FACULTY OF ELECTRICAL ENGINEERING

COOPERATIVE BETWEEN TWO HUMANOID ROBOTS IN COMPLETING TASKS

Tan Ying Ying

Bachelor Degree in Mechatronic Engineering

2017

I hereby declare that I have read through this report entitled “Cooperative between two humanoid robots in completing task” and has found that it has comply the partial fulfilment for awarding the degree of Bachelor of Mechatronics Engineering

Signature : …….

Name : …….

Date : …….

COOPERATIVE BETWEEN TWO HUMANOID ROBOTS IN COMPLETING TASKS

TAN YING YING

A report submitted in partial fulfilment of the requirement for

the degree of Bachelor of Mechatronics Engineering

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2017

I declare that this report entitled “Cooperative between two humanoid robots in completing task” 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 : …….

Date : …….

To my beloved father and mother

ACKNOWLEDGEMENT

First and foremost, I would like to thank Universiti Teknikal Malaysia Melaka (UTeM) for providing me such a good study environment and facilities throughout my four-year degree study. I consider myself as a very lucky individual for able to grab the opportunity to study in such wonderful university. I feel grateful for having chance to meet many wonderful people and professionals who provide a good experience throughout this bachelor program.

Bearing in mind previous I am using this opportunity to express my deepest gratitude and special thanks to Faculty of Electrical Engineering's lecturers who provide me with information and preparation during the process of doing FYP.

I am using this opportunity to express my deepest gratitude and special thanks to my final year project's supervisor, Mr Mohd Bazli bin Bahar. Despite of being extraordinary busy with his duties, he took time out to guide and keep me on the correct path while dealing with my FYP.

Special thanks to my family members, coursemates, peers and lecturers for their moral support and technical support. I choose this moment to acknowledge their contribution gratefully.

I perceive as this opportunity as a big milestone in my skill development. I will strive to use gained skills and knowledge obtained in the best possible way.

ABSTRACT

The implementation of robotic technologies in current society has significantly increased over the years especially in industrial and manufacturing field. It has been a great help in ease human daily life. There are plenty of researchers focus on robot-robot collaboration and human operator-robot collaboration. However, lack of research was done for collaboration between two humanoid robots. This is due to the stability and the complexity of controller in control humanoid robots. Although the control of humanoid robot is difficult, there are still some researchers focus on developing humanoid robots which possesses some human characteristic and behaviour of human being. One of the characteristic that possesses by human being is the gregarious, humans are able to work in team to solve problems together. In this project, the main focus is on the movement of humanoid robot's arm. The proposed control system implement IF-THEN rules for the velocity regulator. The rules are set based on the angle disparity in gyroscope and the velocity of robot arm's movement. PID controller are used to regulate the system so the lifting process can be optimized. To verify the utility of the controller proposed, simulations were conducted using Nao robot in V-Rep environment. There were several simulations conducted to test the reliability of the controller and to prove the performance of the humanoid robot increases as the number of robot increases. The result of simulation shows that two Nao robots perform better than single robot when dealing with heavy object according to the object orientation range which is 66.24% less than single robot. Besides, the stability of robot for single robot is less stable compared to two Nao robots during object lifting as shown by foot force sensitive resistor response.

ABSTRAK

Penggunaan robotik telah meningkat setiap tahun terutamanya dalam sektor industri dan pembuatan. Penggunaan robot dalam kehidupan banyak membantu dalam memudahkan tugasan dan kehidupan manusia. Terdapat banyak penyelidikan yang membincangkan kerjasama antara robot dengan robot dan robot dangan manusia. Oleh disebabkan oleh masalah kestabilan dan kerumitan pengawal dalam mengawal robot humanoid, tidak banyak penyelidikan yang memberi tumpuan dalam kerjasama antara robot humanoid. Walaubagaimanpun, terdapat juga penyelidik yang memberi tumpuan dalam pembangunan robot humanoid yang mempunyai sifat-sifat manusia. Kajian tersebut dapat membantu manusia dalam menyelesaikan masalah yang melebihi kemampuan manusia. Sebagai contoh, bekerja dalam suasana yang bahaya, bekerja untuk masa yang panjang dalam sektor pembinaan dan lain-lain. Salah satu sifat yang dimiliki oleh manusia ialah hidup dalam kumpulan, manusia dapat bekerjasama sama sendiri dalam menyelesaikan masalah. Dalam projek ini, tumpuan akan diberikan kepada pergerakkan tangan robot humanoid. Sistem pengawal yang dicadangkan mengaplikasikan peraturan *IF-THEN* untuk pengawalan halaju. Peraturan tersebut ditetapkan berdasarkan perbezaan sudut dalam giroskop dan halaju pergerakan lengan robot. PID pengawal digunakan untuk mengawal selia sistem supaya proses mengangkat dapat dioptimumkan. Untuk mengesahkan utiliti pengawal yang dicadangkan, simulasi dijalankan menggunakan Nao robot dalam persekitaran V-Rep. Terdapat beberapa ujian yang dilakukan untuk menguji kebolehpercayaan pengawal dan untuk membuktikan prestasi robot humanoid bertambahbaik jikalau bilangan robot humanoid bertambah. Berdasar kepada lingkungan orientasi objek, dua robot Nao menunjukkan prestasi yang lebih baik daripada satu robot Nao semasa menangani objek berat dengan 66.24%. Selain itu, robot untuk kategori satu robot Nao tidak seimbang seperti robot untuk kategori dua robot Nao semasa mengangkat objek menurut kepada graf FSR.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF EQUATIONS

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter describe the background, motivation and problem statements to give an idea of the contribution of this research study. The objective, scope and significance of the study are also described here. Lastly this chapter ends with an outline of the thesis.

1.2 Research Background

The purpose of this thesis is to develop a method to perform collaboration of humanoid robot in completing task. Multiple robots have more advantages compared to single robot in the case that the object needed to be carried is large, heavy or the object that has special shape which could not be carried by single robot [1]. Previously, the main focus of cooperative manipulations were performed by wheeled robots, but due to high level of manoeuvrability, humanoid robot get more attention now[2]. Yet, in completing this cooperative feature, there are many aspects involved in the process or action. For instance, the stability of each humanoid robot, the trajectory of humanoid robot in object manipulation, the communication among humanoid robot are the challenges in this field.

As mentioned by Hanzhong Zheng and J.Jumadinova, the potential applications of multi-robot system are highly diverse in various sectors included landmine detection, search-and-rescue operations and others[3]. These sectors involved in huge amount of action, detection, reaction, communication, cooperation and control. Many model and theory are suggested to perfectionate and improve multi-robot system in terms of cooperative feature including Artificial Immune Network, Cooperative Learning and Master-slave system[4]–[6], [7], [8], [9].

After revise past research, most researchers focus in human-robot collaboration and non-humanoid robot collaboration. Only several researches are focusing in humanoid robots' collaboration[1], [5], [6].

1.2.1 Motivation

This project was carried out based on various motivation which focus on humanoid robots that could manipulate object like human. Similar to human, humanoid robot has high manoeuvrability which sometimes can substitute human in tasks. For example, humanoid robot ARMAR-III developed by Karlsruhe Institute of Technology (KIT) serves as kitchen helper as shown in Figure 1.1[10]. Humanoid robot are expected to serve as human's companions or assistance in the future[11].

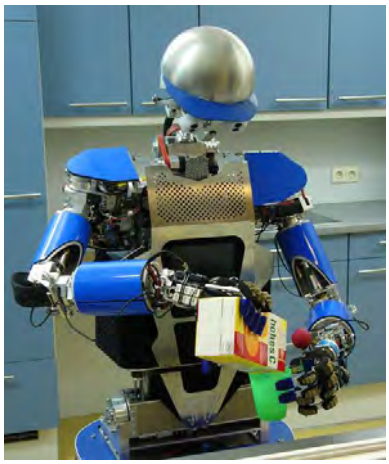

Figure 1.1: The picture of ARMAR-III[10].

Humanoid robots with the ability to lift object able to substitute human from many aspects like serve as labour in goods transportation, serve as waiter in restaurant and serves as bellhop in hotel.

1.2.2 Problem in control humanoid robots to work cooperatively

The main challenge in humanoid robot cooperation is about how humanoid robots can perform simultaneously in completing tasks. In solving the problem, the main component of the humanoid robot is the control scheme. This control scheme must be considered and well-planned for the sake of good performance in object manipulation. Either side of robot which could not react to another robot can cause failure when object manipulation.

Control scheme can be divided into two parts, (1) phase planning and (2) interaction control. As for motion control, the focus of the control scheme is to follow the motion that has been planned to perform object manipulation. Phase planning is a proper plan to separate the whole movement into several phases. The phases are usually separated based on the task requirement at the particular time. However, the motion of humanoid robots in manipulating object are irregular[12]. In case of object transportation with two humanoid robots, mutual position shifts may occur due to the body swinging of robots. Hence, it is necessary to correct the position in a real-time manner[13]. During object manipulation like pushing object required a correct posture to maximize utilization and reduces the load endured at each joint.

The interaction control can be diverse into a few types, included master-slave, Q-learning and reinforcement learning method as well as Artificial Immune Network. Master-slave control is one of a good approach to exchange data among master robot and slave robot. Yet, there is a huge setback for this system at which the whole system will collapse if master robot malfunction. Furthermore, there are time delay exists in the transmission of data between the master and slave side [14]. Q-learning and reinforcement learning has advantage when cooperate with human but not for multi-robot system. Artificial Immune System can perform 2-sided interaction.

1.3 Problem Statements

Cooperative humanoid robots can be applied in hazardous situation such as work under radioactive environment, transport explosive disposal and industrial applications. In present research, a high performance and robust controller was developed for the safe load handling, transportation and trajectory checking[1]. In most of the situation, especially handling complex tasks, a single robot might face problem to accomplish the task on its own.

For example, having problem in lifting or moving object. Hence, cooperation between robots is the best way to complete the tasks. Similar to bio organism, in order to receive help from allies, there must be a sort of contact or communication to inform them or regulate. For example, sound, smoke, light and others. In other words, these signal or communication can help in deliver signal. However, physical signals as mentioned are not suitable to be implemented in a robot network. This is when wireless connection or electrical signal come into solving these issues in coordinate the velocity and amount of torque of the robots in lifting object to balance the object lifted.

Thus, the research question is *how a communication network can be established so other robot can receive the signal?*

Both humanoid robot needs a control scheme in order to regulate their torque or velocity in lifting object to ensure the object lifted always balance. At least two joints from the arm of the Nao robot are needed to lift object, the torque and velocity must be carefully controlled to avoid from causing imbalance of the object lifted. Since both Nao robot might be differed from each other in terms of response time and condition of actuator, the deviation of time, torque and velocity between two humanoid robots may lead to failure of the operation due to imbalance from one side of the robot.

The second research question is *how to control the robot's motion so both humanoid robots can regulate themselves according to the stability of the object?*

1.4 Objective of the Research

From the research question stated in problem statement, the research objectives are:

1. To implement proper trajectory planning for lifting an object using humanoid robot.
2. To design and develop a control system that allows robots to cooperate in lifting object.
3. To develop and analyse the performance of two humanoid robots compared to single humanoid robot.

1.5 Scope of Research

The scope of the research are as follows:

- Simulation work is done by using V-rep.
- Simulations are done using Nao humanoid robot.
- Two Nao humanoid robots are used in the simulations.
- The control method focuses on controlling the motion of the arm which are shoulder, elbow, wrist and finger.
- Nao robots only perform object lifting.

1.6 List of Contribution

This research will contribute to the development of humanoid robot by equipped it with the ability to cooperate with other humanoid robot which similar to human nature. With the capability to cooperate with other humanoid robots, the robot can manipulate objects with its partner which can replace human labour in dangerous environment. For example, manufacture sector and construction sector.

Besides, the number of humanoid robots involved are the key element which brought the significance. The advantages of using two humanoid robots are overwhelming single humanoid robots. In general, the time consume and the energy consumption is short and less as compare to single robot.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter begins with an overview of robotic system. Then, the past works of robotic system in terms of robot's dynamic stability, object manipulation and followed by collaboration between robots. This chapter also discuss about the constraints in the research field and the significance of it. At the end of this chapter, a summary for the whole chapter was discussed.

2.2 Robotic System Overview

According to K.H. Low, robotic is the art, knowledge base as well as the skill in design, apply and use robots in human endeavors[15]. Beside robot, robotic system consists of other devices and systems which collaborate with robot to perform necessary tasks. Robotics is an inter-disciplinary subject that involve mechanical engineering, electrical engineering and electronic engineering, computer science, biology and many other disciplines. The designation of robots depends on the ideas and theory developed in the disciplines involved.

Robotics is broadly defined as the intelligent and interactive connection of perception to work through cognition and planning. The following technologies are including under this general definition:

- Kinematics, dynamics, control and simulation of robots.
- Sensing and perception: vision and other non-contact sensors; tactile and other contact sensing systems.

- Systems control theory and applications as related to the modelling of robotic systems.
- Robot mobility and navigation.
- Robotics-related computer hardware and software components, architectures and systems.
- Advanced command and programming languages for robots.
- Linkages to computer aided design, engineering and manufacturing information systems.
- Electronic and manufacturing science and technology as related to robotics.
- Man-machine interfaces are related to robotics.

As the year goes, the demands for robot that can perform human's tasks increases. According to Appin Knowledge Solutions, many organizations are involved in various fields of robotics[16]. These field of robotics can be broadly categorized as:

- Robotic Manipulator

  Robotic manipulators have become useful and economical tools in manufacturing, medicine and other industries.
- Wheeled Mobile Robots

  Wheeled mobile robots perform many tasks in industry as well as military.
- Legged Robots

  Locomotion on the ground can be realized with slider, liver and wheel. The benefits of legged robots are better in mobility, stability on the platform, energy efficiency as well as has smaller impact on the ground.
- Underwater Robots

  Camera-equipped underwater robots serve many purposes including tracking of fish and searching for sunken ships.
- Flying Robots

  Flying robots have been used effectively in military maneuvers and often mimic the movements of insects.
- Robot Vision

  Provide machines with sensors that mimic that capabilities of the human vision system. This process is the creation of the sensing devices that capture the same raw information light that the human vision system uses.
- Artificial Intelligence

Artificial Intelligent (AI) is a branch of computer science and engineering that deals with intelligent behaviour, learning and adaption in machines.

- Industrial Automation

  Assists human operators with the physical requirements of work, reduces the need for human sensory and mental requirements.

Besides, humanoid robot is getting attention as their actions and motions are built based on human's nature. For example, sitting, lifting and interact with nature. These features or function of humanoid robot can perform human tasks or dangerous job [6], [17]. Study and imitate from human nature, interaction of the robot with environment also become one of the study among researchers[13]. Until now, humanoid robots are able to interact with human operator or another robot in completing tasks like Nao robot does. The development of this study can bring huge advantages to human society especially in manufacturing sector.

2.3 Collaboration between Humanoid Robots

In human society, the cooperation between human are one of the uniqueness in human. Human are able to complete complex tasks due to this uniqueness, a simple example would be cooperation to lift a heavy object. The same concept applies on humanoid robot, as the technology getting advance, humanoid robot can assist human in various tasks [18], [19] and for certain extend they can replace human in some simple job or dangerous places [12]. Among all of the robots, humanoid robots have the potential in handling multiple tasks and walk on any terrain, like human beings. The limitation of actuator output cause humanoid robot unable to work efficiently as human does, hence multiple humanoid robots working cooperatively will be a solution to exploit the capability of robots [6], [13].

Multiple robots can increase the efficiency and the robustness of the system unlike using single robot. A greater number of the robots can produce a self-organization system that is consequently robust to environment changes [4]. The characteristics of collective autonomous mobile robots can be categorized into three: (1) distribution of autonomy, (2) cooperation and (3) diversity [7]. As the complexity of tasks increase in real situation, single robot design has great limitations [8] and multiple robots are expected to perform the complex task cooperatively [7].

Every motion of the robot started with standing position at which the Centre of Mass (CoM) does not deviate from original position that allows both two humanoid robots to be