UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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PROJECT REPORT

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Design and Development of Stairs Climbing Trajectory for Lower Limb Assistive Device

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Bachelor of Mechatronics Engineering

2013/ 2014

“I hereby declare read through this report entitle “Design and Development of Stairs Climbing Trajectory for Lower Limb Assistive Device” and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Mechatronic Engineering”

Signature : ………………………………………

Supervisor’s Name : ………………………………………

Date : ………………………………………

DESIGN AND DEVELOPMENT OF STAIRS CLIMBING TRAJECTORY FOR LOWER LIMB ASSISTIVE DEVICE

TAN CHEE MENG

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

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2013/2014

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Signature : ………………………………………

Name : ………………………………………

Date : ………………………………………

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ABSTRACT

Senior citizens who faced musculoskeletal deterioration and patients who have recovered from stroke often left with substantial level of mobility disorder. They face difficulties while performing daily activities such as stairs climbing. In order to cope with the issues, a lower limb assistive device is proposed to assist them to perform stairs climbing activity independently. Hence, the objective of this project is to build a lower limb assistive device that follow stairs climbing trajectory of a normal person and to test the accuracy of the device. The device is limited two degree of freedom which is the hip and knee. In order to build a lower limb assistive device for stairs climbing trajectory, two main problems are concerned. The first problem is the accuracy of the proposed trajectory derived using trajectory generation of human gait to climb stairs. The motion of stairs climbing may not smooth and the user may fall from stairs or lose balancing if the accuracy that follows the stairs climbing trajectory is not accurate. Before the device is built, the stairs climbing trajectory must be study. The stairs climbing trajectory is derived into cubic polynomial function and the minimum torque required to perform this action is calculated. Experimental tests such as software simulation and lab test will be applied on the proposed trajectory to show the performance of the proposed stairs climbing trajectory in term of accuracy. In the lab test, a prototype is built in order to compare accuracy of the proposed trajectory derived using trajectory generation from human stair climbing gait and the human behavior to climb stairs compare the deviation. As a result, the proposed trajectory derived using trajectory generation, which is the cubic polynomial function is able to achieve the accuracy of the assistive device up to 88.5% when compared to the normal gait of human behavior to perform stairs climbing motion.

ABSTRAK

Warga emas menghadapi masalah otot dan pesakit yang baru pulih dari strok sering menghadapi gangguan pergerakan yang ketara. Mereka menghadapi kesukaran semasa melakukan aktiviti harian seperti menaiki tangga. Dalam usaha untuk menangani masalah warga emas dan pesakit strok, satu alat bantuan kaki dicadangkan untuk membantu mereka melakukan aktiviti naik tangga tanpa bantuan orang lain. Oleh itu , objektif projek ini adalah untuk membina sebuah alat bantuan kaki yang mengikuti trajektori naik tangga oleh orang sihat dan untuk menguji ketepatan alat tersebut. Alat bantuan kaki ini terhad untuk pinggul dan lutut sahaja. Dalam usaha untuk membina satu alat bantuan kaki yang mengikut trajectory naik tangga, masalah telah diutamakan ialah ketepatan alat bantuan kaki. Pengguna boleh jatuh dari tangga atau kehilangan kestabilan jika ketepatan yang mengikuti trajectory menaik tangga kurang tepat. Sebelum alat bantuan kaki dibina, trajecktori mendaki tangga mestilah dikaji. Trajecktori mendaki tangga perlu dikira dalam persamaan dan minimum daya usaha yang diperlukan untuk melaksanakan tindakan ini juga dikira. Ujian akan dilaksanakan pada persamaan trajektori yang dikira dalam bentuk simulasi perisian dan eksperimen makmal untuk mengkaji ketepatan prestasi persamaan trajectory yang dibina tersebut semasa mendaki tangga. Persamman trajektori akan dibanding dengan trajetori orang biasa mendaki dari segi ketepatan untuk membuat perbandingan untuk mengkaji prestasi persamman trajektori mendaki tangga. Akhir kata, persamaan trajectory yang dibina melalui kaedah kubik polinomial dapat mencapai ketepatan sebanyak 88.5% disbanding dengan orang biasa untuk mendaki tangga.

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CHAPTER 1

INTRODUCTION

1.1 Motivation

Physical disability was found to be a major cause of morbidity in Malaysia which are 123,346 cases registered under Malaysia [1]. As Table 1.1 shown, the number of disabled people in Malaysia as reported in year 2011. Physical disability has the second highest number of case reported followed by learning disability as reported in year 2011.

Table 1.1: Number of disable person registered in Malaysia in 2011. Adapted in [1]

Visually Impaired	Hearing	Physical	Learning disability	Speech	Mental	Others	Total
31,924	43,788	123,346	134,659	725	8,927	15,834	359,203

Individuals with physical disabilities often face difficulties to perform daily activities such as walking, stairs climbing, rising from chair and lifting an object. An assistive mechanism or a tool such as wheelchair and crutch usually needed to assist their daily activities.

Besides people with physical disability, most old people (senior citizen) were also has difficulties to perform daily activities due to musculoskeletal deterioration. Figure 1.1 shows the number of total population by age group and sex in Malaysia in 2002 and 2012.

From Figure 1.1, the number senior citizens which are 60-75 years old increase drastically from year 2002 to year 2012. As aging would potentially causes musculoskeletal deterioration, the increase in the number of senior citizens foresees a potential rise in the number of assistive demanded in the near future. Aging of skeletal muscles may cause minor or partially physical disabilities to a person. At the same time, the rapid increase of citizens falling in 50-54 and 55-59 years old age group gives an indication of continuously high demand on joint assistive device, which could be sustainable for at least 10-20 years.

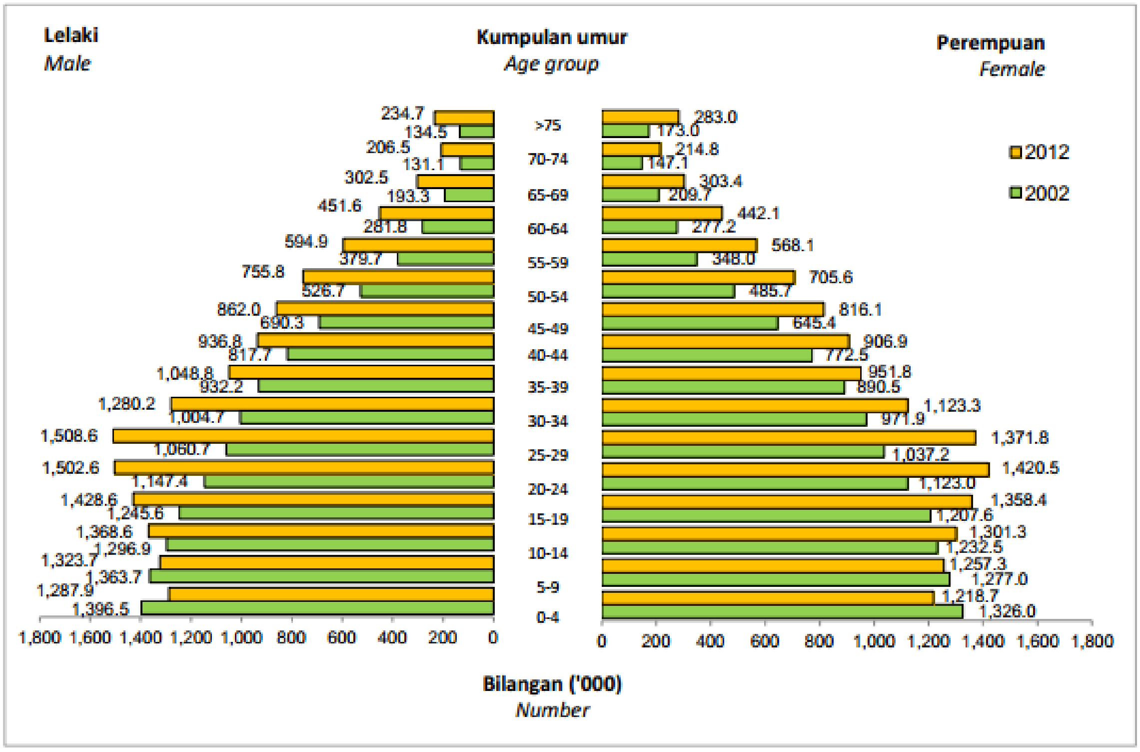

Figure 1.1: Total population by age group and sex, Malaysia, 2002 and 2012. Adapted from [1]

On the other hand, stroke was found to cause of morbidity and the second leading cause of death [2]. 15 million people suffer from stroke every year worldwide. From these 15 million people, 5 million die and another 5 million left permanently disabled [3]. Patients who survived from stroke often left with substantial residual disability which hardly to complete daily activities independently.

Study shows the patient that recover from stroke, 19% were very severe disabled, 4% severely disabled, 26% moderately disabled, 41% minor disabled and 10% had no disability shown in Figure 1.2 [2]. However, after complete stroke rehabilitation, 91.9% of the survivors were fully independent in self-care activities [4]. During the stroke rehabilitation services, the patients undergo a typical therapy programs that can increase their ability to perform activities of daily living. However, time is required for the stroke patient to recover. Thus, an assistive device is needed to assist the patient to perform daily activities while the patient is during the rehabilitation process.

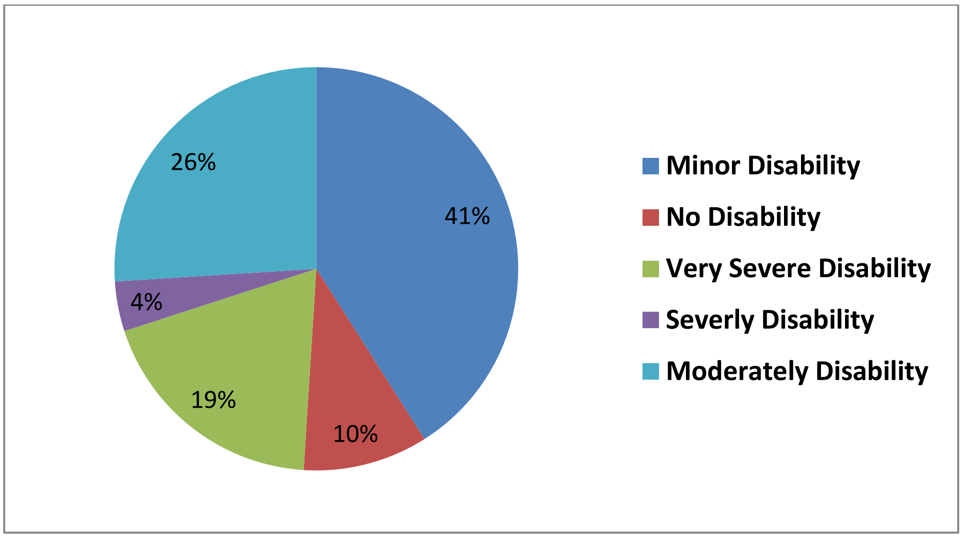

Figure 1.2: Percentage of disability due to stroke

` Based on the data above, an assistive device is needed as tools to assist human daily activities such as mobility assistance for patient that under therapy program to perform their daily activities [5]. Besides, assistive device is needed as well for senior citizens who facing skeletal muscle degenerate problem and lead to minor disability or partially disability. Hence, a lower limb exoskeleton robot is an assistive device and wearable mechanism that assist human in performing daily activities such as walking and stairs climbing. With the help of this exoskeleton robot, patient who suffers from partially physical disabled able to perform daily activities independently.

Development of the exoskeleton robot cannot be achieved without tackling some technical challenges. The challenges in exoskeletons are in three areas which are electromechanical implementation, signals controlling and building up the structure model.

In addition, the device must be easy to control, comfortable, silent and aesthetically acceptable.

1.2 Problem Statement

Climbing stairs will be the motion investigated in this project. In order to climb stair several important factors should be considered including the angle of trajectory for hip and knee to perform stairs climbing motion, the accuracy of the limb assistive device for stairs climbing in term of actuator rotation and the accuracy of the proposed trajectory derived using cubic polynomial compare to the normal human stairs climbing gait.

The trajectory angle for hip and knee of stairs climbing is study by referring to the study from DR S.J. Abbas at year 2013. Besides, the accuracy of the device is ensured by choosing the suitable actuator with high accuracy in term of rotation to ensure the angle of trajectory of limb assistive device is precise to prevent it move excessively. These may cause injury to the user or unstable while completing the stair climbing motion. Therefore, a good actuator with high accuracy in term of rotation in the design is needed to ensure the angle of trajectory is accurate to provide smooth motion for completing one stair climbing motion.

Besides, the accuracy of the proposed trajectory derived using trajectory generation from the normal human gait to climb stairs is compared with the normal human gait to climb stairs. This comparison is made using software simulation and lab test in order to study the accuracy of the proposed trajectory. The accuracy of the proposed trajectory must achieve 80% when compared to normal human gait to perform stairs climbing to ensure the smoothness and balance of the motion. The user may fall from stairs if the accuracy of the proposed trajectory is not accurate.

1.3 Project Objectives

i. The aim of Final Year Project is to develop limb assistive device that follows the staircase climbing trajectory of a normal human.

ii. The objective is to prove the idea of designing the stairs climbing trajectory by using cubic polynomial equation for the limb assistive device is valid in term of accuracy and repeatability while performing stairs climbing motion.

1.4 Scope of the Project

i. The design is limit for 2 degree of freedom.

ii. The design is mainly focus on hip and knee motion.

iii. The stairs climbing trajectory is limited to the design of stairs for public environment with height of 17cm and wide of 29cm.

1.5 Outline of the Dissertation

In Chapter 1, the motivation of the research will be stated. The problem statement are clarified, project objectives and scope of the project are listed. In Chapter 2, the anatomy of stairs climbing are discussed, theoretical background of the exoskeleton is covered, and the trades off solutions for assisting stairs climbing is compared and making a summary of the available trades off.

In Chapter 3, Research Methodology will detail the method to derive the trajectory of stairs climbing from the human behavior to climb stairs by using trajectory generation. Besides, the experiments involve to test on the proposed trajectory including the consideration in term of validity and reliability is discussed. Lastly, the development of the prototype to carry the experiment test is discussed.

In Chapter 4, the result from each test is analyzed in term of statistical method and graphical method. The discussion is made to give reason of the deviation of the results. In Chapter 5, the conclusion and the future works of the research is made. The references and appendix followed after Chapter 5. Figure 1.3 shows the outline dissertation of the report.

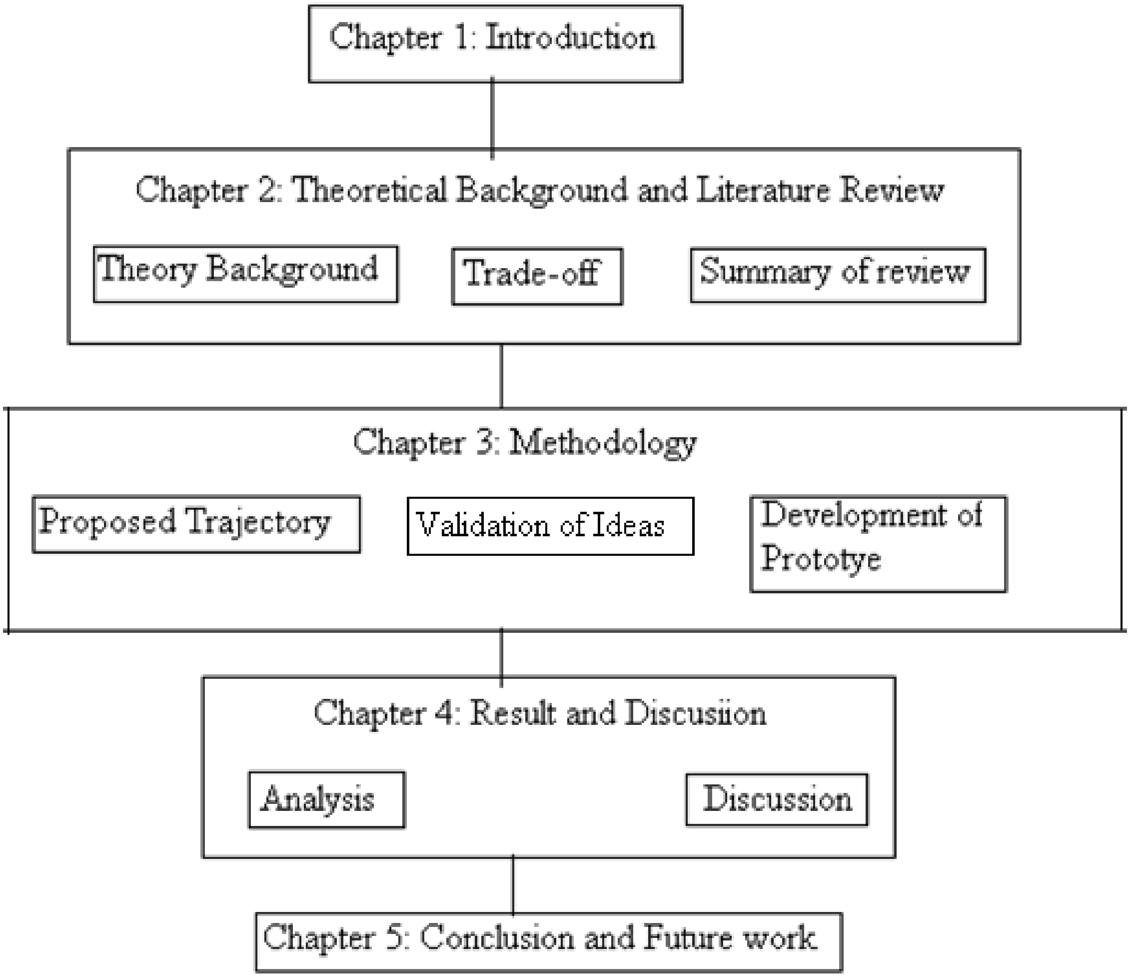

Figure 1.3: Outline Dissertation of Report

CHAPTER 2

LITERATURE REVIEW

The research on exoskeleton robot is conducted. There are 4 fields to be study. The first field is anatomy of lower limb of a normal person for stair ascending motion trajectory. The next section is to study the theoretical background of exoskeleton robot including the system block diagram of the project, trajectory generation to derive the general equations for stairs climbing trajectory, manipulator dynamic to find the minimum required torque for the actuator and list out the performance indices. Moreover, the revision of other works from journal and making comparison on method and listed down the performances and limitations in order to select a suitable method and components for stairs climbing trajectory based on the solution trades offs. Lastly, a research question is proposed based on the literature review and the hypothesis is made.

2.1 Anatomy of Stair Ascending Motion

Human leg consist total of 7 DOF (degree of freedom) which are the hip with 3 rotational degree of freedom, knee with 1 rotational degree of freedom and ankle with 3 rotational degree of freedom. The weight distribution for lower limb of a human is varies from 31.1% to 37.36% [6].

During stairs climbing movement, the lower limbs move in a cyclical pattern similar to that of level walking, the gait cycle is divided into two phases: which are stance and swing phases. The stance phase is 66% and the swing phase is 34% [7, 8]. Human walking gait cycle is represented as the beginning (0%) and ending (100%) at the point of heel strike on the same food [9, 10]. Figure 2.1 shows the walking cycle of stairs climbing. Besides, there are 5 phases of stairs climbing trajectory. The stairs climbing trajectory stance phases include weight acceptance phase, pull-up phase, and forward continuous. On the other hand, the swing phase of stairs climbing trajectory include foot clearance, and foot placement phase. The phases of stairs climbing trajectory are illustrated in Figure 2.2, Figure 2.3, Figure 2.4, Figure 2.5 and Figure 2.6.

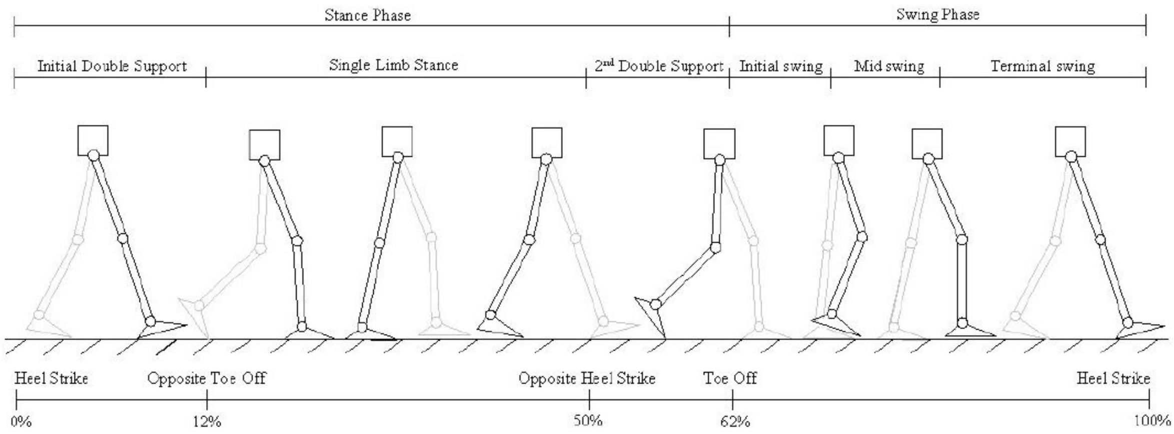

Figure 2.1: Walking cycle for stairs climbing motion, adapted from [6]

Figure 2.2: Weight acceptance phase, adapted from [8]

Figure 2.3: Pull-up phase, adapted from [8]

Figure 2.4: Forward continuos phase, adapted from [8]

Figure 2.5: Foot clearance phase, adapted from [8]

Figure 2.6: Foot placement phase, adapted from [8]

There are 2 types of gait cycles for stair ascending motion which are step-over-step and step-by-step. Figure 2.7 below illustrate the types of gait cycles for stair ascending motion.