UNIVERSITI TEKNIKAL MALAYSIA MELAKA

PSM TITLE :

DESIGN AND DEVELOPMENT OF TRAJECTORY FOR LOWER LIMB ASSISTIVE DEVICE USING CONTRALATERAL LIMB MOTION

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Electrical Engineering (Mechatronic) with Honours.

by

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DESIGN A BND DEVELOPMENT OF TRAJECTORY FOR LOWER LIMB ASSISTIVE DEVICE USING CONTRALATERAL LIMB MOTION

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DECLARATION

I hereby, declared this report entitled "Design And Development Of Trajectory For Lower Limb Assistive Device Using Contralateral Limb Motion" 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 Electrical Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Electrical Engineering (Mechatronic) with Honours.

Signature	:	………………………………………………
Supervisor's Name	:	………………………………………………
Date	:	………………………………………………

ABSTRACT

This report is a proposal about research project on Lower Limb Assistive Device using Contra Lateral Motion. There are two session for this final year project. The first phase covered research on the need elements in assistive device while the second phase focused on prototype development and performance analyzing. The motivation of doing this title is to help mobility disorder patients such as senior citizens and stroke patients in walking forward. The objective of this project is to design and develop a lower limb assistive device that using contralateral motion to perform walking trajectory. The scope of the project is limited to hip and knee joint, and only limited to single leg. At the beginning of this research, the project is planned to focus only for trajectory of assistive device of single leg. Due to costs and safety factors, the prototype was built with double legs as representation of human lower limb with assistive device. The performance indices for this prototype are focused on accuracy and stability. The main idea for this prototype's operation is using a delay as a gap between healthy and impaired legs for walking purpose.

In the early stage of this project, flexible bend sensor was used and after some experiments have been done, several disadvantage of this sensor was identified. Due to this reason, the sensor was replaced by potentiometer and it was used until the end of project. The experiment for this project covers accuracy and stability test. The accuracy test was done by comparing input trajectory and device trajectory while the stability test is done by test the prototype in walking trajectory. From observation in experiments has been done, the trajectory performed by the device reached to 90% for accuracy since the actual values by the device are approximately close to desired value while the stability for the device is out of specification due to unstable position while performing trajectories of walking.

ABSTRAK

Laporan ini adalah satu cadangan mengenai projek kajian mengenai Peranti Bantuan Anggota Bawah menggunakan pergerakan sisi bertentangan. Terdapat dua sesi bagi projek tahun akhir ini. Fasa pertama meliputi penyelidikan pada unsur-unsur keperluan dalam peranti bantuan manakala fasa kedua memberi tumpuan kepada pembangunan prototaip dan menganalisis prestasi. Motivasi menjalankan tajuk ini adalah untuk membantu pesakit gangguan mobiliti seperti warga emas dan pesakit angin ahmar dalam berjalan ke hadapan. Objektif projek ini adalah untuk mereka bentuk dan membangunkan anggota peranti bantuan yang lebih rendah yang menggunakan gerakan sisi bertentangan untuk melaksanakan trajektori berjalan. Skop projek ini adalah terhad untuk pinggul dan sendi lutut, dan hanya terhad kepada kaki tunggal. Pada awal kajian ini, projek ini dirancang untuk memberi tumpuan hanya untuk trajektori peranti bantuan kaki tunggal. Oleh kerana faktor kos dan keselamatan, prototaip dibina dengan dua kaki berfungsi sebagai perwakilan anggota badan manusia yang lebih rendah dengan peranti bantuan. Indeks prestasi bagi prototaip ini tertumpu kepada ketepatan dan kestabilan. Idea utama untuk operasi prototaip ini ialah menggunakan kelewatan sebagai jurang antara kaki yang sihat dan terjejas untuk tujuan berjalan.

Pada peringkat awal projek ini, sensor bengkok fleksibel telah digunakan dan selepas beberapa eksperimen telah dilakukan, beberapa kelemahan sensor ini telah dikenal pasti. Oleh kerana sebab ini, alat tersebut telah digantikan dengan perintang boleh laras dan ia telah digunakan sehingga akhir projek. Eksperimen untuk projek ini meliputi ketepatan dan ujian kestabilan. Ujian ketepatan dilakukan dengan membandingkan trajektori masukan dan trajektori peranti manakala ujian kestabilan itu dilakukan dengan menguji prototaip dalam trajektori berjalan. Dari pemerhatian dalam eksperimen yang telah dilakukan, trajektori yang dilakukan oleh peranti mencapai kepada 90% untuk ketepatan kerana nilai sebenar oleh peranti ini adalah kira-kira dekat dengan nilai yang dikehendaki manakala kestabilan untuk peranti itu berada di luar spesifikasi kerana kedudukan yang tidak stabil ketika melakukan trajektori berjalan.

ACKNOWLEDGEMENT

I would like to express my deepest appreciation to Dr Fahmi Bin Miskon as my supervisors who taught and guided me until finish my final year project. Never forget to my parents that always give support and motivation to me during the period in completion of this project.

I want thank to my colleagues under the project of Lower Limb Assistive Device because have given cooperation in implement this project and to supervisor and both panels of mine who give encouragement to me in doing this research.

There a lot of challenges in doing this project and I’m grateful to God for grant me idea, spirit, strength and healthy during the period until I finish this thesis. Finally, I would like to thank to all people around me who are directly or indirectly involved in this project including lecturers, tutors, staff and friends. Last but not least, thanks to UTeM for giving me chance to study and doing my degree until I finish my study.

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LIST OF ABBREVIATION

DOE	Design of Experiment
DOF	Degree of Freedom
RHC	Right Heel Contact
DS	Double Support
LTO	Left Toe-Off
SS	Single Support
LHC	Left Heel Contact
DS	Double Support
RTO	Right Toe-Off

CHAPTER 1

INTRODUCTION

This chapter will discuss about motivation, problem statement, project objectives, scope of the project, list of contribution and outline of dissertation. The motivation of this project is based on the problem facing by disabled people. Problem statement section initialized the process of this research. Project objectives are the aim at the end of this research. The scope of the project will describe on the limitation of the project as a boundary of reference. List of contribution will discuss on the focus project in the research. Outline of dissertation is the arrangement of this research.

1.1 Motivation

It is human nature where we need to move to live. But not everyone can move normally especially people with disabilities. Previously, they might be involved in incident which leads them to this situation where their lower limb has nerve interference problem or muscle weakness.

According to a study initiated by Christopher & Dana Reeves Foundation, 1 in 50 people living with paralysis [1]. The following figure shows several causes of the paralysis and spinal cord injuries in United Stated (US).

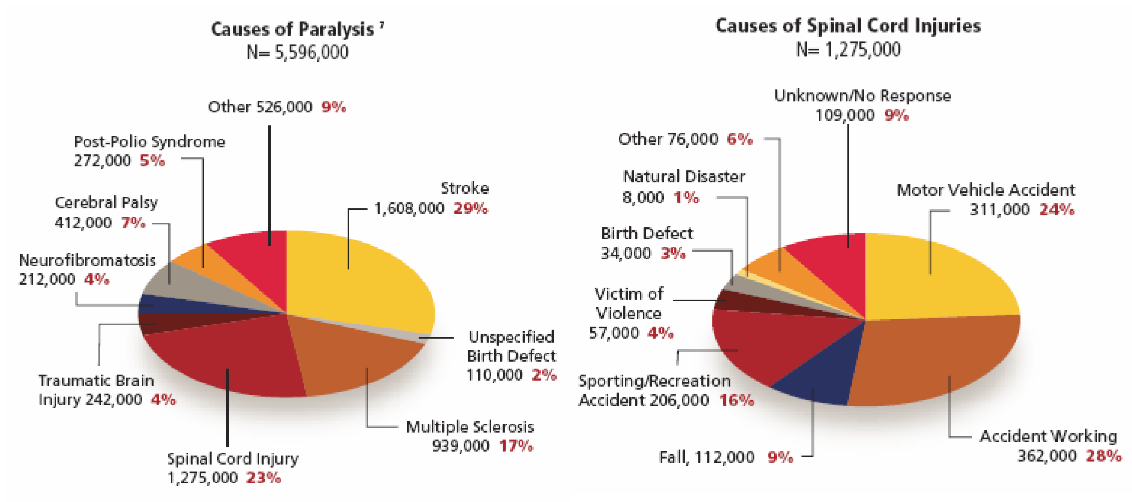

Figure 1: Statistic of the causes of paralysis and spinal cord injuries [1].

Even though these are statistic in US, the problems still no exception in other countries. This problem also faced by Malaysia. Among of disabled people, some of them have impairment leg at one side of their lower limbs. In order to help these people, one of the solution ways is to build the lower limb assistive using contralateral motion. Lower limb assistive device using contralateral motion is a device that used to enhance people who have disabilities at one side of lower limbs to move by using healthy leg side gait pattern. The synonym word for contralateral is opposite side. By developing this device, people who have disabilities which have leg impairment on one side of lower limbs can move like normal healthy person. This will help them a lot in their daily lives.

1.2 Problem Statement

Disabled people who have leg impairment at one side of lower limbs need a support to balance and assist them while walking or moving. Assistive devices available in market to help people to move have limitations. Crutches, walker and wheelchair are assistive device that usually use. These device need hand to use it. Clearly, there is disadvantage on these devices where hand of its user cannot move freely or doing any task that require hand. In development of the lower limb assistive device using contralateral motion, it will be need a least one system to make it operate. The problem is what kind of system that will be used for the device. What kind input and output parameters involves in the system.

The problem for this development of lower limb assistive device using contralateral motion is how to apply the healthy leg gait pattern to the assistive device in helping user to move the affected limb. In order to assist human in walking, the device must suit to kineticism of human leg which means each center of user leg's joint must be in line to the assistive device joint. If this specification is not fulfilled, the device cannot be function well in helping user to walk. Other than that, the accuracy of trajectory is one of important performance need to have by this device or a lower extremity exoskeleton.

This is to make sure that the actual trajectory performed by assistive device follows the desired trajectory by user. Since it is single leg version of assistive device, it is needed to ensure that the device can support human body by considering the stability of center of gravity (COG) of human body while the assistive device with affected leg in support phase (SP). As usual as others engineering design, the design of the assistive device should have safety criteria which it is to make sure the users are not harmed by the assistive device.

1.3 Project Objectives

There are 3 objectives have been set for this project which is:

1. To design a control system for lower limb assistive device using contralateral limb motion.
2. To develop assistive device for disabled people who have impairment at one side of lower limbs.
3. To do analysis such as testing the trajectory, accuracy, stability of the assistive device which generated by healthy limb

1.4 Scope of the Project

The scopes of this project are categorized into the limitation of time and the implementation itself. The period to work up for this project is about 9 months. The implementation of this project is just focusing on helping people who have disabilities with impairment at one side of lower limbs to walk. For safety purpose, this prototype will be developed in scale ratio model.

The first phase of this project is focusing on research and some experiment will be implemented based on hypothesis of the project. The second phase of this project is focusing on lower limbs assistive device prototype development and analysis about prototype’s performance.

The prototype will use external power source to power up its system. Preferable supply for this prototype is rechargeable battery and adapter. Arduino microcontroller board is chosen as the controller in this project. The prototype only focus on hip and knee joints.

1.5 List of Contribution

Lower limb assistive device using contralateral limb motion is a device that used to help disabled people who have leg impairment at one side of lower limbs to walk or move. It operates by using gait pattern of healthy leg side. In order to make it function like its purpose, an angle position type sensor will be placed at the joints or pleat of leg.

1.6 Outline of Dissertation

This thesis is presented as follow:

CHAPTER 1: About the basic point of this research which describe about significant components like motivation, problem statement, project objectives, scope of the project, list of contribution and outline of dissertation.

CHAPTER 2: About the theory that will be used in the research and research on exist exoskeleton.

CHAPTER 3: About the development of idea and come out with sketch of own design of the assistive device. Included in this chapter are data and method use in implementation the experiment have been designed.

CHAPTER 4: About the result and data analyzing

CHAPTER 5: Conclusion of research.

CHAPTER 2

LITERATURE REVIEW

The purpose of this research is to get the knowledge from previous study about exoskeletons and use it to help in the development of the lower limb assistive device using contralateral motion. This chapter is divided into two sections which are the first section will be discuss on theoretical background that will be applied in the project while section two is more on review others work which have been done before.

2.1 System Block Diagram

Basically, a robot control system block diagram consists of trajectory generator and control system. For assistive device like exoskeleton, the control system will be like figure below.

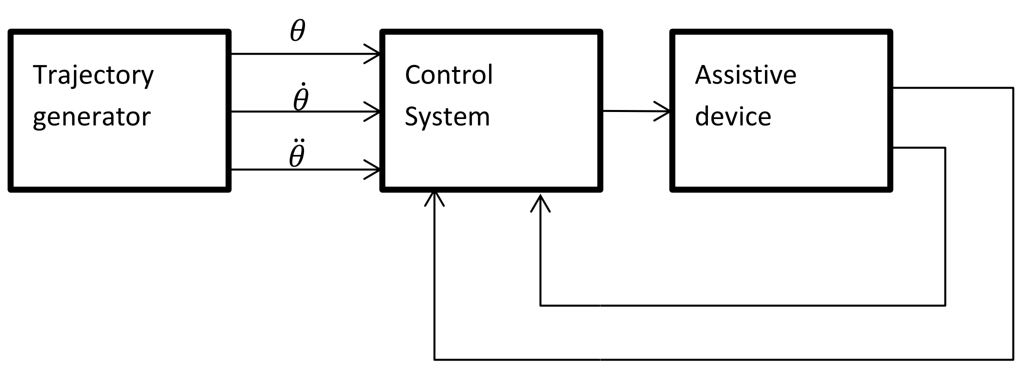

Figure 2: Basic block diagram for robotic

2.1.1 Performance Indices

An invention needs to have several performance indices to take into account. This is must to make sure it meets engineering specification base on the application which applying it. For this assistive device, it has its own specs. We can use design of experiment (DOE) based on the research of previous study after consider the criteria which have been highlighted and make some improvement to our system.

The performance indices that focused for this prototype are accuracy and stability. For this contra lateral prototype, a hypothesis is made. The hypothesis for this project is; by using assistive device using contra lateral motion, the gait performance for disabled people can be improved to 90%.

2.1.2 Method of Analysis

Some of performance indices can be measured directly and some of it can be measured indirectly. For this project, it will cover 2 variables of performance which is accuracy and stability. The accuracy of the system can be analyzed by measuring the angle position of the assistive device and desired output made by healthy limb using flexible sensor. The stability of the system can be measured indirectly by using gyroscope. All of these will be discussed in chapter 3.

2.2 Human biomechanics

In implementation of development of a lower limb assistive device, it is must to have a design where its components fulfill the movement nature of human foot. The physical components like joints and links move and create trajectory. The trajectory is consists of position, speed and acceleration in a time line. But all of these depend on the limitation of leg.

Before begin a deep research, it is needed to know the basic knowledge about human body. Planes of human body are consists of 3 planes which are Coronal (Frontal) plane, Sagittal (Medial) plane and Axial (Transverse) plane. Figure below illustrate the planes of human body.

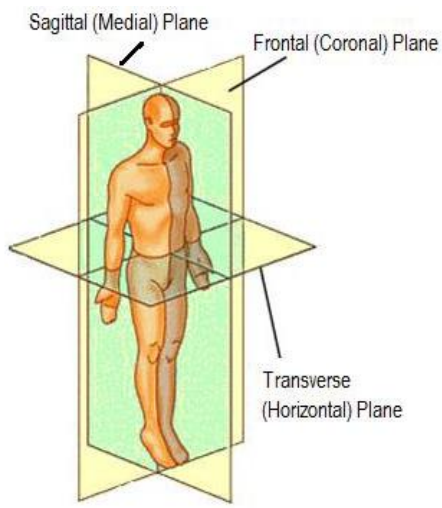

Figure 3: Planes of the body [2].

Kinesiology is science of human movement which it can be used to study about human leg movement. Human leg movement consists of flexion, extension, and hyper-extension. There are several movement can be implemented by human leg. The following figure shows the movement of human leg.

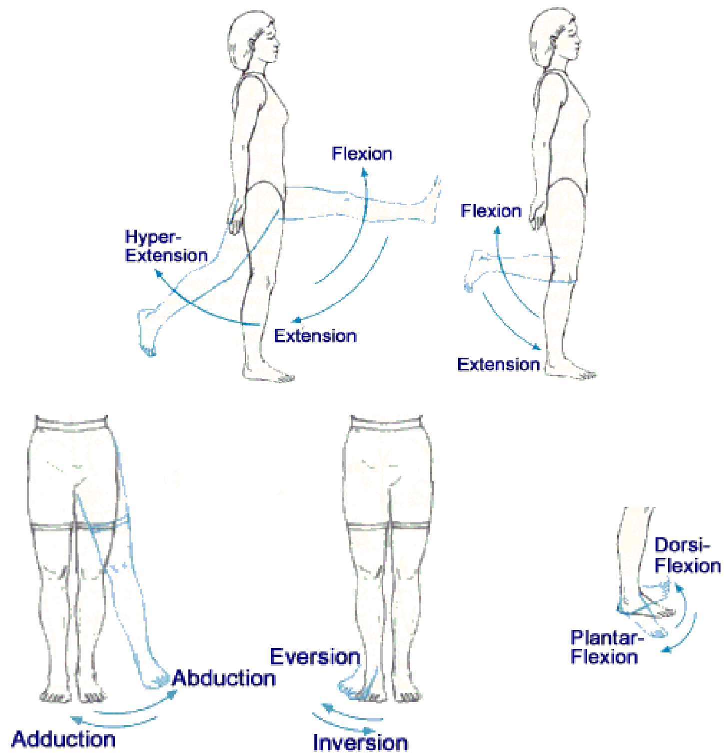

Figure 4: Human leg movements [3].

All of this movement has its own limitation. This limitation also known as range of movement or motion (ROM). The following table shows the range of motion of human leg.

Table 1: Average ROMs (Adapted from Luttgens & Hamilton, 1997)

Joint/Segment	Movement	Source 1*	Source 2*	Source 3*	Source 4*
Hip	Flexion	100	120	125	120
	Hyperextension	30	10	10	30
	Abduction	40	45	45	45
	Adduction	20	-	10	0-25
Extended Hip	Internal Rotation	40	35	45	40-45
	External Rotation	50	45	45	45
Knee	Flexion	150	120	140	130
Ankle	Plantar flexion	20	45	45	50
	Dorsiflexion	30	15	20	20

Table 2: ROM of human leg joint [4]

Joint	Typical Range of Motion (ROM)	Angle (°)
HIP	Flexion	0 – 125
	Extension	0 – 30
	Adduction (inward across body)	0 – 25
	Abduction (outward)	0 – 45
	External (lateral) rotation	0 – 60
	Internal (medial) rotation	0 – 40
KNEE	Flexion	0 – 140
	Extension	0 mark is shin in line with thigh
ANKLE	Dorsiflexion (up toward shin)	20
	Extension (Toes pointed away from leg or plantar flexion)	50
	Inversion (tilt outward)	30
	Eversion (tilt inward)	15

By comparing table 1 and table 2, there are small differences between some of data. Even so, this ROM still can be used as a reference for the development of the lower limb assistive device.

Other than that, mass of lower limb and torque provide by joints at the lower limb need to be considered. Therefore, it is necessary to know human leg anatomy in order to develop a single leg of assistive device. Leg part is consists of links and joints. The links at leg are thigh and shank while the joints are hip, knee and ankle joint. These joints have its limitation capability.

As we know, each object has mass including human body. The total mass of human body is sum of each of body part’s mass. Before developing the assistive device, we need to know leg mass of human body. The purpose of this study is to make sure that the assistive device that will be designed can lift and support the affected leg in any movement. The percentage of body part to body mass total can be found by using body segment parameter which has been done in previous research. The mean of subject which have been selected in research DeLeva, P (1996) is like table below.

Table 3: Number subject of the research

Means			
Subject	Weight (kg)	Age (yrs)	Height (cm)
100 Men	73	23.8	173.1
100 Women	61.99	19.0	173.5

According to the research by DeLeva,P (1996) the average height of The following table shows the body segment parameter from the research.

Table 4: Body segment parameter data from Zatsiorsky et al. (1990), as modified by deLeva (1996) [5]

Segment	Endpoint		Mass (%mass)		CM (%length)		Sagittal k (%length)		Transverse k (%length)		Longitudinal k (%length)	
	proximal	distal	female	male	female	male	female	male	female	male	female	male
Head	VERT	MIDG	6.68	6.94	58.94	59.76	33.0	36.2	35.9	37.6	31.8	31.2
	VERT	CERV	6.68	6.94	58.94	59.76	27.1	30.3	29.5	31.5	26.1	26.1
Trunk	SUPR	MIDH	42.57	43.46	41.51	44.86	35.7	37.2	33.9	34.7	17.1	19.1
	CERV	MIDH	42.57	43.46	41.51	44.86	30.7	32.8	29.2	30.6	14.7	16.9
	MIDS	MIDH	42.57	43.46	41.51	44.86	37.9	38.4	36.1	35.8	18.2	19.7
Upper Trunk	SUPR	XYPH	15.45	15.96	20.77	29.99	74.6	71.6	50.2	45.4	71.8	65.9
	CERV	XYPH	15.45	15.96	20.77	29.99	46.6	50.5	31.4	32.0	44.9	46.5
Mid Trunk	XYPH	OMPH	14.65	16.33	45.12	45.02	43.3	48.2	35.4	38.3	41.5	46.8
Lower Trunk	OMPH	MIDH	12.47	11.17	49.20	61.15	43.3	61.5	40.2	55.1	44.4	58.7
Upper Arm	SJC	EJC	2.55	2.71	57.54	57.72	27.8	28.5	26.0	26.9	14.8	15.8
Forearm	EJC	WJC	1.38	1.62	45.59	45.74	26.1	27.6	25.7	26.5	9.4	12.1
	EJC	STYL	1.38	1.62	45.59	45.74	26.3	27.8	25.9	26.7	9.5	12.2
Hand	WJC	MET3	0.56	0.61	74.74	79.00	53.1	62.8	45.4	51.3	33.5	40.1
	WJC	DAC3	0.56	0.61	74.74	79.00	24.4	28.8	20.8	23.5	15.4	18.4
	STYL	DAC3	0.56	0.61	74.74	79.00	24.1	28.5	20.6	23.3	15.2	18.2
	STYL	MET3	0.56	0.61	74.74	79.00	51.9	61.4	44.3	50.2	32.7	39.2
Thigh	HJC	KJC	14.78	14.16	36.12	40.95	36.9	32.9	36.4	32.9	16.2	14.9
Shank	KJC	LMAL	4.81	4.33	44.16	44.59	27.1	25.5	26.7	24.9	9.3	10.3
	KJC	AJC	4.81	4.33	44.16	44.59	26.7	25.1	26.3	24.6	9.2	10.2
	KJC	SPHY	4.81	4.33	44.16	44.59	27.5	25.8	27.1	25.3	9.4	10.5
Foot	HEEL	TTIP	1.29	1.37	40.14	44.15	29.9	25.7	27.9	24.5	13.9	12.4