DEVELOPMENT OF A MYOELECTRIC DETECTION CIRCUIT WITH IOT APPLICATIONS FOR USER MOTION INTENTIONS

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DECLARATION

I declare that this thesis entitled “DEVELOPMENT OF A MYOELECTRIC DETECTION CIRCUIT WITH IOT APPLICATIONS FOR USER MOTION INTENTIONS is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : LEE LEONG JIN

Date : 22/1/2021

APPROVAL

I hereby declare that I have checked this report entitled "Development of a myoelectric detection circuit with IoT applications for user motion intentions" and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Mechatronics Engineering with Honours

Signature	:	
Supervisor Name	:	Dr. Norafizah binti Abas
Date	:	22/1/2021

DEDICATIONS

To my beloved supervisor, panels, coursemates, friends, and family members. Thank you for all the advise, encouragement and support throughout this journey and in the preparation phase of this report.

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ABSTRACT

In this research, the development of myoelectric muscle sensor with IoT technology for continuous prediction of user motion intention is explored. The myoelectric sensor is designed to measure the EMG signals extracted from the forearm muscles due to the hand movement/grasping at different wrist angle, that is then combined with mechanical sensor modalities (accelerometer and hand dynamometer) for continuous movement predictions to ensure simultaneous movements can be realized. The circuit is designed using simulation software and constructed before analyzed by conducting several set of data collection. After the proof of concept is completed, the sensor is interfaced with IoT technology so that the data can be wirelessly acquired and stored in the cloud where it can be retrieved for rehabilitation assessment. The proposed research contributes towards the enhancement of control strategies to ensure simultaneous movements with proportional articulation that includes user motion intention can be realised to control the exoskeleton hand. It is towards the aim to provide better human-machine interaction for the hand impairment survivors in regaining their hand strength and functionality, and improve their quality of life.

ABSTRAK

Dalam penyelidikan ini, pengembangan sensor otot myoelectric dengan teknologi IoT untuk ramalan berterusan niat gerakan pengguna diterokai. Sensor myoelectric direka untuk mengukur isyarat EMG yang diekstrak dari otot-otot lengan bawah yang disebabkan pergerakan tangan / mencengkam pada sudut pergelangan tangan yang berbeza, yang kemudian digabungkan dengan modaliti sensor mekanikal (accelerometer dan dynamometer tangan) untuk ramalan pergerakan berterusan untuk memastikan pergerakan serentak dapat dicapaikan. Litar ini dirancang menggunakan perisian simulasi dan dibina sebelum dianalisis dengan melakukan beberapa set pengumpulan data. Setelah pembuktian konsep selesai, sensor dihubungkan dengan teknologi IoT sehingga data dapat diperoleh dan disimpan di awan tanpa wayar di mana ia dapat diambil untuk penilaian pemulihan. Penyelidikan yang dicadangkan menyumbang ke arah peningkatan strategi kawalan untuk memastikan pergerakan serentak dengan artikulasi berkadar yang merangkumi niat gerakan pengguna dapat direalisasikan untuk mengendalikan tangan exoskeleton. Ini bertujuan untuk memberikan interaksi manusia-mesin yang lebih baik untuk mangsa cacat tangan dalam memulihkan kekuatan dan fungsi tangan mereka, dan seterusnya meningkatkan kualiti hidup mereka.

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LIST OF SYMBOLS AND ABBREVIATIONS

ADC	-	Analog-to-Digital Converter
API	-	Application Programming Interface
BLE	-	Bluetooth Low Energy
BOM	-	Bill of Materials
CE	-	Coordinator Enable
CH	-	Channel
CMRR	-	Common Mode Rejection Ratio
CNS	-	Central Nervous System
COM	-	Component Object Model
DAQ	-	Data Acquisition
DC	-	Direct Current
DRL	-	Driven Right Leg
DSP	-	Digital Signal Processing
ECG	-	Electrocardiography
EHW	-	Evolvable Hardware Chip
EMG	-	Electromyography
EOG	-	Electrooculography
FCR	-	Flexor Carpi Radialis
FCU	-	Flexor Carpi Ulnaris
FDS	-	Flexor Digitorum Superficialis
FPL	-	Flexor Pollicis Longus
GND	-	Ground
ID	-	Pan ID
IoT	-	Internet of Things
LPF	-	Low Pass Filter
LPT	-	Line Print Terminal
MCU	-	Microcontroller unit
MUAPs	-	Motor Unit Action Potentials
NI	-	National Instruments
PC	-	Personal computer
PCB	-	Printed Circuit Board
PLI	-	Power Line Interference
RMS	-	Root Mean Square
SEMG	-	Surface Electromyography
TTL	-	Transistor-transistor Logic
USB	-	Universal Serial Bus
Vcc	-	Common Collector Voltage

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CHAPTER 1

INTRODUCTION

1.1 Project Background

In the 21st century, health systems are confronted with new challenges such as global aging population, increase number of people with chronic condition and people living with disabilities are now more than ever before. Rehabilitation is required as the country grows and health systems expand, to ensure that people get the best possible result after an accident or illness. It means getting out of the hospital sooner with less risk of complications and less need for ongoing support. However, people do not have access to the rehabilitation services they need in many parts of the world, insufficient numbers of trained rehabilitation practitioners, inadequate facilities and obstacles to access such high out-of-pocket expenses are challenges that need to be addressed [1].

According to the latest Institute for Health Metrics and Evaluation data published in 2020, stroke is the top 3 leading causes of death in Malaysia from 2009 to 2019 as shown in Figure 1.1 [2]. Although stroke is the top 3 leading causes of death in Malaysia but there are a lot of people who survived stroke as shown in Figure 1.2 where it is the most (62%) cases registered for domiciliary health care services [3]. People who survived stroke need to undergo rehabilitation to regain their speech, cognitive, motor, or sensory skills. Rehabilitation program for stroke often involve the training of strength, mobility, and range-of-motion exercises which are monitor by utilising the electromyography (EMG) signals. The EMG signals will record the electrical potential generated during muscle contraction. The EMG signals becomes continuously denser and the maximal peaks in the signal will have a higher amplitude when more force is used [4]. Thus, the properties of EMG signals are useful for doctors to keep track and evaluate the process in stroke rehabilitation of patient to ensure a fast and efficient recovery.

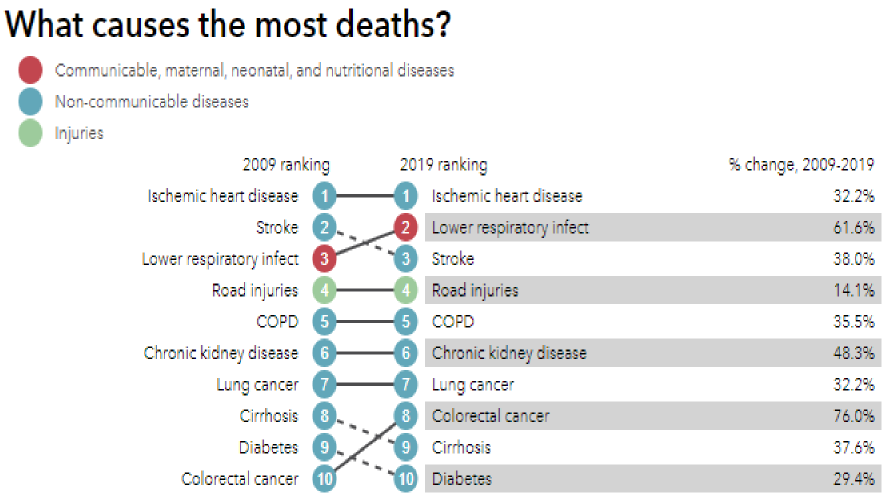

Figure 1.1: Cause of deaths from 2009-2019 in Malaysia [2]

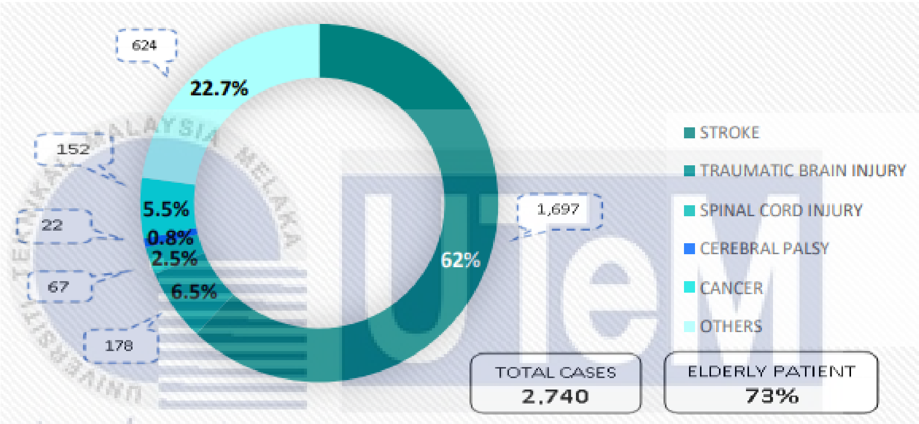

Figure 1.2: Cases Registered for Domiciliary Health Care Services, 2017 in Malaysia [3]

1.2 Motivation

According to a survey performed in 2018, it is observed that the rehabilitation services provided within the state of Selangor and Federal Territories of Kuala Lumpur is distributed unevenly especially for the population of urban poor and people in the rural areas as shown in Figure 1.3 [5]. The costs for development, construction, and manpower would be high to set up new healthcare facilities. An alternative solution should be considered such as the use of a home-based virtual rehabilitation programme. Thus, to visualize this conception, the idea of designing a myoelectric circuit for user motion intention with IoT application is inspired. This development would be able to help doctor to monitor the patient recovery progress from a distant. Besides, the developed circuit can also be utilised as a control signal for prosthetic devices such as prosthetic hands, arms, and lower limbs to achieve human-machine interaction.

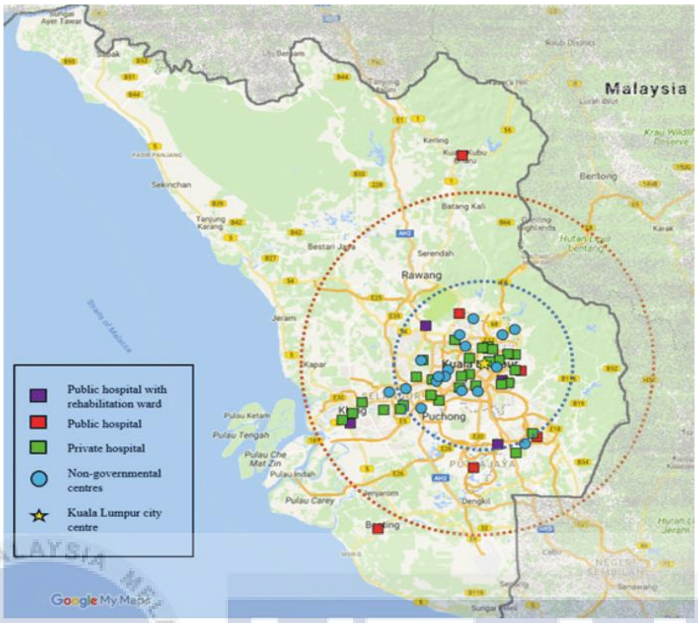

Figure 1.3: Distribution for Rehabilitation Services [5]

1.3 Problem Statement

With the advancement of technologies and breakthroughs in healthcare today, the number of people who survived stroke had risen drastically over the year. This scenario had led to the increase in demand for rehabilitation or assistive devices. In a way to help the patience to recover efficiently, user motion intention needs to be considered to robustly control the assistive devices to be compatible for different people at different level of recovery progress. The user motion intention is observed by the outcome of EMG signals. However, raw EMG signals which is nonlinear and associated with noise is not suitable to be used to study its relationship with user motion intention. Thus, the raw EMG signals requires amplification, filtration, and rectification so that the signal generated is linear enveloped before it can be readily used as control input to control the assistive devices.

At present, there are various of technique in processing the EMG signals. Despite the fact that there are a lot of commercially available EMG detecting circuit in the market but each and every of it had their own design specification and most of the devices does not include IoT application as a part of it. In addition, by adapting IoT into the EMG circuit will ease the process for data collection and enable physician to monitor and track the recovery of a patience from a distance which results in a better treatment and experience with lower expenses as it eliminates the cost for travel, hospital room and exorbitant doctor fees. Besides, during the wide spread of COVID-19 currently, the adaptation of IoT will also lower the risk of one getting affected. Therefore, to ensure seamless interaction between human-machine interaction by including motion intentions and IoT as part of research, the best method of design and gap analysis between research paper need to be contemplated by recognizing the strength and limitation of each so that the circuit designed could respond accordingly and correctly whenever the muscle contracted.

1.4 Objective

The objectives of this project are as follows:

i. To design a myoelectric circuit for detection of user motion intention with IoT application.
ii. To establish relationship between forearm EMG signal with different handgrip force and wrist position using the designed circuit.
iii. To analyse the designed circuit in terms of accuracy and rms error.

1.5 Project Scope

The scopes of this project are as follows:

i. All subjects are normally limbed in this experiment with no previous or present muscular injuries or diseases.
ii. The electrode used in this experiment is subjected to surface electrode only which would not cause harm to subject.
iii. The designed circuit is validated using the data collected by previous researcher using the EMG device by Vernier where the established relationship are compared and analysed.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Throughout recent years, scientist have been utilizing EMG for diagnosis of various of neuromuscular diseases. There are a lot of method in acquiring the EMG signals as for this project will be focus primarily on the development of a myoelectric detection circuit with IoT applications for user motion intentions. In this chapter, the theories of EMG are explained and reviews of previous design approaches as well as associated issues is conducted. Based on the boon and bane discussed from the reviewed paper, an appropriate approach is selected to provide comprehensible design consideration and implementations. In addition, recent development and recommendations from each paper is also taken into account. By comparison study, a better understanding of EMG signal and its analysis procedure is produced which will help in designing a more powerful, flexible, and efficient myoelectric detection circuit.

2.2 EMG Signal

Electromyographic (EMG) signal are electrical potentials generated due to voluntary muscle contraction and is sometimes referred as myoelectric activity. This signal is normally a function of time and is describable in terms of its amplitude, frequency, and phase. The EMG signal is complicated as it is controlled by the nervous system and is dependent on the anatomical and physiological properties of muscles as shown in Figure 2.1 [6]. The amplitude of this signal usually ranges from 50 µV to 20-30 mV. As the amplitude of the raw EMG signal is too small, thus the EMG signal need to be processed before it can be used as a control input for the controller by amplification, filtration, rectification, smothering and etc. Thus, research have been carried out for developing better algorithms, upgrading existing methodologies, improving detection techniques to reduce noise, and to acquire accurate EMG signals [7]. The processed EMG signal can be then used to analyse or use to study the relationship of EMG signal properties with different muscle group. The amplitude of this biopotentials is proportional to the intensity of the contraction. EMGs are detected in a frequency range between 20-450 Hz [6]. EMGs can be also utilize for clinical/biomedical applications, Evolvable Hardware Chip (EHW) development, and modern human-machine interaction [7]. According to the International Society of Electrophysiological Kinesiology [8], the minimum specifications for EMG signals are as below:

- Input Impedance: $>10^{10}\Omega$ en DC y > $10^{8}\Omega$ a 100 Hz
- Amplification gain: 200-100.000 ± 10% on discrete
- Gain nonlinearity: ≤± 2.5%
- Gain stability: Variation should be 5%/year
- CMRR: >90dB

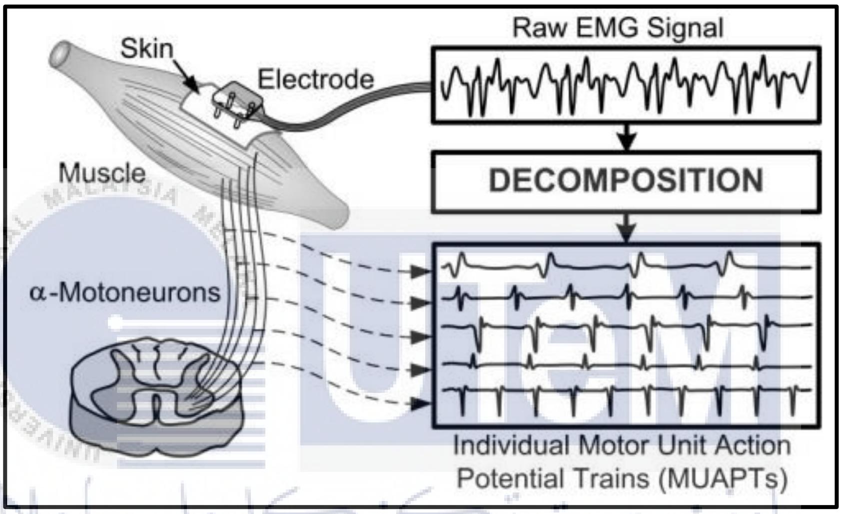

Figure 2.1: Characteristic of EMG signals [6]

2.2.1 Anatomical and physiology background

The central nervous system (CNS) is made up of the brain and the spinal cord. It controls most bodily functions which in includes awareness, movements, sensation, thoughts, speech, and memory. The function of the spinal cord is to send signals (messages) back and forth between the brain and peripheral nerves [9]. The biological signal from the brain is transmitted to the muscle fibers through neurons in the spinal cord resulting in the muscle's movement/contraction when a person intends to move as shown in Figure 2.2 [10]. Neurons have a similar function to wires in an electronic circuit since both neurons and wires serve as the medium to transport signals [11]. Contraction of these activated fibers generates a voltage known as Motor Unit Action Potential (MUAP). The shapes and firing rates of Motor Unit Action Potentials (MUAPs) in EMG signals provide an important source of information for the diagnosis of neuromuscular disorders [7]. The EMG signal is a summation of MUAPs. The amplitude of MUAPs is related to the muscle contraction [12]. The stronger the muscle contraction and the higher the number of activated muscles, the higher the recorded voltage amplitude will be [13].

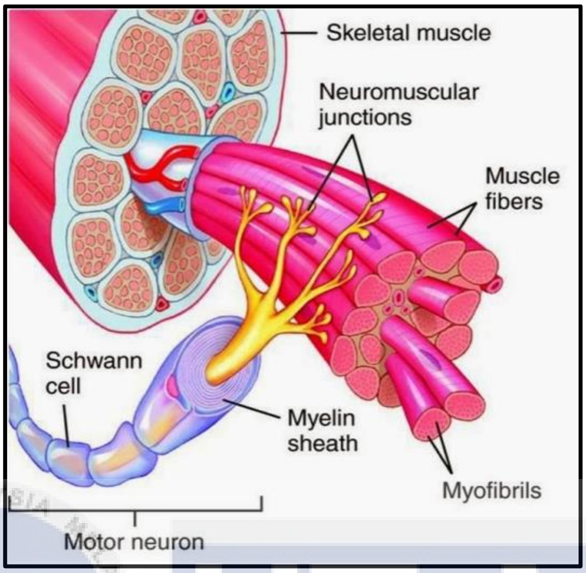

Figure 2.2: Functional motor units which consists of motor units [10]

2.2.2 EMG Measurement Technique

The EMG electrode is used inside a human body's muscle to detect muscle response and bioelectrical activity. There are two main types of measurement technique which are the non-invasive method that involved the use of surface (or skin electrode) and the invasive method that involved the use of inserted electrode. Surface electrode includes gelled and dry EMG electrode which can be either passive or active while inserted electrode includes needle and fine wire electrode [14]. The pros and cons of these electrode will be discussed and explained.

2.2.2.1 Non-invasive Measurement Technique

Surface electrode is often used in the study of muscle activity as it provides the only non-invasive index of the level of muscle activation present [15]. Besides, surface electrodes are better than needle electrodes for recording a compound muscle action potential as they register the total contributions from all discharging motor units [16]. Surface electrodes are applied to the skin of subject and may be in the form of electrolyte gel which purpose is to improve connection, or in the dry form which does