FUNDAMENTAL STUDY ON BRAIN SIGNAL FOR BCI-FES SYSTEM DEVELOPMENT

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Abstract- Electroencephalographic measurements are commonly used in medical and research areas. This article presents an introduction into Electroencephalography (EEG) measurement and the simple experiment of EEG. Its purpose is to develop orientation in EEG field and with building basic knowledge for performing EEG recordings. The normal person used as subject was used in this experiment. It is conducted in three condition; relax, hand grasp and lastly grasp and release. At the end of the experiment, there are some changes of the brain signal due to the activity that subject has been done. It shows that the brain will generate the different signal relate to the activity or the way of thinking of the subject. This study will be used as a fundamental concept for Brain Computer Interface (BCI)- Functional Electrical Stimulation (FES) system development.

I. Introduction

Since more than 100 years of its history, encephalography has undergone massive progress. An English physician Richard Caton has discovered about the existence of electrical currents in the brain in 1875. Caton observed the EEG from the exposed brains of rabbits and monkeys [1]. In 1924, a German neurologist, Hans Berger has used ordinary radio equipment to amplify the brain's electrical activity measured on the human scalp [2]. Berger has announced that weak electric currents generated in the brain can be recorded without opening the skull, and depicted graphically on a strip of paper. The activity that was observed changed according to the functional status of the brain, such as sleep, anaesthesia, lack of oxygen and certain neural diseases like epilepsy. The word electroencephalogram is also used by Berger as the first for describing brain electric potentials in humans. His suggestion that brain activity changes in a consistent and recognizable way when the general status of the subject changes, as from relaxation to alertness was right [3]. Later in 1934 Adrian and Matthews published the paper verifying concept of "human brain waves" and identified regular oscillations around 10 to 12 Hz which they termed "alpha rhythm".

Usually, Brain patterns form wave shapes are sinusoidal. They are measured from cycle (peak to peak) and normally range from 0.5 to 100 μV in amplitude, which is about 100 times lower than EEG signals. Brain waves have been categorized into four basic groups. The groups are:

i. beta (>13 Hz),
ii. alpha (8-13 Hz),
iii. theta (4-8 Hz),
iv. delta (0.5-4 Hz).

Figure 1 shows the brain sample such as beta, alpha, theta and delta band.

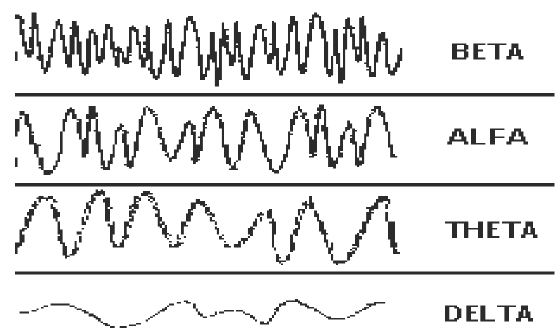

Figure 1: Brain wave samples beta, alpha, theta, and delta band.

The normal alpha rhythm is the best-known and most extensively studied rhythm of the human brain because alpha wave can be usually observed better in the posterior and occipital regions with typical amplitude about 50 μV (peak-peak). Alpha activity is induced by closing the eyes and by relaxation, and abolished by eye opening or alerting by any mechanism (i.e: thinking or calculating). Also alpha was significant between posterior and central regions in comparison to other regions. The simple example is the phenomenon of "eye closing". (i.e. when closing eyes human wave pattern significantly changes from beta into alpha waves). The precise origin of the alpha rhythm is still unknown. Evoked potentials (i.e. generated in brain stem) often consist of fibre potentials (axonal) and synaptic components [4].

Recently, an increasing interest has been observed in applying high density array EEG systems with more than one hundreds channels to analyze patterns and imaging of the human brain, where EEG have desirable property of excellent time resolution [5]. Electroencephalography is a medical imaging technique that reads the scalp electrical activity generated by brain structures. It also one of the part from the group of electrobiological measurements comprises items as electrocardiography (ECG for heart), electromyography (EMG for muscular contractions), electroencephalography (EEG, for brain), magnetoencephalography (MEG for brain), electrogastrography (EGG, stomach), electrooptigraphy (EOG for eye dipole field). Imaging techniques based on different physical principles include computer tomography (CT), magnetic resonance imaging (MRI), functional MRI (fMRI), positron emission tomography (PET), and single photon emission computed tomography (SPECT) [6]. This is call modern medical checkup for certain applications. In Brain Computer Interface (BCI) technology, the electroencephalogram (EEG) is defined as electrical activity of an alternating type recorded from the scalp surface after being picked up by metal electrodes and conductive media. The EEG measured directly from the cortical surface is called electrocortiogram while when using depth probes it is called electrogram.

EEG features are classified into 2 classes. One is exogenous EEG like Visual Evoked Potential (VEP) and P300 which need external trigger signal. The other one is endogenous EEG like Event Related Desynchronization (ERD) and Bereitschaftspotential (BP) [7]. In EEG method like ERD is always used as a control signal which can be extracted before and during motor imagery/execution around motor area [8], [9]. It is because it has a voluntary aspect which can reflect subject's intention. In order to move some part of human, human intention is needed such as to move hand or leg.

EEG measures electric brain activity caused by the flow of electric currents during synaptic excitations of the dendrites in the neurons and is extremely sensitive to the effects of secondary currents [10]. When brain cells (neurons) are activated, local current flows are produced. The amplitude of electrical bio-signals is the order of microvolts. Consequently, the signal is very sensitive to electronic noise. External sources such power-lines may generate background noise and thermal, shot, flicker, and burst noises are generated by internal sources [11]. Design considerations should be addressed to reduce the effects of the noise, such as electromagnetic interference shielding or reduction for common mode signal, amongst others [12].

EEG measures mostly the currents that flow during synaptic excitations of the dendrites of many pyramidal neurons in the cerebral cortex. So, in this study, only focused to EEG measured from the head surface. Thus electroencephalographic reading is a completely non-invasive procedure that can be applied repeatedly to patients and normal adults with low risk or limitation.

II. Method

Encephalographic measurements employ recording system consisting of electrodes with conductive media and recording device, (PC).

The raw signal has been taken at Electronic medical Lab Faculty of Electrical, University Tun Hussein Onn Malaysia (UTHM). The subject is a normal person and does the simple activity; grasp and release hand. Electrodes read the signal from the head surface and personal computer (or other relevant device) stores and displays obtained data. Scalp recordings of neuronal activity in the brain, identified as the EEG, allow measurement of potential changes over time in basic electric circuit conducting between signal (active) electrode and reference electrode [13]. Extra third electrode, called ground electrode, is needed for getting differential voltage by subtracting the same voltages showing at active and reference points. Minimal configuration for mono-channel EEG measurement consists of one active electrode, one (or two specially linked together) reference and one ground electrode. The multi-channel configurations can comprise up to 128 or 256 active electrodes.

For obtaining basic brain patterns of individuals, subjects are instructed to do simple activities, grasp and then release hand. The subject will wear the EEG cap which was connected direct to the computer. The computer will record/capture the signal needed while subject do the activities. Subject will do each activity in three set. Figure 2 was the illustration for the experiment setup for this study.

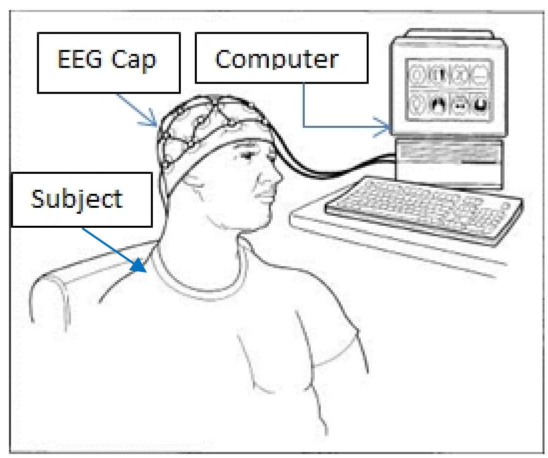

Figure 2: An Illustration setup of the EEG experiment

Before start the experiment, some impedance checking for the subject was needed. Figure 3 shows the example of the subject impedance checking.

The important condition for a good EEG signal is good contacts of the EEG electrodes to the head. An impedance meter helps to achieve such good contacts. The usage of the impedance meter is easy and fits in the process in a seamless way. It is because successful neurofeedback builds on a good EEG signal. Using a distorted EEG signal is like trying to listen to a music in the middle of a construction site.

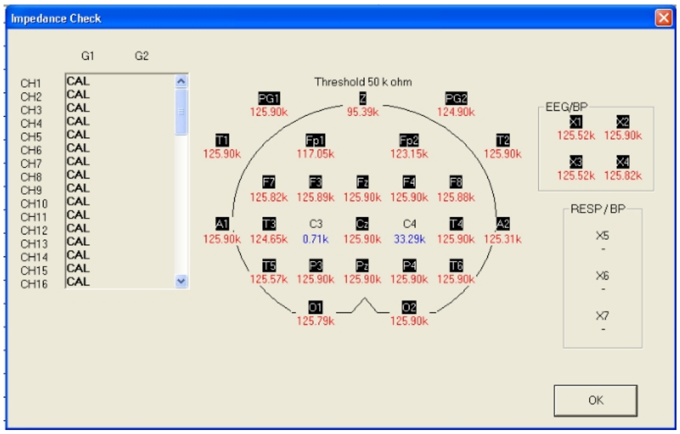

Figure 3: EEG impedance checking

III. RESULT and DISCUSSION

There has some changes in the brain signal due to the activities that the subject has been done. The experiment consist three activities of the subject. The first activity is relax. Figure 3.1 shows the signal reading by EEG device.

a) 1st activity (relax)

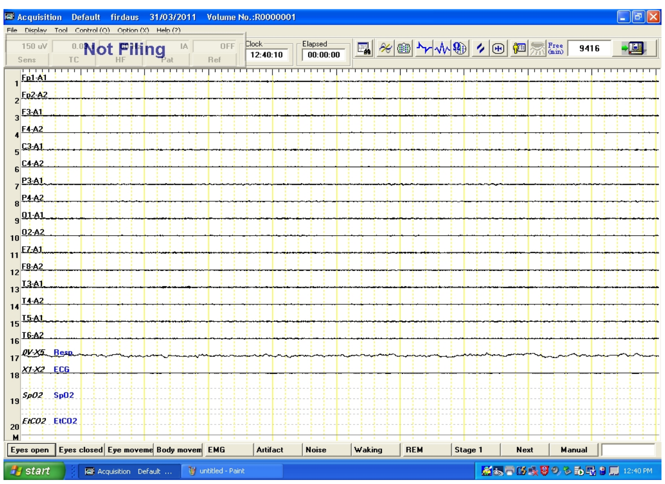

Figure 3.1: Signal reading by EEG device for 1st action in experiment

Basically, there is nothing happen to all signals in normal condition. The subject is just sit and relax. The subject just sits and thinks nothing also do nothing. It show that the signal pattern has really effect to the activity done by subject.

While in Figure 3.2, the signal reading by EEG device for second activity (hand grasp).

b) 2nd activity (hand grasp)

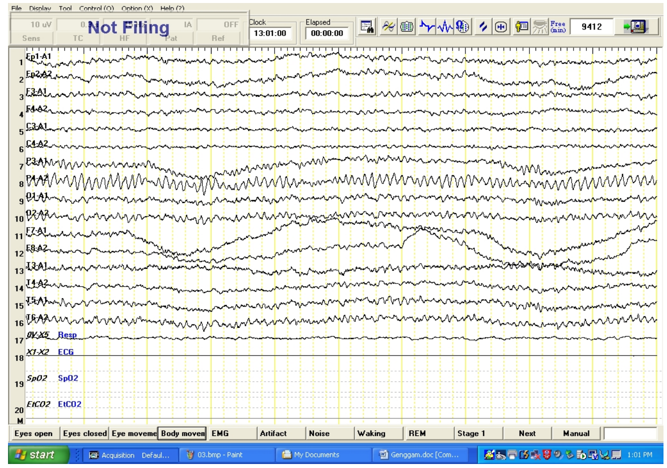

Figure 3.2: Signal reading by EEG device for 2nd action in experiment

In 2nd activity, the subject must grasp the hand in 5-10 second. There is a changes on the EEG signal. The signal in F1-A7 has a big changes compare to the previous result in Figure 3.1.

Figure 3.3 shows the signal reading by EEG device in grasp and release hand activity.

c) 3rd activity (grasps and release hand)

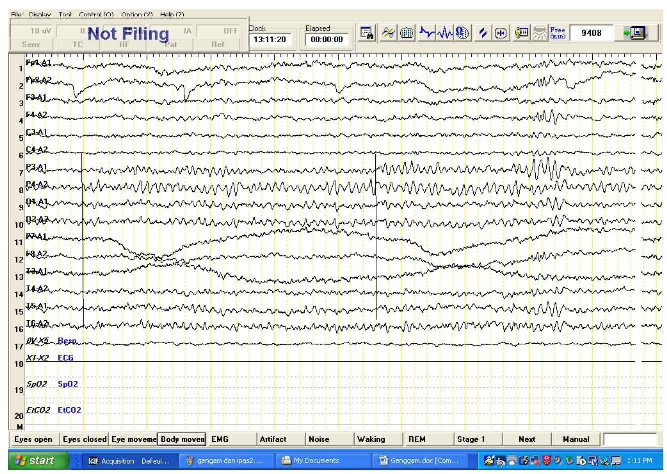

Figure 3.3: Signal reading by EEG device for 3rd action in experiment

The last activity is the subject must grasp hand in 5-10 second and then release again. The drastic changes was happened to the signal especially to the F7-A1, F8-A2 and T3-A1. Also a little bit changes on signal Fp1-A1 and Fp2-A2.

The purpose of this simple experiment is to investigate how the human brain signal reflects to the human activities and thinking. This is important to support the fundamental concept of the research that will be carried out in new future. The main research aim is to develop the Brain Computer Interface (BCI) - Functional Electrical Stimulation (FES) control system of knee joint movement for paraplegic. BCI is a technology that detects a patient's intention from this brain signals. While FES is a promising method to restore mobility to individuals paralyzed due to spinal cord injury such as paraplegic. The main goal of BCI is to create an alternative communication system for patients with severe motor impairments. This BCI will record the signal from patient brain and then will be transferred to paralyze part which need to be controlled. Therefore, in at the end of this research the integration between BCI and FES system that enables the direct brain control of knee joint movement in Spinal Cord Injury (SCI) patient will be investigated.

CONCLUSION

There have three activities of the subject in this experiment which is relax, grasp hand, grasp and release hand. The main target of this experiment is to identify either there have impact to the brain signal due to the action (activity and thinking). Based on the data collected from this simple experiment, it proves that all of the action (activity and thinking) will give impact to the brain signal. Also from the experiment the more action can be done by the subject will give huge reflect to the brain signal. Each action will produce its own signal and this is the easy way to recognize the action done by subject by refer to the brain signal pattern. This fundamental study will be applied in the BCI and FES system development that enables the direct brain control of knee joint movement in SCI patient.

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