study of brain activities precisely is an important step in BCI system. Many invasive and non-invasive neuro-imaging techniques are being conducted. In this paper, a comparative analysis of these different approaches has been reviewed such as electro-encephalography (EEG), electro-corticograph (ECoG), magneto-encephalograph (MEG), intra-cortical neuron recording (INR), and magnetic resonance imaging (MRI).

Keywords: *BCI, EEG, MEG, ECoG MRI, NIRS, INR.*

1. Introduction

Brain-computer interface (BCI) is an emerging technology which has astounded the world with its results. It is a system which interrelate the neuron signals and transfer it to the interconnected machine. For disabled or partially paralyzed persons, it is very difficult to communicate with their surroundings or even express their feelings. BCI system aims to improve their quality of living. It is a combination of hardware and software that helps people which may be the victim of a neurological or a neuromuscular disorder. This system uses control signals acquired by EEG and controls the interconnected machine with the help of them.

BCI is a synthetic intellectual system that can identify a certain set of patterns in neuron signals. The description of complete process of BCI system is as follows: Firstly, data is acquired from brain i.e. neuron signals are captured via different techniques and pre-processing of the same is done, i.e. if there is any noise present in the signal captured then it is removed and pure signal is fed further for feature extraction. Feature extraction maps those signals in two sets, one is effective feature set and the other is discriminant features set, in such a way that the vector is of low dimension. This is so because these vectors are used in classification in which these are classified and then decodes the persons' intentions to be expressed. Finally, the signals are fed to the control machines or connected devices.

BCI technology has been considered as a complex system due to the reason that the signals obtained from brain or neurons may or may not be correct or these may vary. Moreover, BCI system requires real-time signal processing but such a technology has not been in terms lately and if it was there it was overpriced.

Recently, there has been a great advancement in research and development and this has gone under a lot of changes in last few decades.

As this is a new field and also it is an integrative field which might include researchers from medical, engineering and their fields. Researchers are workings really hard to make advances in this field but the lack in that due to the fact they don't have a common language to communicate so the systems they design could be more advanced and helpful, i.e. they need a general framework for the system design.

BCI systems use the neuron signals to know about the intentions of the person and for that HCI system records brain signals and render those in a predictable form. Neuroimaging is a method to monitor brain activity, which could be done either with an electrophysiological method or by a hemodynamic method.

The electrochemical transmitter's exchanges information results in activities known as electrophysiological activities. It is a branch of science and physiology that studies the flow of ions in tissues and also studies the electrical recording techniques that measure this flow of ions. These activities are measured by electro-encephalography (EEG), electro-corticography (ECoG), magneto-encephalography (MEG), and electrical signal acquisition in single neurons.

To perform physical activities body adjusts the blood flow to provide those stressed tissues glucose and oxygen for proper functioning. This activity is known as a hemodynamic activity. This glucose and oxygen delivered results in a surplus of oxy-hemoglobin in the veins of the active area changing the ratio of oxy-hemoglobin to de-oxy-hemoglobin in that area. Such changes can be monitored with the neuro-imaging techniques such as functional magnetic resonance and neuro-infrared spectroscopy.

The following sections of this paper reviews about the different neuro-imaging technologies being used by researchers in BCI systems. These are either invasive or noninvasive techniques which include EEG, ECoG, MRI, INR, MEG.

1.1 Electro-Encephalo Graph (EEG)

EEG is non-invasive technique which acquires the brain signals. It captures very weak signals produced by neuron activities with the help of electrodes. These electrodes are placed on the scalp to record the activities caused due to the flow of electric current during synaptic excitations in neurons. Although these recorded signals are of poor quality, as these have to pass through different layers: skull, scalp, etc., but these could be retrieved with the help of filters. BCI system mostly uses this technology as it is a non-invasive, low-cost setup and even portable.

EEG system consists of electrodes, which are to be placed on scalp, amplifiers, analog-to-digital converter and a recorder to record these signals acquired. Electrodes fed the captured signals, from the scalp, to amplifiers so that these weak are amplified for further usage. Then, A/D converter digitizes these signals and finally the recorder, such as personal computer, storage devices or display devices, saves it for future use.

EEG measure the potential difference between the active and reference electrodes and a ground electrode is used to measure differential voltage between these two electrodes. Silver chloride (AgCl) is used to make these electrodes. A number of electrodes may vary from 128 to 256 electrodes as per channel configuration. EEG includes different frequency signals which are classified as: delta (below 4Hz), theta (4 to <8 Hz), alpha (8 to 12Hz), beta (12 to 30 Hz), gamma (30 to 100Hz). Table I shows their brief description.

Gamma activity interprets both visual and auditory stimuli, but these are not used due to artifacts. In spite of artifacts these activities increases information transfer rate.

Electrodes are placed over the scalp, to record EEG, based on International 10-20 system [1]. This system uses two reference points, one at nasion (above the nose) and other at inion (bony lump at the base of the skull).

1.2 Magneto-Encephalo Graph (MEG)

Table 1. Brief Description of Brain Signals

Signal	Brain Location	Description
Delta (δ)	Frontal(adults) Posterior(children)	Sleep time, frequent in babies. Active in attention tasks.
Theta (θ)	Different locations	Mostly found in young children Active in drowsiness or arousal in older children and adults

		Idle state Found to be spike when a person in attempting to repress action or response
Alpha (α)	1.Posterior, both sides 2.Higher in amplitude on dominant side 3.Central sites at rest	Relax or Reflecting state Closing of eyes.
Beta (β)	Both on left & right side of brain Symmetrical distribution activity Most evident frontally	Alert or focused, active, busy state
Gamma (γ)	Both left & right sides of brain, midline to front and back	Sensory processing Short term memory activities

MEG records the neuron signals (brain signals) with the help of magnetic field so produced by electrical activities due to the flow of blood. It gives steep temporal and spatial resolution. Unlike EEG which is sensitive to secondary currents, MEG is very sensitive to primary current [1]. It also localizes the active regions in the brain.

In MEG, the magnetic field is detected by SQUID, i.e. superconducting quantum interference devices. These devices are highly sensitive to magnetic flow due to neuron activity. Also, MEG must be kept to very low temperature, near about -273 degrees, to facilitate sensor superconductivity. The equipment also requires shielding from interferences so it must be installed at such a place where magnetic shielding has been done. The magnetic shielding room consists of three layers: aluminium layer, ferromagnetic layer (highly permeable), molybdenum permalloy layer.

This technique is not mostly used due to its cost. MEG is highly expensive as well as there is need of a separate place which must be shielded beforehand so that magnetic interference could be avoided. Also, the size of MEG machine is quite large which makes it more difficult for the researchers to work with it.

Although this technology provides the clear or higher resolution signals but it is not being used as much due to its size, cost and also due to the factor that it must be isolated to avoid the magnetic field interferences.

The researchers must come up with such a method which makes it easier to use, i.e. there is no effect of magnetic field interferences on the signals induced by the neurons when captured with this machine.

2. Electro-Cortico Graph (ECoG)

ECoG is an invasive technique to capture neuron (brain) signals. In this technology, the electrodes are directly placed to the exposed area of brain which is either exposed due to the operation or a small surgical incision is required to implant the ECoG grid into the skull. The signals are acquired by placing the electrodes underneath the skull i.e. either on epidural or on subdural mater [2].

ECoG has higher signal-to-noise ratio as compared to other neuroimaging technologies. The spatial resolution is also much higher in this. The vulnerability to artifacts is also less in ECoG.

Because ECoG generally follows a drop-off in signal power [3], task-related brain signals may remain larger than the noise floor of the amplifier/digitizer, and thus be detectable, at higher frequencies than for EEG. The signals at higher frequencies carry critical information of cognitive, language tasks as well as motor information which are mainly required in BCI systems. It also provides long-term functional stability.

ECoG involves specific frequency bands and locations which are selected by taking in account features that show the difference between action state or imagery state and the rest state.

In spite of its better results, this technique has its limitations. The most important limitation is that this technique is completely dependent on the variability and constraints implied by the subject which are mostly the patients under study for their seizure localization or any cortical functions before the surgical treatment i.e. for their epilepsy.

Secondly, the environmental noise is very high, as these recordings are generally performed in hospitals, and these are very hard to reduce. Also, the spatial resolution of single neuron readings is low. ECoG is an invasive method so there is also a high risk in the procedure for implanting the grid.

3. Intra-cortical Neuron Recordings

The intra-cortical neuro-imaging technique is an invasive technique in which there is a need to embed microelectrodes array inside the cortex (the gray matter). It is used to record spikes and local field potentials. This mainly records three signals: single unit activity (SUA), multi-unit activities (MUA) and local field potentials (LFPs). SUA and MUA measure the spiking activity of the neuron. The signals from neurons are referred as multi-unit or single unit activities. The only difference between SUA and MUA is that SUA is obtained with high pass filtering as it comes from single neuron, but MUA is recorded from multiple neurons. LPFs are analog signals that are obtained by low pass filtering.

There are few major issues that must be resolved prior to clinical use include their long-term safety, the stability of their signals and their capabilities in actual practical applications significantly beat those of less invasive techniques [4].

4. Magnetic Resonance Imaging (MRIs)

MRI is a non-invasive, manipulative technique in which the subject is trained to change the commotion in a specified region of the brain to observe the changes. It measures the blood oxygen level-dependent (BOLD) signal related to neuron activity with high spatial resolution [5].

With MRI, a participant does not have to be trained to regulate brain activities. The spatial resolution of this technique is much higher than other techniques and even the temporal resolution is high.

MRI allows brain activities in very specific parts of cortical and sub-cortical regions of the brain to be extracted [6]. The changes in blood oxygenation result in changes in the inhomogeneity of magnetic field and it is measured with MRI technique. The increase in the concentration of deoxyhemoglobin increases image intensity.

The major disadvantages of this technique are that the set-up cost is much higher as compared to other setups. Even the complexity of the development and usage of the system is also one of its limitations.

5. Overview of Neuroimaging Techniques

This section shows the overview of the different neuroimaging techniques. Table II reviews about the different techniques, their measuring methods, and other factors to distinguish these techniques.

Table 2. Overview of Neuroimaging Techniques

Technique / Comparision	**EEG**	**MEG**	**ECoG**	**INR**	**MRI**
Acitvity measured	Electophysiology Activity	Electophysiology Activity	Electophysiology Activity	Electophysiology Activity	Hemodynamic Response
Nature of measured Acticity	Electical	Magnetic	Electical	Electrical	Metabolic
Compatability	Non-invasive	Non-invasive	Non-invasive	Invasive	Invasive
Temporal Resolution	~0.05s	~0.05s	~0.003s	~0.003s	~1s
Portability	Portable	Non-portable	Portable	Portable	Non-portable
Accuracy	Modest	Modest	High	High	high
Cost	Moderate	Expensive	Expensive	Expensive	Expensive

6. Conclusion

This paper reviews the different approaches that are being used by the researcher for neuroimaging for data acquisition such as EEG, ECoG, MEG, MRI, INR, NIRS. It is concluded that EEG is the better technique. This technique is a non-invasive technique with lower cost set-up. Although it gives distorted and weak signals but signals could easily be recovered with the help of amplifiers and filters. Due to advantages of EEG neuroimaging technique over other neuroimaging techniques, EEG is also being used in many surgical applications such as in detection of tumors, detection and analysis of epileptic seizures, etc.

References

[1]. L. F. Nicolas-Alonso and J. Gomez-Gil, Sensors, **(2012)**.
[2]. G. Schalk and E. C. Leuthardt, IEEE Reviews in Biomedical Engineering, **(2011)**.
[3]. K. Miller, L. Sorensen, J. Ojemann and M. D. Nijs, PLoS Computational Biology, **(2009)**.
[4]. J. R. Wolpaw and N. Birbaumer, Electroenceph. Clin. Neurophysiol, **(2002)**.
[5]. N. Weiskopf, K. Mathiak, S. W. Bock and F. Scharnowski, IEEE Transactions on Biomedical Engineering, **(2006)**.
[6]. R. Sitaram, A. Caria, R. Veit, T. Gaber, G. Rota, A. Kuebler and N. Birbaumer, "Review on fMRI Brain-Computer Interface: A Tool for Neuroscientific Research and Treatment", Hindawi Publishing Corporation Computational Intelligence and Neuroscience, Article ID 25487, doi:10.1155/2007/25487, **(2007)**.