

DESIGN OF BIPED ROBOT MODEL CONTROLLER

KAMALESHVARAN A/L BALAKRISHNAN

This report is submitted in partial fulfillment of the requirements for the award of
Bachelor of Electronic Engineering (Computer Engineering) with Honours.

Faculty of Electronic and Computer Engineering
Universiti Teknikal Malaysia Melaka

May 2008

REKABENTUK PENGAWAL MODEL BIPED ROBOT

KAMALESHVARAN A/L BALAKRISHNAN

Laporan ini dikemukakan untuk memenuhi sebahagian daripada syarat penganugerahan Ijazah Sarjana Muda Kejuruteraan Elektronik (Kejuruteraan Komputer) dengan Kepujian

Fakulti Kejuruteraan Elektronik dan Kejuruteraan Komputer
Universiti Teknikal Malaysia Melaka

Mei 2008



UNIVERSITI TEKNIKAL MALAYSIA MELAKA
FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

Tajuk Projek : **DESIGN OF BIPED ROBOT MODEL
CONTROLLER**
Sesi Pengajian : 2007/2008

Saya **KAMALESHVARAN A/L BALAKRISHNAN**

mengaku membenarkan Laporan Projek Sarjana Muda ini disimpan di Perpustakaan dengan syarat-syarat kegunaan seperti berikut:

1. Laporan adalah hakmilik Universiti Teknikal Malaysia Melaka.
2. Perpustakaan dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan laporan ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. Sila tandakan () :

SULIT*

(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972)

TERHAD*

(Mengandungi maklumat terhad yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)

TIDAK TERHAD

(TANDA TANGAN PENULIS)

Alamat Tetap: NO : 452, JALAN SRI SEMANTAN 18,

TAMAN SRI SEMANTAN 3A,

28000 TEMERLOH, PAHANG.

Tarikh: 2 MEI 2008

Disahkan oleh:

(COP DAN TANDA TANGAN PENYELIA)


SHARATUL IZAH BT SAMSUDIN

Pensyarah

Fakulti Kejuruteraan Elektronik dan Kejuruteraan Komputer (FKEKK),
Universiti Teknikal Malaysia Melaka (UTeM),
Kampung Berkunci 1290,
Ayer Keroh, 75450 Melaka

Tarikh: 2 MEI 2008


“I hereby declare that this report is the result of my own work except for quotes as cited in the references.”

Signature : 

Author : Kamaleshvaran a/l Balakrishnan

Date : 9 May 2008


“Saya akui laporan ini adalah hasil kerja saya sendiri kecuali ringkasan dan petikan yang tiap-tiap satunya telah saya jelaskan sumbernya.”

Tandatangan : 

Nama Penulis : Kamaleshvaran a/l Balakrishnan

Tarikh : 9 Mei 2008

“I hereby declare that I have read this report and in my opinion this report is sufficient in terms of the scope and quality for the award of Bachelor of Electronic Engineering (Computer Engineering) with Honours .”

Signature : 

Supervisor’s Name: Pn. Sharatul Izah Binti Samsudin

Date : 9 May 2008

“Saya akui bahawa saya telah membaca laporan ini dan pada pandangan saya laporan ini adalah memadai dari segi skop dan kualiti untuk tujuan penganugerahan Ijazah Sarjana Muda Kejuruteraan Elektronik (Kejuruteraan Komputer) dengan Kepujian.”

Tandatangan : 

Nama Penyelia: Pn. Sharatul Izah Binti Samsudin

Tarikh : 9 Mei 2008

DEDICATION

For my beloved mother and father also to my family who always give me support.

ACKNOWLEDGEMENTS

By the Grace of Al-Mighty, finally I have completed my project based on the knowledge and experience that I got during my entire first half of my project flow. Here I would like to take this opportunity to thank the people for their utmost help and guidance given to me. I sincerely appreciate the following people for their utmost cooperation to me during my project flow. To Universiti Teknikal Malaysia Melaka (UTeM), Dean, Head of Department and Lecturers of Faculty of Electronic and Computer Engineering who had always given me their undivided guidance and corrected my mistakes during doing my PSM. I extend my appreciation to the respective Pn. Sharatul Izah Binti Samsudin, my project supervisor who has shared her working experience as well as give me information and also given me full support and guidance in order to build my confidence and ability while doing my project. My panel lecturers who conduct the secondary evaluation for my PSM, En. Mohd Shakir Bin Md Saat and Pn. Siti Huzaimah Binti Husin. Last but not least, my respective parents and my beloved friends who were always keep in touch and guide me during the project. This project is dedicated to everyone who was involved while I am doing the project because without his or her help and support, I would not have been able to create this project successfully.

ABSTRACT

In this project, a controller for a biped robot model is designed. The biped structure modeled is a five link, two dimensional walking robot with a torso and knees but no ankles. The simulation environment contains simulation block for the biped model and a PD controller block for controlling the model. This project covers the modeling and simulation of a biped robot and will be implemented using Matlab/Simulink software. As a basic for the robotics industry, designing model controllers for robots are the most crucial area. We will be able to build a robot in the future by designing a robot model controller. My project is based on the usage of Matlab/Simulink as the software for simulation instead of Solidworks for better performance. The mathematical models used easily appear to be highly nonlinear and high-dimensional preventing the effective use of traditional modeling and control methods. Matlab/Simulink will be used as the software to design the biped robot model controller since Solidwoks software is quite sensitive towards disturbance. Matlab/Simulink software also offers greater performance besides it is easier to control. Other than that, the stability of the biped robot can be improved by using the Matlab/Simulink since biped robot involves gate control and kinematics. There are five main objectives of designing the biped robot model controller. Firstly, to formulate the exact mathematical model of the biped robot. Next, to build biped robot model in Matlab/Simulink and to design model controller of the biped robot. Finally, the objectives are also to analyze controlled biped robot model and to develop graphical user interface, GUI for simulation and biped motion animation. In order to complete my design on the biped robot, I have used a few methods in gaining information. To conclude the work done in this thesis, it can be stated that all of the goals mentioned will be achieved. Where, the simulation of controlled biped robot model will be succeeded and working simulator environment will be developed.

ABSTRAK

Dalam projek ini, sebuah sistem kawalan untuk model robot biped telah direka. Model struktur kawalan biped ini mempunyai 5 rangkaian, gerakan robot dua dimensi dengan torso dan lutut tetapi tiada buku lali. Projek ini merangkumi pemodelan dan simulasi sebuah robot biped dan akan dilaksanakan dengan menggunakan perisian Matlab/Simulink. Simulasi yang dijalankan melibatkan gambarajah blok bagi model biped dan pengawal terbitan seimbang. Sebagai asas kepada industri robot, merekabentuk model kawalan adalah bahagian yang sangat penting. Kita akan dapat membina sebuah robot pada masa hadapan dengan merekabentuk model kawalan robot. Bagi meningkatkan kecekapan projek ini melibatkan penggunaan perisian Matlab/Simulink digunakan dan tidak menggunakan perisian Solidworks. Model matematik yang digunakan adalah tidak linear dan berdimensi tinggi. Matlab/Simulink digunakan sebagai perisian untuk merekabentuk model kawalan robot biped kerana perisian Solidworks adalah sensitif terhadap gangguan. Matlab/Simulink juga menawarkan prestasi yang lebih baik di samping lebih mudah untuk dikawal. Selain itu, tahap kestabilan robot biped juga boleh dipertingkatkan kerana biped robot melibatkan kawalan get dan kinematik. Terdapat lima objektif utama dalam mereka bentuk model kawalan robot biped ini. Antaranya adalah untuk menerbitkan formula matematik bagi model robot biped. Selain itu, ia adalah untuk membina model robot biped ini dalam Matlab/Simulink dan merekabentuk model kawalan robot biped. Objektif yang terakhir adalah untuk menganalisa model kawalan robot biped dan menerbitkan paparan grafik pengguna (GUI), untuk simulasi dan gerakan animasi biped. Pada akhir projek ini, sebuah model kawalan robot biped akan dibina sebagai permulaan untuk pemodelan dan kawalan berasaskan data. Selain itu, satu alat simulasi Matlab/Simulink akan diwujudkan untuk memudahkan pengumpulan data dan simulasi model. Sebagai kesimpulan, semua matlamat yang telah dinyatakan dapat dicapai. Di mana, simulasi

bagi model kawalan robot biped dapat dijayakan dan persekitaran kerja simulasi akan diwujudkan.

CONTENTS

CHAPTER	DESCRIPTION	PAGES
	TITLE OF PROJECT	i
	TAJUK PROJEK	ii
	BORANG PENGESAHAN LAPORAN	iii
	DECLARATION – AUTHOR	iv
	PENGAKUAN – PENULIS	v
	DECLARATION – SUPERVISOR	vi
	PENGAKUAN – PENYELIA	vii
	DEDICATION	viii
	ACKNOWLEDGEMENTS	ix
	ABSTRACT	x
	ABSTRAK	xi
	CONTENTS	xiii
	LIST OF TABLE	xvii
	LIST OF FIGURE	xviii
	LIST OF SYMBOL / SHORT FORM	xx
	LIST OF APPENDIX	xxi
	 INTRODUCTION	 1
1.1	Introduction	1
1.2	Objectives of Project	2
1.3	Problem Statement	3
1.4	Scope of Project	4

1.5	Methodology	5
1.6	Structure of Report	6
LITERATURE REVIEW		7
2.1	Biped Model Structure	7
2.1.1	Biped Dynamics	8
2.1.2	Ground Contact Forces	10
2.1.3	Knee Angle Limiting	12
2.1.4	Biped model block	12
2.2	PD Controller	13
2.2.1	PD controller	13
2.2.2	Control Loop Basics	14
2.2.3	Limitations of PID Control	15
2.3	Graphical User Interface (GUI)	16
2.3.1	Graphical User Interface Functionalities	17
III	METHODOLOGY	18
3.1	Flowchart	19
3.2	Flow of The Work	20
3.2.1	Gather information	20
3.2.2	Choose the proper software	20
3.2.3	Formulate mathematical model	20
3.2.4	Build the mathematical model	21
3.2.5	Design controller of biped model	21
3.2.6	Analyze	21
3.2.7	Develop graphical user interface	21
3.3	Summary	22

RESULTS AND DISCUSSION	23
4.1 The dynamic model	23
4.2 Simulink blocks	30
4.2.1 Simulink block initial structure	30
4.2.2 Biped model blocks	31
4.2.2.1 Biped model/Dynamic model	35
4.2.2.2 Dynamic model $A(q)$ and $b(q,pq,M,F)$	36
4.2.2.3 Biped model/Ground contact	37
4.2.2.4 Ground contact/Calculate forces (L)	38
4.2.2.5 Calculate forces (L)/Leg tip Projection	39
4.2.2.6 Leg tip projection/Vectors	39
4.2.2.7 Calculate forces (L)/Controls	40
4.2.2.8 Calculate forces (L)/Controls/ Control $y'g$	40
4.2.2.9 Calculate forces (L)/Controls/ Control $x'g$	41
4.2.2.10 Controls/ Control $x'g$ /Control	42
4.2.2.11 Calculate forces (L)/Force Projection	43
4.2.2.12 Biped model/Knee stopper	43
4.2.2.13 Knee stopper/Knee control (L)	44
4.2.3 PD Control	45
4.2.3.1 PD control/Create references	48
4.2.3.2 Create references/Walking cycle	49
4.2.3.3 Walking cycle/Phase	50
4.2.3.4 Walking cycle/Step length error	51
4.2.3.5 Double support phase control	51
4.2.3.6 References changes	52
4.2.3.7 Single support phase control	53
4.2.3.8 References changes	54
4.2.3.9 PD control/Controller	55

4.2.3.10	Controller/Detect phase	55
4.2.3.11	Select parameters	56
4.2.3.12	Controller/PDs	57
4.2.3.13	PDs/Discrete PD 1	58
4.2.3.14	Convert to moments	59
4.3	Simulation outputs	60
4.3.1	Results comment	64
4.4	Graphical user interface	65
4.4.1	GUI functionalities	65
4.5	Programming	69
4.5.1	Parameters for the Biped model block	69
4.5.2	Parameters for the PD control block	71
4.5.3	Animation of the Biped movements	72
4.5.4	Biped simulator	75
V	CONCLUSION AND SUGESSTION	85
5.1	Conclusion	85
5.2	Suggestion	86
	REFERENCES	87
	APPENDIX	

LIST OF TABLES

NO	TITLE	PAGE
4.1	Biped model block parameters definitions	29

LIST OF FIGURE

NO	TITLE	PAGE
2.1	Biped model coordinates and constants	8
2.2	External forces	9
2.3	Sketch of one leg in touch with the ground	10
4.1	Biped library model	31
4.2	Biped model	31
4.3	Biped parameter dialog box	32
4.4	Biped model coordinates and constants	33
4.5	Biped model block	34
4.6	Dynamic model block	35
4.7	Dynamic equations block	36
4.8	Ground contact block	37
4.9	Calculate force (L) block	38
4.10	Leg tip projection block	39
4.11	Vectors block	39
4.12	Controls block	40
4.13	Control y'g block	40
4.14	Control x'g block	41
4.15	Control block	42
4.16	Force projection block	43
4.17	Knee stopper block	43
4.18	Knee control (L) block	44
4.19	PD control model	45

4.20	PD controlled Biped model	46
4.21	PD control block	47
4.22	Create references block	48
4.23	Walking cycle block	49
4.24	Phase block	50
4.25	Step length error block	51
4.26	Double support phase control block	51
4.27	DSP reference changes block	52
4.28	Single support phase control block	53
4.29	SSP reference changes block	54
4.30	Controller block	55
4.31	Detect phase block	55
4.32	Select parameters block	56
4.33	PDs block	57
4.34	Discrete PD 1 block	58
4.35	Convert to moments block	59
4.36	Biped model simulation	60
4.37	Biped model simulation output	60
4.38	PD controller model simulation	61
4.39	PD controller model simulation output	61
4.40	PD controlled Biped model simulation	62
4.41	PD controlled Biped model simulation output	62
4.42	PD controlled Biped model with noise simulation	63
4.43	PD controlled Biped model with noise simulation output	63
4.44	Graphical user interface for a controlled Biped system	65
4.45	GUI functionalities	66
4.46	Simulink model	67
4.47	Slow motion	68

LIST OF SYMBOLS / SHORT FORMS

M	-	Momentum
F	-	Forces
PD	-	Proportional-derivative
DSP	-	Double support phase
SSP	-	Single supportphase
GUI	-	Graphical user interface
SP	-	Setpoint
PV	-	Process variable
MV	-	Manipulated variable
PID	-	Proportional-integral-derivative

APPENDIX

NO	TITLE	PAGE
A	Methodology	88
B	Plan of project	89
C	PSM poster	91

CHAPTER I

INTRODUCTION

In this chapter the introduction of project, objectives of project, problem statement, scope of project, brief of methodology and structure of report are presented.

1.1 Introduction

This document describes the biped robot simulation tool for Matlab/Simulink. The tool enables the simulation of the exact dynamics of a two-dimensional biped robot model on a walking surface. The simulation environment contains a simulation block for the biped model, PD controller block for controlling the model and data-based controller block which implements the so-called clustered regression control. A graphical user interface for simulation and biped motion animation is also included. The biped structure modeled is a five-link, two-dimensional walking robot with a torso and knees but no ankles. The walking surface can be defined as a sequence of points connected with straight lines. The interaction between the biped and the ground is modeled using external forces acting on each leg tip when the leg touches the ground. This enables the use of one seven degrees of freedom dynamic model to describe the dynamics of the system in all situations. The ground contact forces are calculated by

separate PD controllers. The PD control method presented for controlling the gait is quite cumbersome, its main purpose being only to enable data collection from the walking biped system. Using this data, the clustered regression model structure is applied to the biped control.

1.2 Objectives of project

This thesis work handled the modeling and controlling of a simple biped walking robot. There are five main goals of designing the biped robot model controller:

- a) To formulate the exact mathematical model of the biped robot. The walking surface is modeled by the external forces (collected in vector F), which are calculated using PD controllers when the leg is touching the ground. The actual control of the biped is done with the moments (in vector M) applied to the joints of the robot.
- b) To build biped robot model in Matlab/Simulink. The structure of the two dimensional model is designed. Then, the momentum (M), forces (F) and the coordinates (q) is determined. The mathematical formula is formulated according to the momentum, coordinates and the forces acting on it and it is then applied in Matlab in the form of coding to determine the motion of the biped robot.
- c) To design model PD controller of the biped robot. To enable the data collection from the biped walking movement, a PD control scheme for the system was developed. The controller contains four independent SISO PD controllers, which follow continuously updated reference signals.
- d) To analyze controlled biped robot model. The animation shows the resulting gait, which is by no means optimal as the parameters of the controllers were tuned by hand. The input and output data of the system can be collected.

e) To develop graphical user interface, GUI for simulation and biped motion animation. Graphical user interface (GUI) was created for simulating a Simulink model including the biped model block and an arbitrary controller. The GUI enables the biped model simulation with specified parameters and the animating of the system behavior. It is also possible to save all the simulation data or only one state of the system to the Matlab workspace.

1.3 Problem Statement

Robotic field is very important in this new millennium. This field is growing widely all over the world. In the growth of this field, Malaysia also has its own robotic based industries. As a basic for the robotics industry, designing model controllers for robots are the most crucial area. We are able to build a robot in the future by designing a robot model controller. My project is based on the usage of Matlab/Simulink as the software for simulation instead of Solidworks for better performance.

Walking robots offer challenging problems in the field of system modeling and control. The mechanical structures of the walkers are usually complex, being composed of many joint-connected parts which impact also with the surrounding environment. We only consider only the input and output data of the system, that is, with the help of data-based techniques. If the relation between the control values given and the resulting state of the robot could somehow been captured, the actual internal structure of the system could be forgotten. Therefore the mathematical models easily appear to be highly nonlinear and high-dimensional preventing the effective use of traditional modeling and control methods.

Here Matlab/Simulink will be used as the software to design the biped robot model controller since Solidwoks quite sensitive towards disturbance. I propose to use the Matlab/Simulink because it offers greater performance besides easy to control. Other than that, the stability of the biped robot can be improved by using the Matlab/Simulink since biped robot involves gate control and kinematics.