AUTONOMOUS HUMANOID BODY BALANCE WHILE CARRYING AN OBJECT

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FACULTY OF ELECTRICAL ENGINEERING

FINAL YEAR PROJECT REPORT 2

AUTONOMOUS HUMANOID BODY BALANCE WHILE CARRYING AN OBJECT

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Bachelor of Mechatronic Engineering (Hons)

DECLARATION

" I hereby declare that I have read through this report entitle Autonomous Humanoid Body Balance While Carrying An Object and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Mechatronic Engineering"

Signature : ....

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Date : ....23/6/16.................

AUTONOMOUS HUMANOID BODY BALANCE WHILE CARRYING AN OBJECT

AHMAD YUSUP SAMSUDIN

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

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2016

DECLARATION

I declare that this report entitle Autonomous Humanoid Body Balance While Carrying an Object is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

Name : AHMAD YUSUP BIN SAMSUDIN

Date : 23/6/16

DEDICATION

To my beloved family.

ACKNOWLEDGMENT

Alhamdullilah, praises to the Allah, the compassionate one yet merciful for giving me the courage and strength to finish and complete this report within allocated time given.

Time flies in a blink of an eye we are now pursuing our final years in Universiti Teknikal Malaysia Melaka (UTEM). We could not mere grateful to UTEM as it allow us to pursue the Bachelor of Mechatronics Engineering in this very own university and to be UTEM graduate.

UTEM have been a great place for to study the field of engineering. While equipped with its own facility, UTEM have been provided us with the appropriate learning environment which is suitable for engineering studies.

Many efforts have poured down to this report. However, it would have not been completed without the support and help from individual and organization. First and foremost, I would like to thank my parent for giving me strength and support to complete this report. Without their support I would have been stuck for a long time to complete the report.

Second, I would like to thank my advisor and guidance which is Encik Bazli Bahar. Without his guidance I would really lost to complete this project.

Last but not least I would like to thank all my friend, especially Shukri Abdul Rahman and Khalid Nor Salikin that have been helping me so much in completing this project.

Last but not least, thank you for all who directly and indirectly helping and supporting me.

ABSTRACT

This final year project highlights on the development of an autonomous body balance while carrying an object for humanoid robot. This project aims to increase the capability and application of humanoid robot in this modern world. The algorithm used need to match the control trajectory need to robust from any disturbances for it to functional well. Experimental result highlights the importance of the control is it improved from the previous research or not. One of the most important criteria in balancing humanoid robot is to control the COM to be in support polygon through entire locomotion. As we know, position of COM changes when humanoid robot moves. In addition when humanoid robot carry load with certain weight especially heavy weight, the position of COM will shift out far from support polygon. Thus, the robot will fell down. To overcome problem robot falling down, suitable method to control the position of COM suggested and be tested.

ABSTRAK

Untuk Projek Sarjana Muda ini menjelaskan tentang pembangunan keseimbangan badan autonomi semasa mengangkat objek untuk robot mirip manusia. Projek ini bertujuan untuk meningkatkan kebolehan serta kegunaan robot mirip manusia di dalam era moden ini. Algorithma yang digunakan perlu bertepatan dengan kawalan trajektori supaya ianya teguh dari segala halangan supaya ianya berfungsi dengan baik. Keputusan dari eksperimen yang dilakukan akan memberi penjelasan mengapa perlunya kepentingan sistem kawalan dan adakah ianya meningkat daripada penyelidikan yang pernah dijalankan sebelum ini.Salah satu kriteria yang penting dalam mengimbangkan robot mirip manusia adalah dengan mengawal pusat jisim supaya sentiasa berada di dalam poligon penyokong sepanjang pergerakan berlaku. Posisi pusat jisim sentiasa berubah ketika robot mirip manusia melakukan pergerakan. Tambahan pula bila adanya penambahan beban untuk dibawa terutamanya beban yang berat, posisi pusat jisim akan berganjak jauh dari poligon penyokong. Sekaligus ianya akan menyebabkan robot tumbang secara spontan.Untuk mengelakkan perkara ini dari berlaku, kaedah yang sesuai perlulah digunakan dan akan dicadang serta dikaji keupayaannya.

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CHAPTER 1

INTRODUCTION

This chapter tells about the motivation, problem statement, objective, and the scope of this project.

1.1 Motivation

Ever since humanoid robot invented, there is high gain interest in humanoid robot especially among researcher, engineer and scientist. Humanoid robots have many functional capability in human environment if use wisely. Imagine if a humanoid robot helping human in daily routine like carrying an object. It might be useful and make task easier. For human carrying an object is so routine that human are almost not aware of it. But, for humanoid robot with two legs it is one of most difficult task. It require considerable energy resources and computing power. The most important criteria when carrying an object is to maintain the body balance.

Thus, with better understanding in body balance for humanoid robot, gives great advantage in robotics and can make humanoid robot become increasingly smarter. With this knowledge, a more realistic and advance humanoid robot can be invent. Perhaps, in future humanoid robot able to replace human in industrial to increase more profit, efficiency and flexibility.

Many research with different method already be done on body balance humanoid robot. K. Kajita perform a research on humanoid robot carry a heavy object using force sensor information [8], Choi Youngjin prefer a method COM Jacobian for humanoid robot balancing [15], Papa. E using the telescopic inverted pendulum (TIP) to perform analyze the sit-to-stand motor task.

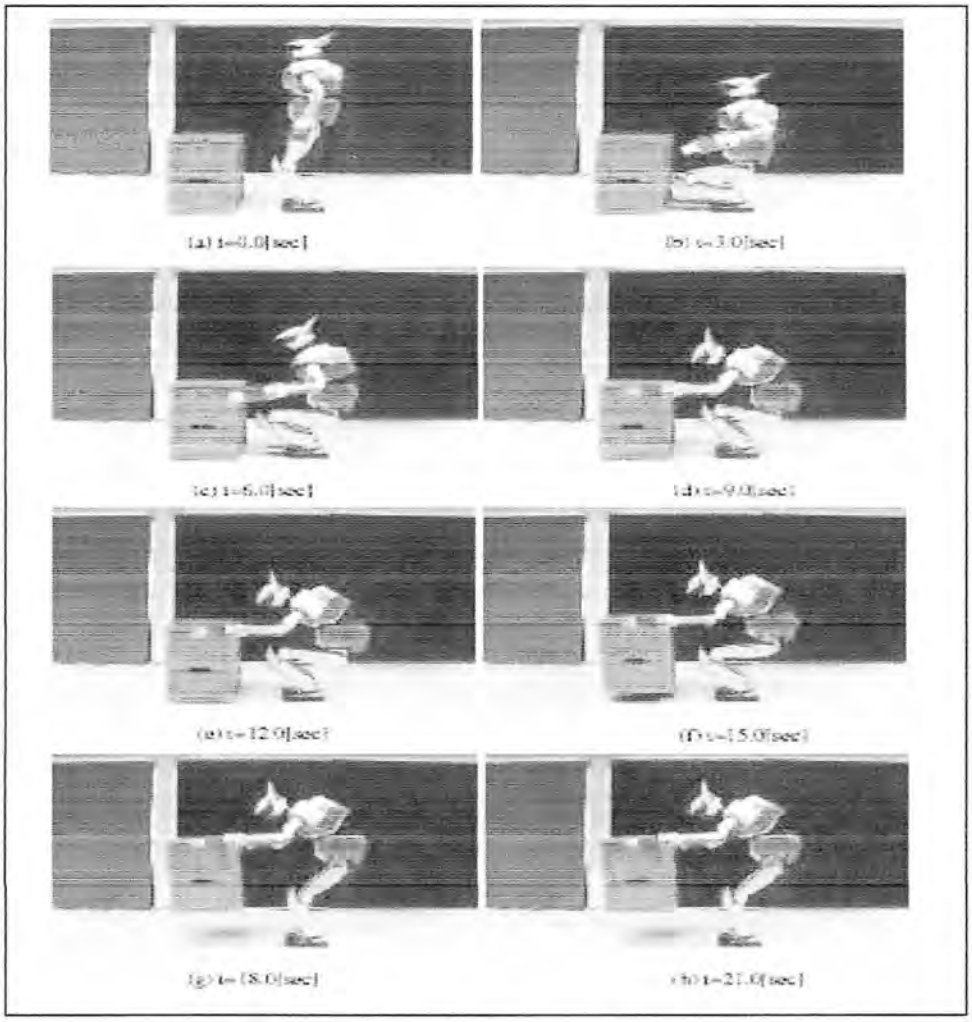

Figure 1.1: A robot carrying an object

From Figure 1.1 above, shows the capability of humanoid robot carrying an object perform by K. Kajita group. The data recorded and information is collect, to estimate how was lifting/carrying an object be done..

From doing this project, new understanding and knowledge can be discover. It is also important as it can help in various industry such as manufacturing industry. Apart from research purpose, humanoid robot built to perform human tasks like personal assistance such as to assist sick people, doing dangerous or dirty job like space and deep sea exploration mission. Thus, this study can be a platform to build a capable and more realistic system of humanoid robot for education and learning purpose in the future.

1.2 Problem Statement

The main challenges while carrying an object for humanoid robot is to maintain the center of mass (COM) to be always inside support polygon. The support polygon is an area where the ground is in touch with the limb or body. For Nao robot, the support polygon located at the foot.

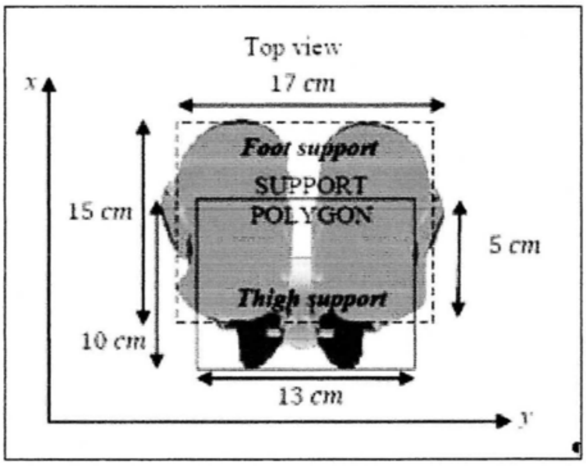

Figure 1.2: Support polygon for Nao robot.

Thus, to maintain or bring COM into support polygon, a good trajectory planning and joint angle determination of robot must be calculated. In other words, an object weight should be identify and hip joint adjustment should be done to perform a carrying/lifting motion.

1.3 Objective

The objective of this project are as follow:

1. To develop and validate a system that able to identify COM.
2. To develop and validate a method to perform autonomous humanoid body balance while carrying an object.

1.4 Scope

The scope of this project covers:

1. This project focusing on lifting an object with proper trajectory.
2. The robot lift an object from table with fixed height which is 0.25 m.
3. The weight object to be lift from 0.1 kg up to 1 kg.
4. Nao robot able to identify the mass from torque reading to find the COM position.
5. The experiment carry out in V-Rep software interface with Phyton software.
6. All analysis for this project based from simulation in V-rep software.

1.5 Summary

From this chapter, motivation, problem statement, objective and scope of this project are clearly describe and stated. The motivation for this project are to gain knowledge to make more realistic humanoid robot system. The main problem are how to make the COM always in support polygon for stability and balancing. The objectives for this project consists of two while the scope for this project are six.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter represent about the theoretical background of humanoid robot which tell about basic knowledge about robotic history, description of trajectory generation, dynamic and kinematic law, artificial intelligence (AI), locomotion and control system, and cognition. This chapter also touches past studies and researches of several people in robotics field. At the end, there is conclusion about best method.

2.2 Theoretical Background

2.2.1 Humanoid Robot

A robot with its body shape built resembles to human body shape is called humanoid robot. Due the designed that resembles human body, humanoid robot are widely used as a research tools in many different sector such as biomechanical and medical purpose. According to [10], humanoid robot should have three features which are 1) able to replace human performing task in environment, 2) able to use tools for humans and 3) resembles human-like shape.

For the first feature, designated humanoid robot should be able to cope with human environment like walking on an uneven floor. The second feature means humanoid robot able to use tools like using screwdriver by articulated fingers. For the third features, it is deals about capability humanoid robot to impersonate human with their human-like shape such as dancing, speaking and so on.

Development of humanoid robot starting with WABOT-1, first humanoid robot in the world develop by Ichiro Kato from Waseda University in 1973 [10]. WABOT-1 able to recognize object by vision, understand spoken language and can manipulate object by two hands and can walk on biped legs. Then, WABOT-2 develop at 1982 by Ichiro Kato's group and able to play piano and performing at Tsukuba Science Expo'85 in Japan [10]

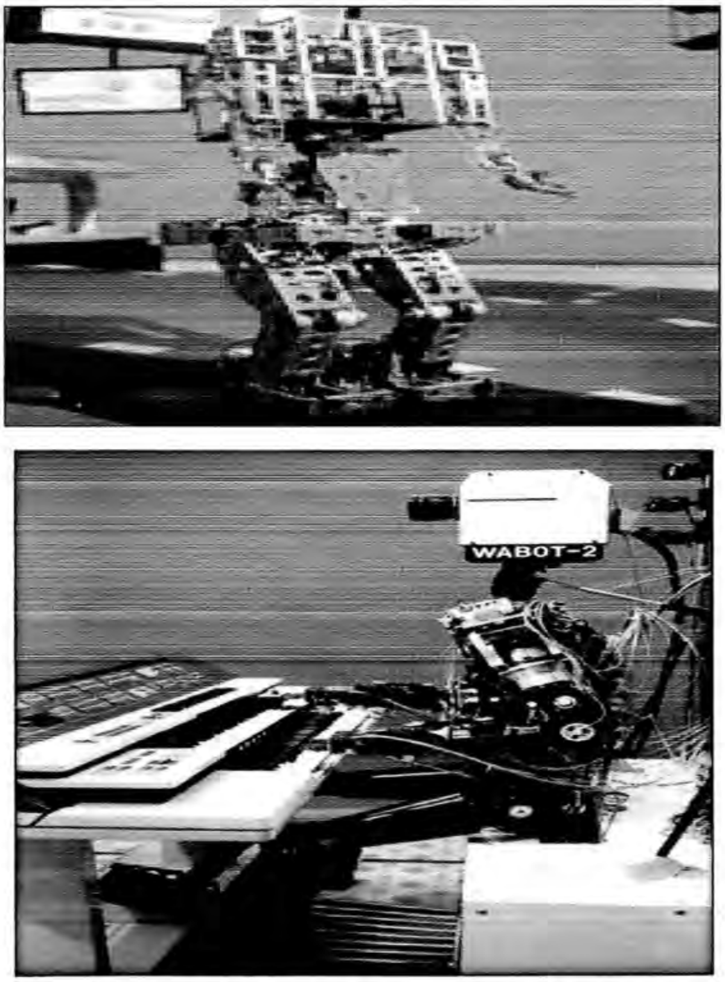

Figure 2.1: WABOT-1 (up) and WABOT-2 (down) humanoid robot [10].

2.2.2 Trajectory Generation

Trajectory generation is desired motion for the manipulator to move in space. According to [1], trajectory refers to time history of position, velocity and acceleration for each degree of freedom. The desired trajectory generation for the robot to move smooth is important. The problem occur when dealing with trajectory generation is human-interface problem which is on how to specify and control a trajectory (initial position to desired position) through space [1]. Figure 2.2 below shows process of trajectory generation from initial to desired position taken from J.J Craig book Introduction To Robotics.

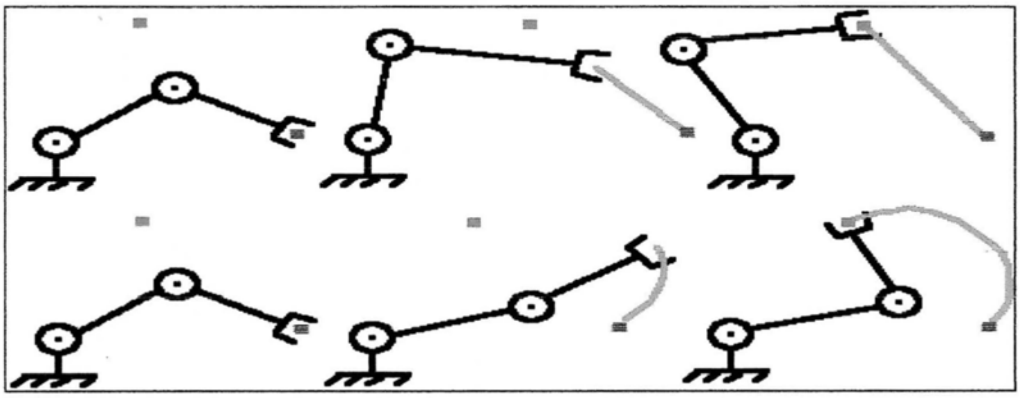

Figure 2.2: Example of robotic arm smooth trajectory generations.

2.2.3 Dynamic and Kinematic Law

Research and study in robotics need deeply understanding on dynamics and kinematics fundamental law. According to [1], kinematics is science of motion that treats the subject without regarding the force that cause it while dynamics is study about forces required to cause motion.

In kinematics, there is forward and inverse kinematics. Thus also same for dynamics, where there is forward and inverse dynamics. For forward dynamics, it tells about problem of controlling the manipulator (robot) while inverse dynamics is about problem of simulating the manipulator (robot).

Basically, kinematics involve with complex geometry manipulator, which require user to able locate and control position of manipulator within time-frame as the mechanism articulates to its desired motion. In order to compute this movement, various method can be used such as Jacobian matrix. Jacobian is a square matrix. Equation (2.1) below shows Jacobian matrix that consists of matrices a, b, c, and d that relates Cartesian velocity (x, y) and joint velocity (q1, q2).

$$\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} a & c \\ b & d \end{bmatrix} \begin{bmatrix} q1 \\ q2 \end{bmatrix} \quad (2.1)$$

For dynamics manipulator, a rigid body (robot) that can move in 3 dimensional have many possible rotation axes. Centre of mass (COM) of a rigid body located at a single point which the mass distribution throughout the body are balance. According to the Newton 2nd Law,

$$F = MA \quad (2.2)$$

Thus, force (F) will acting through COM and give acceleration (A) to the rigid body with respect to the total mass (M) of a rigid body.

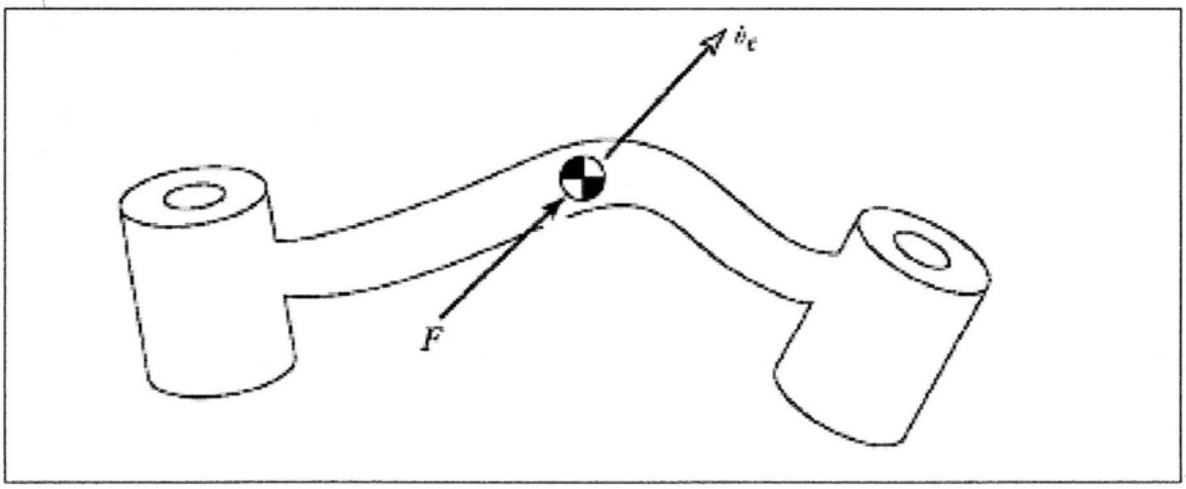

Figure 2.3: Force, F acting through COM.

2.2.4 Artificial Intelligence

According to Elaine Rich in [2], artificial intelligence is the study on how to make computers do things at which, at the moment, people are better. There are many example of artificial intelligence such as fuzzy logic controller. According to [11], fuzzy logic control provides formal methodology for manipulating, represent and implement a human's heuristic knowledge about how to control a system. Figure 2.3 shows the basic architecture of fuzzy logic system.

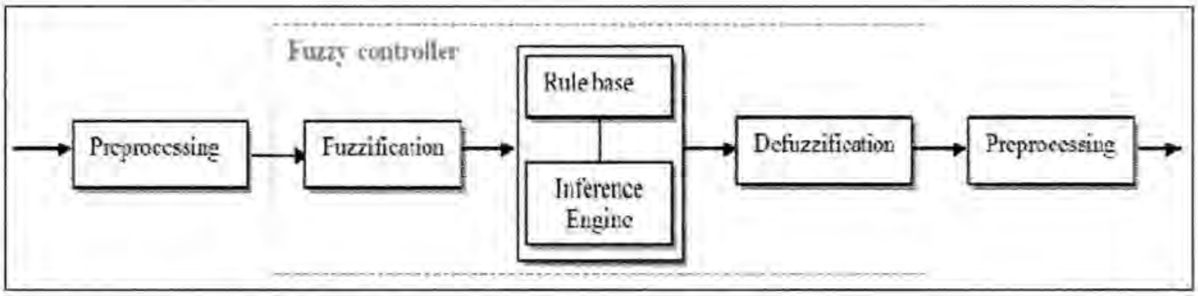

Figure 2.4: General architecture of fuzzy logic control.

2.2.5 Locomotion and control system

In general, locomotion means is an ability or capability to do motion. There are variety motion that can include in robotic such as sitting, standing, walking, rolling and so on. These motions have their own energy consumption, kinematics and dynamic parameter, stability different from each other. Besides that, to perform and control the motion, a controller is need. There is a lot of controller that can be use and applied in robotics. Common controllers are linear, non-linear, PI, PD and PID controller.

For linear controller, the location of dominant poles in the real-imaginary plane shows the nature of the motions of the system [2]. There are 3 types of linear control that must be decide if the equation have,