EEG-based Brain Computer Interface for Smart Home Control Using Arduino

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Specially dedicate to my beloved parents and also to my siblings and friends who give encouragement and support for me to complete this project. For my supervisor, Dr. Low Yin Fen who gave me a lot of guidance and advices throughout this project until successfully. Thank you very much to all of you.

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ABSTRACT

Electroencephalography (EEG) is a technique that acquiring of neural electrical activity of human by placing electrodes to human scalp. EEG-based Brain Computer Interface (BCI) for smart home is a system that allows direct communication between human brain and the computer. The main objective of this project was to generate control signals that can be used as commands to control a simple smart home system. This included development of a prototype for smart home system which can let the user to have visualization towards the smart home system. In order to achieve the target, EEG signal was first acquired by using low cost Emotiv EPOC device. Then, the EEG signal was analyzed and classified by using MATLAB software. The feature extraction method was set at amplitude of the EEG signal after the signal was analyzed and trained. Furthermore, the classified signal was used to control a real-time feature of home appliances by sending a command to Arduino UNO devices. Therefore, communication between Emotiv EPOC devices with computer is then established to turn on and off of the home appliances. Moreover, a user friendly graphical user interface (GUI) was developed which assist the real time communication between Emotiv EPOC and smart home system. Last but not least, the quality of life was improved besides ease the life of disabled people.

ABSTRAK

Electroencephalography (*EEG*) adalah satu teknik yang merekodkan aktiviti-aktiviti neural manusia dengan meletakkan elektrod pada kulit kepala manusia. *EEG* berdasarkan berhubungan antara otak manusia dan komputer (*BCI*) untuk rumah pintar adalah satu system yang menjalin komunikasi secara langsung antara otak dan computer. Objektif utama projek ini adalah untuk mejana isyarat kawalan yang boleh digunakan sebagai arahan untuk mengawal sistem rumah pintar mudah. Projek ini termasuk pembinaan prototaip untuk sistem rumah pintar yang membolehkan pengguna mempunyai visualisasi ke arah sistem rumah pintar. Dalam usaha untuk mencapai sasaran itu, isyarat *EEG* pertama kali diperolehi dengan menggunakan kos rendah peranti *Emotiv EPOC*. Kemudian, isyarat *EEG* telah dianalisis dan dikelaskan dengan menggunakan perisian *MATLAB*. Kaedah ciri pengekstrakan telah ditetapkan pada amplitud isyarat *EEG* selepas isyarat dianalisis dan terlatih. Tambahan pula, isyarat yang diklasifikasikan digunakan untuk mengawal ciri-ciri masa sebenar peralatan rumah dengan menghantar arahan untuk peranti *UNO Arduino*. Oleh itu, komunikasi antara peranti *Emotiv EPOC* dengan komputer kemudiannya ditubuhkan untuk menghidupkan dan mematikan daripada peralatan rumah. Selain itu, persahabatan antara muka pengguna grafik pengguna (*GUI*) telah dibangunkan yang membantu komunikasi masa sebenar antara *Emotiv EPOC* dan sistem rumah pintar. Akhir sekali, kualiti hidup telah bertambah baik di samping meringankan kehidupan orang kurang upaya.

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LIST OF ABBREVIATION

API	-	Application Program Interfacing
BCI	-	Brain Computer Interface
EEG	-	Electroencephalography
GUI	-	Graphical User Interface
GYRO	-	Gyroscope
PC	-	Personal Computer

LIST OF APPENDIXES

CHAPTER I

INTRODUCTION

EEG-based Brain Computer Interface (BCI) for smart home control is a system that allows the communication between brain signal with the computer system to generate commands for controlling home appliances such as light, fan, radio and etc. The aim of this project is to develop an EEG-based BCI system for smart home control which able to improve life quality. In addition, this project works on cost savings concept as home appliances can be turn off when they are not in use.

1.1 Project Background

Home automation idea was first introduced in 1984 by the American Association of House Builders. [1] As time goes by, technology in home automation had evoked in many stages. Currently, home automation system is able to support a wide range of application which including automation, monitoring, security, entertainment, care for children and the elderly, and so forth. [2] From here, we can see that home automation system has become one of our market trends.

Electroencephalography (EEG) is a technique that detects and records the electrical activity induced by human brain (cortical surface) through metal electrodes equipped with unique conductive media placed on the scalp with an EEG bio amplifier. In order words, EEG can reflect hundreds and millions neurons' activities within the brain. This is because the brain waves imply that there was a communication among brain cells and thus generate an electrical pulse. Therefore, the implementation of EEG into home automation technology would be a great turning point which related human's ability in technology.

Besides that, EEG-based Brain Computer Interface for smart home control using Arduino UNO is a project which is environmental friendly as electrical energy can be saved by using only a main switch to turn on or turn off home appliances. This system is designed by Emotiv EPOC which is considered as a low-cost device if compared to other brain acquired devices. Therefore, it is considered as cost-effective as well. In addition, this is a novel system as it is not available in current market yet. Moreover, this project has its own potential to sustain in market as long as there is existence of human brain's activities.

In this project, a prototype of simple home appliances will be developed. The development of this project consists of the design of the graphical user interface (GUI). The designed GUI was used to control the smart home appliances directly and at the same time, the GUI would produce a visualization for the user. This project mainly works in order to improve the quality of life. Besides that, it can help handicapped people to carry out their life without depend on people's help.

1.2 Objectives

The main objectives of this project are:

i. To interface the EEG signal with MATLAB software by using a low-cost EEG system.
ii. To analyze the brain signal using signal processing method.
iii. To generate control signals that can be used as commands to control a simple smart home system.
iv. To develop a prototype of a smart home system.

1.3 Problem Statement

As time goes by, the world is changing rapidly. People are more likely to concern and pursue a quality life. Because of the busyness in life, technology has been implemented on smart home system to overcome the insufficient time for managing home life in well. Most of the smart home system using a number of sensors which used to performs different functionality in the system. For instances, smart home energy management that had been developed which used light sensor, temperature sensor, and humidity sensor in their design. [3] However the more the number of sensor used, the higher the chances of malfunction when the system in use. The circumstances of which the system become breakdown affect its sustainability and hence affect user's decision on choosing the system.

Besides that, a low cost EEG-based smart home system with Arduino is currently not yet implemented together with brain signal in order to control home devices. There was a project on brain signal in smart home control, but it is used in graphical user interface (GUI) on the computer screen to control various devices in smart home. [4] Therefore, this project worked by sensing brain wave signal in real application of Arduino for a smart home system. With this system, user was able to control home devices through the thought. Moreover, EEG signal is easily disturbing by noise as the detection level of EEG signal is lower than noise. Hence, the EEG signal was undergoing signal processing in order to get more accurate signal.

1.4 Scope of work

The focus of this project will be on developing a prototype of smart home system that can be controlled by EEG signals. At the very beginning, the communication between the low cost brain computer interfacing device Emotiv EPOC with the Personal Computer (PC) will be established. The EEG signals will be acquired by the Emotiv EPOC device and process with simple signal processing by using MTLAB software. After that, the signal will be then performing feature extraction to extract the most suitable feature as a command to control the home appliances. Finally, a reliable and user friendly graphical user interface (GUI) will be developed to allow user have a clear visualization on the interface.

1.5 Report Structure

This thesis is a combination of five chapters that contain the introduction, literature review, methodology, result and discussion and the last chapter is the conclusion and recommendation of the project.

The introduction of this project will be discuss in Chapter 1. In this Chapter 1, I will explain the introduction and objective of the project and the concept behind of the project and overall overview of the project also will be discussed within this chapter.

The literature review of the EEG-based Brain Computer Interface System will be mentioned in the Chapter 2.

Chapter 3 will explain about the project methodologies of this project. This chapter will show the process of acquisition of the EEG signal from human scalp to computer system by using MATLAB software. The project flow of the application working principle will be demonstrated in detail.

Chapter 4 will discuss about result of this project. The discussion will involve the result of the EEG signal that acquired from human and the result of signal processing method that applied on the real time EEG signal. Final discussion will be the how the EEG signal will be transform as command to trigger the home appliances.

The final chapter which is Chapter 5 will explain about the conclusion and recommendation of this project.

CHAPTER II

LITERATURE REVIEW

This chapter discuss the literature review of the EEG-based Brain Computer Interface for Smart Home Control and its implementation in different fields.

2.1 Electroencephalography (EEG)

Generally, EEG is a technique that used to detect the electrical activity of the brain by placing the electrodes on the scalp surface. Electrical impulses were generated because there was the communication between brain cells. The EEG reflects a summation of extracellular potentials of synchronized population of neurons with high temporal resolution and it can measure from the human scalp surface directly by using specific electrodes. The specific designed electrodes will either place on the surface of human's hairy scalp or inserted through the skull [5]. The electrodes which placed on the surface on human's scalp are able to record the electrical activities which send out from the underlying cortex. The signal that recorded will be displayed as EEG after implementing appropriate amplify algorithm and filter algorithm. The EEG will display the real-time generated aperiodic either in slow or fast oscillatory brain activity recorded by the electrodes. The fields of application of the electroencephalogram range from performance in activated states, quiet waking or wake-fullness, normal and pathological sleep, as well as general anesthesia [5]. EEG is widely used in biomedical for example detection and diagnosis of epilepsy and other seizure disorders.

In 1929, an experiment was conducted by a German Psychiatrist called Hans Berger which he placed some electrodes on his daughter's head when the time his daughter doing mental arithmetic. This experiment was conducted in order to verify his hypothesis related to the electrical activity of brains. At the end of this experiment, Berger founded that the brain activity had been increased when his daughter was calculating some difficult mathematic multiplications [6]. This experiment was a great success and development in science history as the measurement of human brain electrical activity was reachable. In addition, a neuroscientist named Adrian had demonstrated scalp-recorded brain activity in live during the meeting of the Physiological Society in London during year 1935. Started from here, the electroencephalographic measures became more widely accepted in the biomedical research community [5]. The rapid development of EEG in data collection, data reduction, and data analysis have resulted important progress in this area.

2.2 Characteristics of EEG

The normal characteristics of the EEG can be characterized with respect to many different parameters. The EEG signal is categories into several groups and it is depending on the excitation of the brain activity. It is believing that the EEG signal between states of wakefulness and states of sleep are remarkably different. The characteristic of the EEG is normally described in term of the pattern which can divide into bands by frequency.

Figure 2.1: Alpha waves. [8]

Alpha (α) wave is primary waves signal will be observed in normal relaxed adults and normally will be occur after the age of thirteen. The frequency range of the Alpha is fall between 8 and 12Hz and it is easy to be observed in the posterior area of the skull. The alpha wave will be generating during eyes closed when relaxation but will be decrease during thinking process.

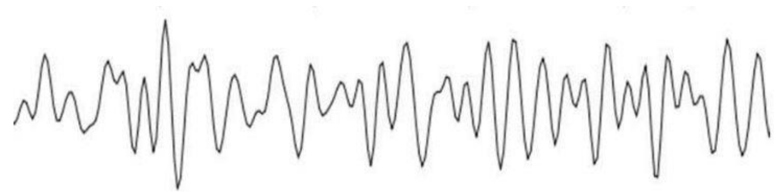

Figure 2.2: Beta waves. [8]

Beta (β) wave is known as a normal wave form by human brain and it is outstanding signal in most patients who are alert or restless. Besides that, the beta signal can be seen during the eyes open. The frequency range of the Beta is fall between 14 to 20 Hz and it is higher frequency than alpha signal. Beta signal is considering as fast activity and normally it is obvious frontally.

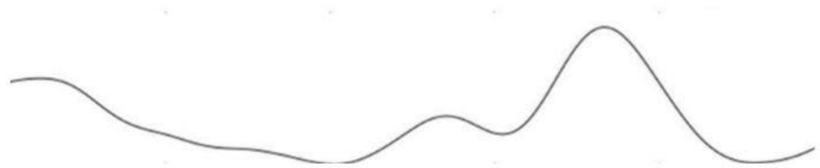

Figure 2.3: Delta waves. [8]

Delta (σ) has the highest amplitude compared to all EEG signal. The frequency range of the Delta (σ) is 3 Hz or below of the 3 Hz. It is an outstanding signal in new born child that up to one year and during the sleep stage of 3 and 4.

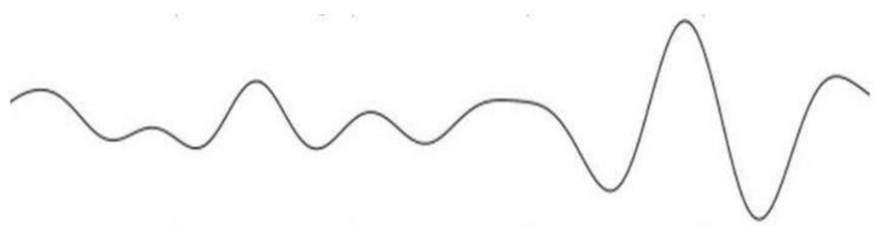

Figure 2.4: Theta waves. [8]

Theta (τ) is classified as slow signal activity and it is happen during irregular in awake adults. The frequency range of the Theta (τ) is fall between 3.5 to 7.5 Hz and it is happen during the sleep stage of normal children that up to 13 years of age.

Figure 2.5: Gamma waves. [8]

Gamma (γ) is often classify as a distinct class by many researcher of Electroencephalogram and include the Gamma (γ) signal in beta brain signal. The frequency range of the Gamma (γ) is associated between 40 Hz and 70 Hz. The Gamma (γ) normally happen during perception and consciousness of human [9].

2.3 Brain Computer Interface (BCI)

In 1964 which is the first Brain-Computer interfacing system was described by Dr. Grey Walter. On that time, Dr. Grey Walter had constructed an experiment on patient's brain which the patient actually undergoing some surgery for another reason. Some electrodes were connected directly to the specific part of the patient's brain. Dr. Grey had asked the patient to press a button to advance slide projector and at the same time he start to record the data of the patient's brain. In the result, Dr. Grey Walter founded that the patient can control the system without any movement after he introduced a delay from the detection of the brain activity. This actually is the first Brain Computer Interface [10].

Generally, Brain-Computer Interface (BCI) is a system that measures brain activity and converts the measured activity into artificial output that replaces, restores, enhances, supplements, or improves natural output and thereby changes the output interaction between the computer system and its external or internal environment [11]. A Brain-Computer interface system must have four components. There are:

a. It must directly record the activity from human's brain by using some specific component.
b. It must provide feedback to the user
c. It must run in real-time.
d. It must rely on intentional control.

The BCI offers different ways for communication and control. This is an artificial system that bypasses the human body's normal translation pathways, which are the neuromuscular output channels. The BCI system is directly measures the brain signal and translates the measured signal into corresponding control signal for specific applications.