Development of Visualisation Suite for a Low Cost Electroencephalography (EEG) System

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ABSTRACT

Electroencephalography (EEG) is a technique that recording of neural electrical activity of human by attaching electrodes to human scalp. The EEG has been used widely in the medical field to measure brain function and to evaluate brain disease such as sleep disorder, brain death and so on. The low-cost encephalography or low-cost bio amplifier that recently entered into the market making it more affordable for the use of practical research applications and gaming purpose. Since the low-cost EEG normally comes with Graphical User Interface (GUI) with less features and function, this project will present about the development of a new visualisation suite for low-cost EEG using MATLAB software. The brain signals are picked up by attaching the electrode of low-cost bio amplifier to human scalp surface. The device will then connect to PC/laptop. In order to interface with MATLAB, the connection between PC/laptop and low-cost bio amplifier had been established so that MATLAB can read the brain signals from a low-cost bio amplifier. Furthermore, the project also described about the function and feature of different GUI by comparing few visualisation suite in the market. Each step of this project that presented in flow chart are also clearly discussed in Methodology part. At the end of this project, a user friendly graphic user interface (GUI) was developed which showing real time information of EEG signal. Some signal processing method was also applied to the EEG signal which are 2D Plotting, 3D surface plotting, FFT and Gyroscope. For future improvement, it is recommended that the GUI can implement more signal processing method such as 3D brain mapping and power spectrum. Also, it is advised to load the recorded EEG data and expose it in the GUI.

ABSTRAK

Electroencephalography (EEG) adalah satu teknik yang merakam aktiviti elektrik neural manusia dengan melampirkan elektrod pada kulit kepala manusia. The EEG telah digunakan secara meluas dalam bidang perubatan untuk mengukur fungsi otak dan juga menilai penyakit otak seperti gangguan tidur, mati otak dan sebagainya. Encephalography berkos rendah yang baru-baru memasuki ke dalam pasaran menjadikannya lebih murah untuk kegunaan aplikasi penyelidikan praktikal dan tujuan permainan. EEG berkos rendah biasanya datang dengan Antara Muka Pengguna Grafik (GUI) yang mempunyai ciri-ciri dan fungsi yang lebih kurang, projek ini akan membentangkan mengenai pembangunan suite visualisasi baru untuk EEG berkos rendah menggunakan program MATLAB. Isyarat otak diambil dengan melampirkan elektrod dari EEG berkos rendah ke permukaan kulit kepala manusia. Selepas itu, EEG berkos rendah akan disambung dengan PC / laptop. Untuk kerja antara muka dengan MATLAB, sambungan antara PC / laptop dan EEG berkos rendah telah dibina supaya MATLAB boleh membaca isyarat otak daripada EEG berkos rendah. Tambahan pula, projek ini akan menerangkan prebezaan fungsi dan ciri GUI dengan membandingkan beberapa suite visualisasi dalam pasaran. Setiap langkah projek ini akan dibentangkan dalam carta aliran dan juga dibincangkan dalam bahagian Kaedah secara menjelas. Pada akhir projek ini, muka pengguna grafik pengguna (GUI) yang mesra pengguna telah dibina dengan menunjukkan maklumat masa sebenar dari isyarat EEG berkos rendah. Beberapa kaedah pemprosesan isyarat juga digunakan untuk menunjukkan isyarat EEG. Antaranya ialah 2D, permukaan 3D, FFT, dan giroskop. Untuk penambahbaikan pada masa hadapan, lebih banyak kaedah pemprosesan isyarat boleh dilaksanaakan dalam GUI seperti pemetaan otak 3D dan spektrum kuasa. Selain itu, isyarat EEG adalah dicadangkan bahawa boleh dipaparkan dalam komponen paksi GUI.

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LIST OF ABBREVIATION

GUI	-	Graphical User Interface
EEG	-	Electroencephalography
GYRO	-	Gyroscope
API	-	Application Program Interfacing
FFT	-	Fast Fourier Transform

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CHAPTER I

INTRODUCTION

An electroencephalography (EEG) is a system that measures and records the electrical activity of the human brain. It provides evidence of how the brain functions over time and used to be the first line method in the evaluation of brain disorders for medical industry nowadays. An electroencephalogram also able to detect abnormalities in the brain waves or electrical activity of the brain. During the procedure, electrodes consisting of small metal discs with thin wires are pasted on the scalp. The electrodes detect tiny electrical charges that result from the action of the brain cells. The charges are amplified and appear as a graph on a computer screen or as a recording that may be printed out on paper then the reading will be interpreted.

Recently, low cost EEG systems, Emotiv EPOC have entered the marketplace, making accessible consumer-level recording of neural activity. Emotiv EPOC or known as low cost bio-amplifier is a consumer Brain Computer Interface (BCI) based on EEG technology. The price of 499 USD making it lots more affordable compared to ordinary EEG systems. It offers 14 electrodes mounted on a wireless headset, which is effortless set up and connected to a computer. Initially, it was introduced for PC gaming, but the research edition enables access to raw data for further analysis. It may offer various opportunities for scientists to conduct new experiments or integrate it as support for existing ones [1].

In this project, a visualization suite that provides real time information will be developed for a low-cost EEG system. The development of this project consists of designing a graphical user interface (GUI) to show the brain's signal activity on laptop/desktop by connecting EEG device (bio-amplifier) for signal amplification. The EEG device will be connected either wireless or wired to laptop/desktop. A reliable and sensitive visualization suite with real-time information is expected to be developed from low-cost EEG.

1.1 Problem Statement

Low cost EEG system, Emotiv EPOC usually includes a built in visualization suite after purchase by the user. However, the Graphical User Interface (GUI) that come with the device is simple and provide less features and function. It is not flexible enough to alter according to user requirement. Furthermore, the purchase of the software GUI with the low cost EEG system is quite expensive. Consumer have to purchase the EEG system in order to get the visualization suite. User also cannot use the software in other purpose as it is already dedicated to the device. Hence, the project is to develop a new GUI of the low-cost EEG system which provide real-time information and additional functions or feature using MATLAB software application to greatly enhance the user experience.

1.2 Objectives

The main objectives of this project are:

- to develop a visualization suite that able to show real-time information from a low cost EEG system,
- to implement simple signal processing method using MATLAB software.

1.3 Scope of work

The projects will primarily focus on the implementation of signal processing methods using MATLAB application to access and display the neural activity in the brain through EEG signal. In order to do that, the communication will be developed between low cost bio-amplifier (Emotiv EPOC) and Personal Computer (PC). Besides, the new graphic user interface (GUI) allowing users to flexibly and interactively process their high-density EEG dataset. It is user friendly since users can load raw data of EEG signal into the software GUI or connecting it by the low cost EEG system to show real time information for analysis purpose. The two-dimensional (2D) and three-dimensional (3D) brain mapping will be also implemented into the visualization software. Techniques such as independent component analysis (ICA), time/frequency analysis (TFA), as well as standard averaging methods will be used to process and analyse brain signals.

CHAPTER II

LITERATURE REVIEW

2.1 Electroencephalography

2.1.1 Electroencephalography

Electroencephalography is a medical imaging technique that reads the brain electrical activity via human scalp. The different type of electrical brain activity and signal that recorded by attaching the metal electrode and conductive media to scalp surface is known as an electroencephalogram (EEG). The EEG measured directly from the cortical surface is called electrocortiogram while it is called as electrogram once using depth probe [2]. Electroencephalography (EEG) is also a device to measure the brain electrical activity to provide a non-invasive and inexpensive method to directly measure brain function and make inferences about the regional brain activity. It has many advantages as a direct measure of brain function that can be used in various applications in the bio behavioural sciences, ranging from studies of basic recognition processes to function of emotion, dysfunction and development [3]. The device also has its own limitation that the user must know about the method made to use.

2.1.2 History of Electroencephalography

In 1875. Richard Catton who regarded as the first scientist to study and investigate the brain potentials. During his investigation, The results (presented in 1875) showed that ‘‘weak currents of changing directions pass through the multiplier when the electrodes are placed at two points of the external surface, or one electrode on the gravy matter and one on the surface of skull.’’ This observation can be considered as the discovery of electroencephalographic activity. In 1890, Adolf Beck, physician of and professor of physiology from University of Lwów Galicia, had investigated the spontaneous activity of the brain of rabbits and dogs. He discovered the rhythmical oscillations of neural activity and “alpha blocking” which is the disappearance of rhythmical oscillations when the eyes were stimulated with light [3]. Then, his co-worker Napoleon Cybulski presented the electroencephalogram in a graphical form by applying a galvanometer with a photographic attachment. He also the first person who observe epileptic EEG activity in a dog effected by an electric stimulation [4]. In 1929, Hans Berger recorded the first electroencephalogram (EEG) from surface of human scalp [5]. Eventually, in 1935, the major fields of today’s clinical electroencephalography was born by the research from F. Gibbs and H. Davis [3].

2.1.3 Application of Electroencephalography

Electroencephalogram (EEG) plays an important role in health and medical applications. One of the famous application used is the detection of epileptic seizures and localisation of the seizure foci. Another best application of using EEG device is to investigate the sleep disorders [6]. Both applications are using electroencephalography due to the greater advantage of EEG which is speed. The brain activity that consists of complex patterns able to be recorded within fractions of a second after a stimulus has been executed. Since EEG produce less spatial resolution compared to Magnetic resonance imaging (MRI) and Positron emission tomography (PET), its images often combined with MRI scans for

better brain allocation. Besides, EEG can determine the position and strength of neural activity in different regions of brain [2].

Brain computer interface (BCI) is a communication system that recognizes user's command only from his or her brainwaves and reacts according to them. In this application, the personal computer (PC) and subject must be trained so that simple task can be executed which consist of desired motion of an arrow then displayed on the screen of PC through subject's imaginary of the motion of human's left or right hand. As conclusion of imaging process, certain characteristic of the brainwaves that shown can be used for user's command recognition [2].

Another related application is Neuro-feedback, a type of biofeedback for the brain, which practitioners say can address a host of neurological ills among them attention deficit hyperactivity disorder, autism, depression and anxiety. This application allowing patients to alter their own brain waves through practice and repetition. The procedure is controversial, expensive and time-consuming. Brain cells communicate with one another, through a constant signal of electrical impulses. Their patterns show up on an electroencephalogram (EEG), as brain waves with different frequencies. A major attraction of the technique is the hope that it can help patients avoid drugs, which often have side effects. Besides, patients practice routines that seem more like exercising a muscle [7].

Based on research from R. Bickford (1987), the clinical applications of the EEG in humans and animals are used to [8]:

- Monitor alertness, coma and brain death
- Locate areas of damage following head injury, stroke, tumor, etc.
- Test afferent pathways (by evoked potentials)
- Monitor cognitive engagement (alpha rhythm)
- Produce biofeedback situations, alpha, etc.;
- Control anaesthesia depth
- Investigate epilepsy and locate seizure origin

- Test epilepsy drug effects
- Assist in experimental cortical excision of epileptic focus
- Monitor human and animal brain development
- Test drugs for convulsive effects
- Investigate sleep disorder and physiology

2.2. Low cost electroencephalography

Multi-electrode, medical grade EEG system have already been used in the medical industry such as hospitals and laboratories for a long time. Fortunately, the invention of low-cost electroencephalography also known as a low-cost bio amplifier makes it available to take this technology from the medical industry to informal environments for example schools and homes. The price of this device is cheaper compared to the medical EEG system is easy to use [9].

There are several types of low-cost bio amplifier exist commercially in the market today, such as NeuroSky MindWave^{TM} Headset as shown in Figure 2.1. The headsets are designed to be used by developers to get to market quickly with complete EEG-monitoring products. The MindWave headset turns your computer into a brain activity monitor. The headset safely measures brainwave signals and monitors the attention levels of individuals as they interact with math, memory and pattern recognition applications. This headset is useful for OEMs building games, educational applications or activities for entertainment [10].