UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BRAIN-MACHINE INTERFACE DEVICE FOR AMYOTROPHIC LATERAL SCLEROSIS (ALS) DISEASE USING ARDUINO

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Electrical Engineering Technology (Industrial Automation and Robotics) with Honours.

by

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DECLARATION

I hereby, declared this report entitled "Brain-Machine Interface Device For Amyotrophic Lateral Sclerosis (ALS) Disease Using Arduino" is the results of my own research except as cited in references.

Signature	:	…………………………………………………
Author's Name	:	………………………………………………….
Date	:	…………………………………………………..

APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfilment of the requirements for the degree of Bachelor of Electrical Engineering Technology (Industrial Automation and Robotics) with Honours. The member of the supervisory is as follow:

………………………………………………….

(MASLAN BIN ZAINON)

ABSTRACT

Ice bucket challenge campaign was introduced in 2014 to let people feel the pain and numbness experienced by Amyotrophic Lateral Sclerosis (ALS) patients. ALS patients are diagnosed with a type of disease that attack the nerve cells responsible for controlling voluntary muscles, which leads to an impact on the ability of movement . The human brain consists of a number of motor neurons, so in order to capture the activities of the brain, the brain-machine interface (BMI) device is used. This BMI test kit consists of electrodes that able to receive signals from a human brain and transport them to a machine prototype. This allows the prototype to function. Basically, the BMI test kit does not read human thoughts and is not able to see through a human's mind but it uses electrical impulses generated from the brain's neurons to control subjects. In this project, a machine prototype consists of servo motors is used to replace a wheelchair, and the prototype is linked to a wirelessly controlled Arduino microcontroller. This method can be considered as a non-invasive technique. Conclusively, this project is about controlling the movements of a servo motors' prototype that replacing a wheelchair through a microcontroller-based electroencephalogram (EEG) headband. The results from this project proved that it can help ALS or mobility disable patients to move around by using the concentration of their mind in daily life and allow them to lead an independent life.

ABSTRAK

Kempen cabaran baldi ais telah diperkenalkan pada tahun 2014 bagi memberi peluang kepada masyarakat untuk merasai kesakitan dan kekejangan seperti yang dialami oleh pesakit "Amyotrophic Lateral Sclerosis" (ALS). Pesakit ALS didiagnosis dengan sejenis penyakit yang menyerang sel-sel saraf yang bertanggungjawab untuk mengawal otot terkawal, dan memberi kesan terhadap keupayaan bergerak. Otak manusia terdiri daripada sejumlah neuron motor, oleh itu untuk mengesan aktiviti-aktiviti otak, peranti pengantara muka mesin-otak (BMI) digunakan. Kit ujian BMI ini terdiri daripada sejumlah elektrod yang mampu menerima isyarat-isyarat dari otak manusia dan mengangkut isyarat-isyarat tersebut ke prototaip mesin. Ini membolehkan prototaip tersebut berfungsi. Secara asasnya, kit ujian BMI tidak dapat membaca fikiran manusia dan tidak boleh melihat melalui minda seseorang manusia akan tetapi ia menggunakan impuls elektrik yang dijanakan oleh neuron-neuron untuk mengawal sesuatu subjek. Dalam projek ini, sebuah prototaip digunakan bagi menggantikan kerusi roda, dan prototaip tersebut dipautkan dengan mikropengawal Arduino yang dikawal secara wayarles. Kaedah ini boleh dianggap sebagai teknik tak invasif. Secara ringkasnya, projek ini adalah mengenai pengawalan pergerakan prototaip motor servo yang menggantikan kerusi roda melalui cekak kepala elektroensefalogram (*EEG headband*) berasaskan mikropengawal. Keputusan dari projek ini membuktikan bahawa bahawa projek ini boleh membantu pesakit ALS atau pesakit lumpuh untuk bergerak dengan menggunakan konsentrasi minda dalam kehidupan seharian dan mampu hidup berdikari.

DEDICATION

To my beloved parents

To my supervisor, Mr. Maslan Bin Zainon

To my lecturers

And not forgetting to all my peers.

ACKNOWLEDGEMENT

Good day to all the readers.

Firstly I would like to thank my dear Lord who gives me strength, patience and the courage to enable me successfully complete this project. All praise the Lord for blessing all the students that on-going with final year project regardless race or religion.

I would like to take this opportunity to express my thankfulness to my supervisor, Mr. Maslan Bin Zainon, for his guidance, valuable assistance, motivation and not giving up on me by helping me to complete this work successfully without any obstacles. Thank you.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURES

ALS	=	Amyotrophic Lateral Sclerosis
BCI	=	Brain-Computer Interface
EEG	=	Electroencephalogram
LED	=	Light-emitting diode
PWM	=	Pulse width modulation
USB	=	Universal Serial Bus
ICSP	=	In-Circuit Serial Programming
FMRI	=	Functional magnetic resonance imaging
FNIRS	=	Functional near-infrared spectroscopy
Ag	=	Silver
AgCl	=	Silver chloride
CPU	=	Central processing unit
RAM	=	Random-access memory
ROM	=	read-only memory
EEPROM	=	Electrically Erasable Programmable Read-Only Memory
USART	=	Universal Synchronous/Asynchronous Receiver Transmitter
ADC	=	Analog-digital convertor
TQFP	=	Quad Flat Package
MLF	=	Micro lead frame
SPI	=	Serial Peripheral Interface

GND	=	Ground
VCC	=	Voltage
AC	=	Alternating Current
RX	=	Receive (digital ‘0’)
TX	=	Transmit (digital ‘1’)
RGB	=	Red, green and blue
CAD	=	Computer-aided design
ADHD	=	Attention deficit hyperactivity disorder
PIC	=	Peripheral interface controller
ARM	=	Advanced RISC machines

CHAPTER 1

INTRODUCTION

1.0 Introduction

This chapter will explain the background of the project, problem statement, objectives, work scope, and chapter conclusion.

1.1 Background

The combination of brain machine interface test kit and Arduino prototype is inspired to help patients such as Stephen Hawking who was diagnosed with an Amyotrophic Lateral Sclerosis (ALS). This disease causes the patient's body to be paralysed except for the brain to function as a normal person. In order to help these patients, a Brain-Computer Interface was introduced to the world. BCI is mainly for people who are diagnosed with severe motor impairments that can be considered as partly paralysis of voluntary muscles except for the eyes or one part of the human features. Based on Stamatta Ferreiro et al (2013), the research field that is related to the brain-computer interface has started since the mid-70s in a diverse area of knowledge such as neuroscience, biomedicine, automation, and control engineering as well as computer science.

In the journal from Nacy (2016), they stated that the first brain-computer interface as an idea, was introduced by Dr. Grey Walter in 1964, after an EEG signal was recorded from all lobes of the cortex for the first time at Beryer in 1943. Dr. Walter performed an open brain surgery to record the electrical activities of the cortex region on a volunteer. This surgery successfully proven that electrical signals can be obtained from a motor cortex. There are various success on BCI that was implemented throughout these years such as using human skin as a touch interface, or controlling a wheel chair using tongue. One of the greatest inventions is by Vernon, where Joshi's ear muscle is used to control a television. This project is demonstrated using a prototype. The prototype will help the patient to learn on how to be more independent and capable to move in a walking distance with the aid of an EEG headband. EEG stands for electroencephalography, which is an electrical voltage that is produced by neurons in the brain cortex, it is then received and recorded in a system in a graph form or waveform to view the brain activities. The EEG headband consists of electrodes that are able to receive in the range of microvolts (microvolt / 1/1,000,000 of a volt). In other words, the EEG headband can interpret the activities of the brain by measuring the brain wave patterns.

Through Zeater.A et al (2011), the process of measuring a non-inversely electrical brain activity on the scalp was first recorded by Hans Berger in 1924 [Gevins, 1998]. From his research, he identified a correlated different patterns in EEG signals with certain brain diseases. The brain wave pattern shown is actually an accumulation of a synchronous activity of neurons. Arduino microcontroller acts as an intermediate between the EEG headband and the prototype. Upon receiving signals from the EEG headband, it will send a signal to Arduino microcontroller to be programmed to run the prototype. The prototype will respond by giving a reaction such as moving forward.

1.2 Problem Statement

In 2014, an Ice-bucket challenge was introduced to raise awareness for Amyotrophic lateral sclerosis (ALS). This is a type of disease that attacks the nerve cells *(neurons)* which are responsible for controlling voluntary muscles (muscle actions that we are able to control; such as those in the arms, legs, and face). This disease belongs to a group of disorders under the category of *motor neuron diseases.* This project is expected to help the movements of paralysed or disabled patients using their mind control, provided they have to wear an electroencephalography (EEG) headband. Through the EEG, any electrical activities of a human brain could be observed. In this project, a preliminary test using an LED will be used to represent a wheelchair that will be controlled by the EEG using LED colour changes with the aid of Arduino microcontroller. After receiving signals from the EEG headband, Arduino will be the one to interpret and response such as the LED shows different colours depending on the patient's concentration. Upon completion of this test, several servo motors will be used to represent the wheelchair's actual movements that are controlled by the patient's concentration.

1.3 Objectives

The three main objectives of this project are as follows:

(a) To develop a brain-assisted wheelchair prototype with a mind control feature for paralysed or disabled patients.

(b) To analyse a mind-controlled electroencephalography (EEG) headband data which is processed by an Arduino microcontroller.

(c) To validate a mind-controlled EEG headband data with a wheelchair movements represented by servo motors.

1.4 Work Scope

The two major components that will be explored in this project are the NeuroSky mind-wave headband and Arduino.

NeuroSky Mind-wave headband is one of the EEG biosensor technologies. This headband consists of sensors to detect brainwaves and interprets the meaning of brainwaves instead of the human thoughts. The headband is bound with a dry-electrode, it senses the signals from the human brain, then filters out the noise and electrical interference and converts to a digital power. It can detect up to 50 or 60Hz AC interference.

Arduino Uno is a type of microcontroller. “Uno” means one in Italian and it is also the first product of Arduino released, can be considered as the basic for the beginners. It has 14 digital input/output pins (of which 6 pins can be used as PWM outputs), 6 analog inputs, a 16MHz ceramic resonator, a USB connection, a power jack, an ICSP header , and a reset button.

After the coding had been verified, it will be saved as a memory and will be applied when there is an input detected. This is one of the benefit for consumers as it does not require to attach a computer anymore after saving the memory. It is more convenient as it can be carried and moved around desirably. The servo motors will function by itself provided Arduino received signals from the EEG headband.

1.5 Conclusion

The results obtained from the experiments may not be comprehensive. This is because, if a patient’s concentration is not strong enough or that patient have concentration issues, the prototype might not move as efficiently as expected. One of the major effects that affects the results was the dependency of human’s concentration. In another word, patients must not be distracted while controlling the prototype using the EEG headband. The constraint of this project is the difficulty of getting patients to try this prototype. On average there is one ALS patient for every 500,000 people in the developed countries, but the cost of the products might not be affordable to the poor. This might be the question for any company to further develop the product as it not profitable.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

The main source of this chapter is mostly taken from journals. The studies in this chapter include the Brain-Machine Interface, Atmega328 as a microcontroller, Bluetooth communicating system, software and last but not the least servo motors. The above components had been chosen because they are related to the project scope.

2.1 Brain-Machine Interface

2.1.1 NeuroSky Mindwave Headset

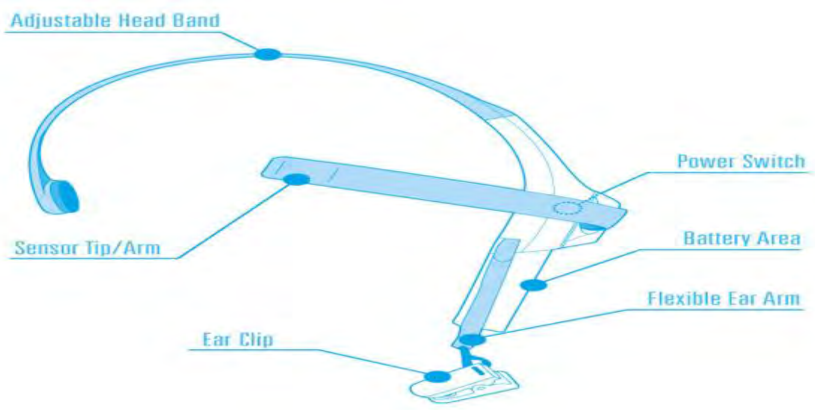

Figure 2.1: Blueprint EEG headset provided by NeuroSky Technology

Source: http://support.neurosky.com/kb/mindwave/mindwave-diagram (Accessed on 6/4/2017)

According to Jose, P.G. et al. (2016) the NeuroSky EEG headset will be used as the main communication tool. The NeuroSky Mindwave headset looks like a modified headphone but it is equipped with a different functions in it. It is white and silverfish-grey in colour that required an AAA battery to activate the headset. It consists of 2 main sensors; one is located at the forehead, which is adjustable to fit and touch a person's forehead. The other one is located at the left ear, it is an ear clip for ground connection. This headset included an LED power indicator and on-off switch. Figure 2.1 shows Neurosky appearance. This is a non-invasive sensor equipment that is user friendly. Moreover, it is radioactive free so it will not bring any harm to a person or people in the vicinity.

2.1.2 Basic Principles on How NeuroSky Headset Works

Salvekar, D. et al. (2015) stated that with the sensor provided by NeuroSky Technologies, the headset can receive and transmit signals after activating it. The headset can lasts up to 8 hours with the aid of an AAA battery. There's an LED power indicator light to guide the user. First, it will blink after switching on the power switch. After a few seconds, it will change to a blue light when the headset is activated and connected to a Bluetooth, provided the user wears it, otherwise it is in red. If both colours blink, it means the headset is out of power. The user may have to replace with a new battery. Whereas Jose, P.G. et al. (2016) mentioned that the forehead sensor is used to detect electrical signals from the brain. At the same time, the sensor also picks up an ambient noise from the body and other external electrical devices such as computers, light bulbs and nearby electrical appliances. The ear clip that embedded with NeuroSky's chip will filter out all the electrical noise from the body and surrounding environment and focus on the brainwaves.

Figure 2.2 shows an overview of this project; data is received from the brain signals and transmitted to a USB dongle. The dongle is a Bluetooth device that will pair up with the NeuroSky and microcontroller that are attached to

Arduino. The microcontroller will perform the interpretation, react accordingly and shows the effects on the prototype.

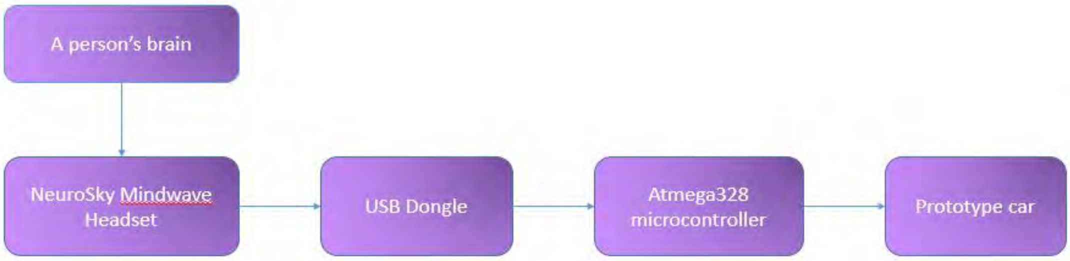

Figure 2.2: A flow chart for the devices and components used

2.1.3 Methods and Techniques of Brain Machine Interface

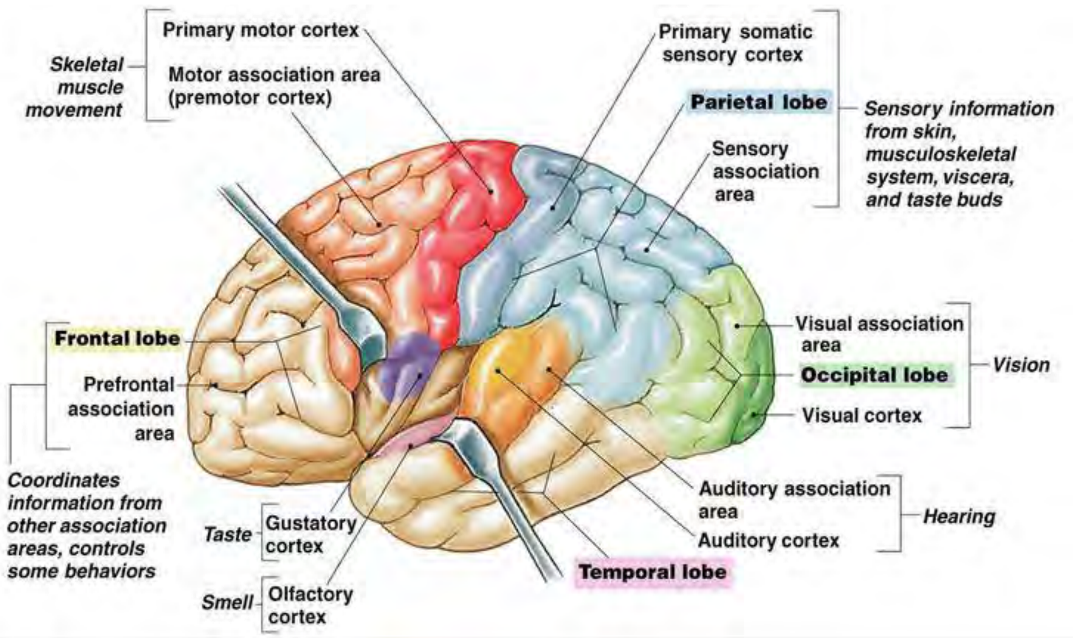

Figure 2.3: The human brain cortex and its parts. Nacy, S.M. et al. (2016).

According to Ferreira, A.L.S. et al. (2013) professionals had implement 3 methods for the brain machine interface which are the invasive, partially invasive and non-invasive. For the invasive methods, patients are required to perform a surgery just to implant a sensor into the grey matter that is located inside the brain which is shown in Figure 2.3. There is a high possibility that surgeons may not get the desired results and it might imposed a higher cost due to the limitation of medical facilities used in the pre and post-surgery. On the contrary, the non-invasive method is not harmful and may get the most accurate results as the improvement of technologies, it is more beneficial to both parties compared to the invasive method. Whereas for the partially invasive method, the sensors are implanted and placed between the human skin and skull, meaning the patients are required to undergo a minor surgery too. Therefore, the non-invasive method is highly recommended for ALS and motor neuron disease patients as they are easily available, user-friendly and low-cost. These highlights are the main reasons for the professionals to develop further in this area.

After introducing the methods that can be used to capture the interaction between the human brain and machine. The following will discussed on the techniques to access information from the human brain. Most commonly technique that had been used is an electroencephalograms (EEG). Electrodes will be used to capture the brain signals as each of the neurons has electrical signals provided from the dendrite. As stated by the BBC UK (2014) neurons are classified into 3 types; the sensory neurons, motor neurons and association neurons. These neurons will carry their own information respectively. The electrical signals are known as the nerve impulses. In order to trigger nerve impulses, the neurons have to be excited. For example, facing physical and emotional sensitivity such as light, sound or happy etc. When a nerve impulse carries information, it will reach the other end of a different neuron, then, a neurotransmitter chemical is released and excites the next neuron. Nuffield Department of Clinical Neurosciences (2017) explained the second technique to be used is a functional magnetic resonance imaging (fMRI) which is shown in Figure 2.4. An FMRI is a technique that will infer brain activity by measuring changes in the blood flow. Patients are required to lay on a designated table and send into a cylindrical tube that consist of a very powerful electro-magnet field. An FMRI is a magnetic signal from the hydrogen nuclei in water that can discriminate between grey matter, white matter and cerebral spinal fluid in the structural images of the brain. It has a few advantages, such as it is a non-invasive technique and doesn't involve radiation. It has an excellent spatial and good temporal resolution. It is easy for engineer and scientist to use, therefore it has become a popular tool for the psychologist who wanted to explore further on the human thoughts and reactions. Finally, the last technique to be discussed is the functional near-infrared spectroscopy (fNIRS) which is shown in Figure 2.5. John M. Grohol, Psy D. (2016) explained that FNIRS is a technique by measuring changes and monitor blood flow in a part of the brain with the aid of a near-infrared light. It is basically to monitor the oxygenated blood and blood volume in pre-frontal cortex in the near-infrared range between 700 and1000nm. Patients are required to attach this sensor at the forehead so that it can be monitored directly from the computer. The hypotheses can be tested on how brain activity is affected by the patient's behaviour.

Figure 2.4: An FMRI technique

Source: http://news.stanford.edu/news/2013/march/brain-imaging-inaccuracies-030713.html (Accessed on 6/4/2017)

Figure 2.5: An FNIRS technique

Source: http://www.pitt.edu/~huppert1/Huppert_Lab/Welcome.html (Accessed on 6/4/2017)

2.1.4 Brainwaves

According to Nacy, S.M. et al. (2016) the electrical signals produced are only from the range of 0.5-100µVolts.

Table 2.1: The frequency band of EEG signals

Brainwave type (EEG band)	**Frequency Range**
Gamma, γ	30-100 Hz
Beta, β	12-30 Hz
Alpha, α	8-12 Hz
Theta, θ	4-7 Hz
Delta, δ	0-4 Hz