"I hereby declare that I have read through this report entitle "EMG and Cubic Polynomial Based Lower Limb Rehabilitation Device for Post Stroke Patient" and found that it has comply the partial fulfillment for awarding of Bachelor of Mechatronics Engineering."

Signature : …….

Supervisor's Name : ……..

Date : …….

EMG AND CUBIC POLYNOMIAL BASED LOWER LIMB REHABILITATION DEVICE FOR POST STROKE PATIENT

TAN JIN SIANG

A report submitted in partial fulfillment of the requirements for the degree of Bachelor of Mechatronics Engineering

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2015

I declare that this report entitle “EMG and Cubic Polynomial Based Lower Limb Rehabilitation Device for Post Stroke Patient” is the result of my own research except as cited in the reference. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ……..

Name : ……..

Date : ……..

To my beloved mother and father

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ABSTRACT

Nowadays, stroke is the second disease killer in Malaysia. Post stroke patient are having the problem of hemiparesis and unable to walk without assistance. The lower limb rehabilitation device in the market using the different type of controller and sensor which can affect the repeatability of the system and also the accuracy of EMG sensor which is self-made is unknown. Therefore, a cubic polynomial and EMG trajectory planning lower limb rehabilitation device which is a better design compare to the device in the market is designed. The main objective of this project is to design a cubic polynomial and EMG based trajectory planning lower limb rehabilitation device for the post stroke patient to regain their walking ability. The design of lower limb rehabilitation is wearable type with 2 DOF with the training covers the thigh and knee. This is because the user is assumed to have muscle weaken at thigh and knee only but the ankle can move freely like the healthy person. The EMG sensor is self-made by using amplifier to condition the signal and using AgCl electrode to receive the EMG signal. The controller used is EMG controller which map the EMG signal with Initial Contact and Loading Response of the walking gait cycle act as an on off switch of the device. Three experiments are conducted which are data collecting for EMG value, accuracy analysis for EMG sensor and repeatability analysis for the device. The data of the EMG signal are recorded from 5 persons so that the device can be rotate based on the EMG signal. The repeatability analyze of the device is by repeating 10 times of the experiment and comparing the desired trajectory angle value with measured angle value. The accuracy of the EMG signal conditioning is analyzed by comparing the EMG signal conditioning value with muscle sensor value. After the experiments are carried out, it is found that the average EMG signal value is 0.512V for maximum and -0.2856V for minimum. The experimental results of the device of RMS error are 0.2699 radian for hip joint and 0.4037 radian for knee joint and the repeatability in terms of consistency are between the range of 0.0156 radian and 0.0612 radian for both if the joint. The accuracy of the EMG sensor is 96.86%.

ABSTRAK

Pada masa kini, strok adalah pembunuh penyakit kedua di Malaysia. Pesakit strok ischaemic selepas mengalami masalah hemiparesis dan tidak mampu berjalan tanpa bantuan. Peranti pemulihan kaki di pasaran menggunakan jenis yang berbeza daripada pengawal dan sensor yang boleh memberi kesan kepada kebolehulangan sistem. Oleh itu, merancang trajektori polinomial dan EMG padu peranti pemulihan kaki yang reka bentuk yang lebih baik berbanding dengan peranti ini di pasaran direka. Objektif utama projek ini adalah untuk mereka bentuk polinomial kubik dan EMG trajektori berdasarkan peranti pemulihan kaki untuk pesakit pasca strok mendapat semula keupayaan berjalan kaki. Reka bentuk pemulihan kaki adalah jenis boleh pakai dengan 2 DOF dengan latihan yang meliputi paha dan lutut. Ini kerana pengguna dianggap mempunyai otot lemah di paha dan lutut sahaja tetapi pergelangan kaki boleh bergerak bebas seperti orang yang sihat. Sensor EMG adalah buatan sendiri dengan menggunakan penguat kepada keadaan isyarat dan menggunakan AgCl elektrod untuk menerima isyarat EMG itu Pengawal digunakan adalah EMG pengawal yang memetakan isyarat EMG dengan Hubungi Awal dan Loading Response kitaran perbuatan gaya berjalan berjalan kaki sebagai suis off peranti. Tiga eksperimen dijalankan iaitu pengumpulan data untuk nilai EMG , analisis ketepatan sensor EMG dan analisis kebolehulangan untuk peranti. Data isyarat EMG yang direkodkan dari 5 orang supaya peranti boleh putar berdasarkan isyarat EMG itu. The kebolehulangan menganalisis peranti ini dengan mengulangi 10 kali percubaan dan membandingkan nilai sudut trajektori dengan nilai sudut diukur. Ketepatan penyesuaian isyarat EMG dianalisis dengan membandingkan nilai penyesuaian isyarat EMG dengan nilai sensor otot. Selepas eksperimen dijalankan, didapati bahawa purata nilai isyarat EMG adalah 0.512V untuk maksimum dan -0.2856V untuk minimum. Keputusan eksperimen peranti ralat RMS adalah 0.2699 radian bagi sendi pinggul dan 0.4037 radian untuk sendi lutut dan konsisten adalah antara pelbagai 0.0156 dan 0.0612 radian radian untuk kedua-dua jika sendi. Ketepatan sensor EMG adalah 96.86 %.

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θ(t)	-	Angle
$\frac{\delta\theta_{i-1}}{\delta t_{i-1}}$	-	Angular velocity
a_0, a_2, a_3	-	Unknown
R	-	Resistor
f	-	Frequency
C	-	Capacitor

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Chapter 1

INTRODUCTION

1.1 Research Background

According to World Health Organization (WHO) [1], stroke is caused by the blood vessel burst due to the clot blocking the blood vessel. This will cut off the supply of the oxygen, nutrients and causing the brain damage. According to The Star: Health [2], there are 2 major type of stroke which are ischaemic and haemorrhagic. Ischaemic stroke occurs when a blood vessel in the brain are blocked. Haemorrhagic stroke occur when a blood vessel inside the brain is weak or burst and causing the blood leak into the brain. The risk of having stroke increase from age to age as shown in the Table 2. From The Star: Health [2], the people after the age of 55 will having the double increase in the risk of having stroke for every decade the person is alive. There are also some other risk that can increase the risk of having stroke like hypertension, diabetes, atrial fibrillation and so on. According to My Malaysia Health [3], stroke is second disease killer in Malaysia as shown in Table 1.1.

Table 1.1: Top disease killer in Malaysia (source: My Malaysia Health) [3]

No	Top 5 Cause of Death	%
1	Coronary heart disease	22.18
2	Stroke	11.67
3	Influenza & pneumonia	9.2
4	Road traffic accidents	7.85
5	HIV/ AIDS	5.53

According to National Stroke Association [4], about 50% of the acute ischemic post stroke patient having a problem which is called hemiparesis. Hemiparesis is the weakness of the muscle of one sided of the body. This will cause the disability of walking, grabbing things and also eating due to the muscle weaken of the one sided of the body and the patient usually will have more than one disability problem.

1.2 Motivation

According to Genentech USA, Inc [5], about 50% of acute ischemic stroke which is one type of stoke will having hemiparesis and 30% of the patient unable to walk without assistance which is the top 1 and top 3 of the disabilities as shown in Figure 1.1. Difficulty of general movement like walking and stabilizing are due to muscle weaken which also called impaired motor control. Impaired motor control of one sided body is called hemiparesis. This disability is the most factor that nowadays most of the post stroke patient are having this disability. Most of the patients will have more than one kind of disability.

The stroke disease in Malaysia is also very serious. It is a second disease killer in Malaysia which is 11.67% as shown in Table 1.1. This means that there are many people in Malaysia having

this kind of disease. The post stroke patient in Malaysia also have the disabilities like hemiparesis and unable to walk without assistance.

Nowadays, lower limb rehabilitation device is an important and the only device that can help the post stroke patient who have hemiparesis problem and unable to walk without assistance to regain their walking ability by having training at their lower limb. Therefore, lower limb rehabilitation training for the post stroke patient is needed to allow them to regain the skills and having a normal life like before the stroke.

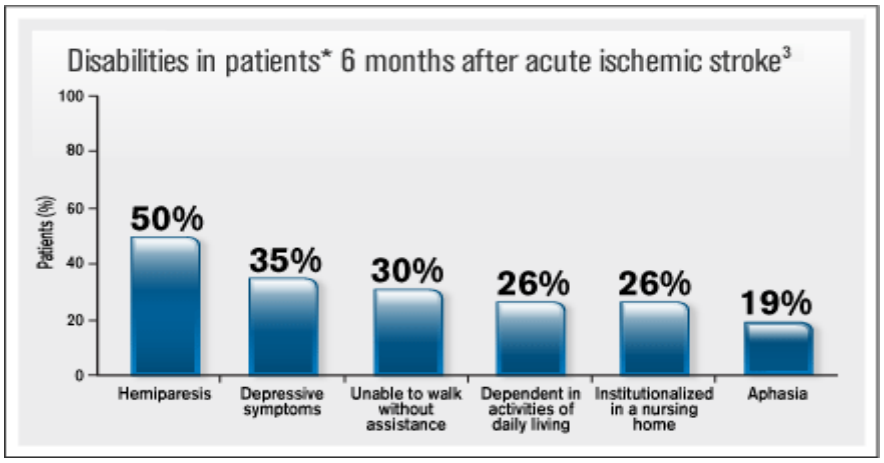

Figure 1.1: Stroke patient disability statistic (source: Genentech USA, Inc) [5]

1.3 Problem Statement

Based on Figure 1.1, hemiparesis and unable to walk without assistance are the most common disabilities faced by post stroke patients who had experienced at least 6 months of acute ischemic. Both disabilities limits or impairs patient's ability to walk which affect their quality of life and it demands resources for assistive and rehabilitation. Thus, rehabilitation device for lower limb is considered as crucial to restore the walking ability of the post stroke patients. Therefore,

rehabilitation device for lower limb is a must for post stroke patient who have this kind of disability to restore their walking ability.

From Iñaki Díaz [6], the lower limb rehabilitation system can be categorized into two types which are wearable and non-wearable. The wearable which is used in both environment, indoor and outdoor, while the non-wearable can be used in indoor only. The non-wearable usually need a treadmill to work to and a therapist as training assistant. It also only allowed the patient to walk in predetermined path. Hence, the wearable type of rehabilitation device is preferred. Even though it might offer complexity in fundamental design, but it have more benefits than the non-wearable rehabilitation system. The wearable rehabilitation system can allow the user to walk their own path rather than just the predetermined path which is very noticeable that almost all systems reviewed have been commercialized. Besides that, the wearable rehabilitation system does not need the treadmill to work. However, rehabilitation training for a wearable rehabilitation system in the market mostly only cover one part of the lower limb only or knee and ankle only or hips, knee and ankle but the training for the hips, knee and ankle is costly due to an extra actuator needed. Moreover, there are don't have the training for the hips and knee. Therefore, a hips and knee wearable training rehabilitation system is needed for the patient having disability at hips and knee.

According to Iñaki Díaz [6], there are so many type of controller in the lower limb rehabilitation system in the market like Fuzzy logic, PID and so on. Most of the controller are high performance. However, those controllers involves complex algorithm and calculation. Therefore, a simple but with high performance controller is needed for the lower limb wearable rehabilitation system. Therefore to reduce the complexity of the controller, the EMG controller can be implemented in the system as a primary controller to control the lower limb rehabilitation system.

Different type of device using different type of trajectory planning. Different type of trajectory planning could cause the different effect. By using EMG as the controller could cause the consistency of the device decrease but can increase in terms of time response. The cubic polynomial could cause the response time of the device decrease but it will increase the consistency and accuracy of the device. As a summary, a cubic polynomial and EMG based trajectory planning lower limb wearable rehabilitation device with EMG as a primary controller which cover the hips and knee is designed in solving the problems.

1.4 Objective

1. To design a cubic polynomial and EMG based trajectory planning lower limb rehabilitation device for the post stroke patient to regain their walking ability.
2. To analyze overall system performance in terms of accuracy and repeatability.

1.5 Scope

1. In this project, the patient is assumed to have a hemiparesis problem with weaken muscle at thigh and knee but the muscle function normal at the ankle. Therefore, the lower limb rehabilitation prototype is only cover thigh and knee.
2. The test bed used is improved based on crutches developed by previous student, Yong Xian.
3. The prototype has 2 DOF which indicates the rotational movement at hip and knee only.
4. The EMG controller only act as an on off switch to switch on or off the designed rehabilitation device.
5. The trajectory planning of the device is based on the normal forward walking gait of a healthy person.
6. The AgCl electrode is placed at the rectus femoris muscle to detect the EMG of the lower limb and the own signal conditioning is used to condition the signal of muscle.
7. The performance of overall system is analyzed in terms of accuracy and repeatability by analyzing the accuracy of controller signal receiving from the lower limb by comparing them with the muscle sensor and the repeatability prototype is analyzed by comparing the trajectory planning with angle of the device with 10 times of repetition.

1.6 Report Outline

This report is about the development of lower limb rehabilitation device for post stroke patient. In this report, the chapter 1 covers about the research background of the post stroke patient and motivation for designing a lower limb rehabilitation device for post stroke patient. The objective and scope of the design is stated in this chapter. The theory and basic principle and the review of previous related work of the lower limb rehabilitation device is covered in chapter 2 of the report. This report also lists out the methods and techniques used in this design which stated in chapter 3. The result and the conclusion are covered in chapter 4 and chapter 5 in this report.

Chapter 2

LITERATURE REVIEW

2.1 Theory and Basic Principle

Theory and basic principle of the lower limbs rehabilitation device for the post stroke patient is discussed in details in this section. It covers stability of human body, lower limb muscle, electromyography, post stroke patient, weight bearing for the lower limb as well as its motion during walking.

2.1.1 Basic Principle of Lower Limb Rehabilitation Device

2.1.1.1 Post Stroke Patient

In this section, the research will discusses about the disability of the post stroke patients. According to National Institute of Neurological Disorder and Stroke [10], the post stroke patients will have several disability in physical and also have some problem in their mental. The problems like problems of controlling movement, problems of using or understanding the language, sensory disturbance and also emotional disturbance.

According to National Stroke Association [4], about 80% of the post stroke patients will have a problem which is called hemiparesis. Hemiparesis is the one sided muscle weakness especially at the arm and lower limb. This can affect the motion of the arm and also the lower limb like walking or grabbing things.

From National Stroke Association [4], hemiparesis can be separated into 2 parts which are right sided and left sided. The right sided hemiparesis will have the problem of using or understanding the language. The left sided hemiparesis will have memory problems. Damage of the lower brain will cause the motion failure of the arm and also the lower limb which is called ataxia.

2.1.1.2 Motion of the Lower Limb during Walking

According to Aaron M. Dollar [13], there are 8 stages of the motion while a human walking. Figure 4 shows the one gait cycle when a human walking. There are 2 important phase for the gait cycle which is stance phase and swing phase. The stance phase is the phase when the human body moves forward and the swing phase is when the lower limb back into the initial position.

From Aaron M. Dollar [13], human lower limb contains of 7 degree of freedom (DOF) which is the rotation of the ankle, abduction-adduction of the ankle, flexion-extension of the ankle, flexion-extension of the knee, rotation of the thigh, abduction-adduction of the thigh and flexion-extension of the thigh. For a human to walk forward, the lower limb only uses 3 DOF which is flexion-extension of the thigh, flexion-extension of the knee and flexion-extension of the ankle.

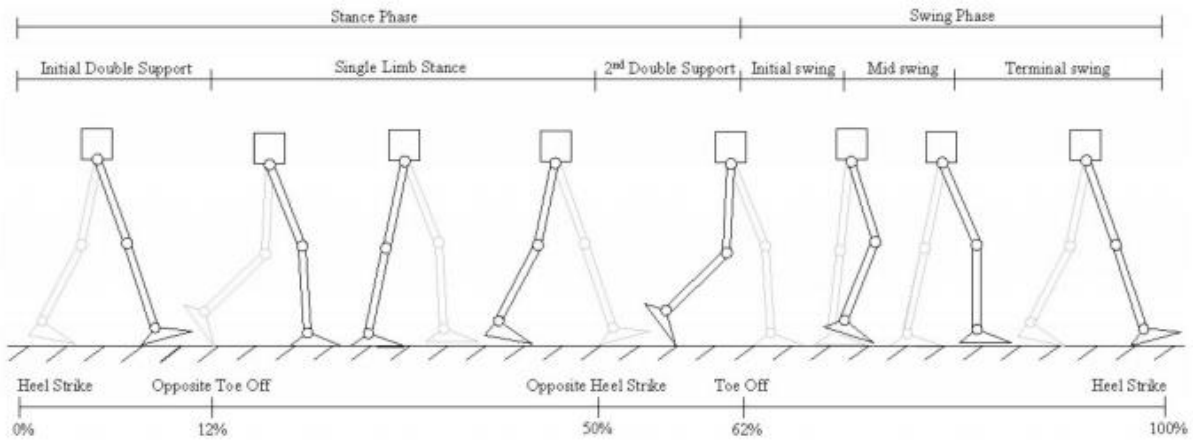

Figure 2.1: Motion of the lower limb during walking (source: Lower Extremity Exoskeletons and Active Orthoses: Challenges and State-of-the-Art) [13]

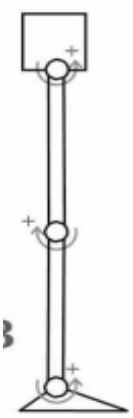

Figure 2.2: DOF of the lower limb (source: Lower Extremity Exoskeletons and Active Orthoses: Challenges and State-of-the-Art) [13]

2.1.1.3 Center of Gravity and Stability

Based on the book, Scientific Basis of Human Motion [7], the center of the gravity of human body is different on height, body size and also as well as the gender. The standing position