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TWO-LINK MUSCULOSKELETAL STRUCTURE

WORKSPACE FORCE CONTROL

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Bachelor of Mechatronics Engineering

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SUPERSVISOR ENDORSEMENT

“I hereby declare that I have read through this report entitle “Two-Link Musculoskeletal Structure Workspace Force Control” and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Mechatronics Engineering)”

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Date :…………………………………………..

TWO-LINK MUSCULOSKELETAL STRUCTURE WORKSPACE FORCE CONTROL

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A report submitted in partial fulfillment of the requirement for the degree of Bachelor in Mechatronics Engineering

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“I declare this report entitle “Two-Link Musculoskeletal Structure Workspace Force Control” is the result of my own research except as cited in the references. The report has been not accepted for any degree and is not concurrently submitted in candidature of any other degree”

Signature :........…………………………………..

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ABSTRACT

This project presents the force control for two-link musculoskeletal manipulator modeling where force control had been used to control the force at end-effectors while end effector of the manipulator touching the environment. Proper force control algorithm for two-link musculoskeletal manipulator had been developed and simulated by using a robotic dynamics simulator. All the kinematic and dynamic properties are shown to address the presence of environmental contact with the manipulator. From this contact, the force control algorithm were explored, by comparing the performance of the manipulator in term of settling time and accuracy when different force references have been given. Force control algorithm were divided into two types which is independent muscle control and end effector muscle control. The results for independent muscle control show the increment of force references will make the force applied to the end effector and muscles increased. Meanwhile, for end effector muscle control, the result shows the maximum force applied to the manipulator increased if the reference forces increased but through this it will also improve the settling time of force that had been applied to each muscles in the manipulator.

ABSTRAK

Projek ini membentangkan mengenai kawalan daya untuk model robot dua hubungan yang dipacu oleh penggerak selari yang bertindak sebagai otot kepada model robot. Di mana kawalan kuasa telah digunakan untuk mengawal daya pada pengesan hujung pengolah semasa pengesan hujung pengolah menyentuh alam sekitar. Algoritma kawalan daya yang betul untuk robot dua hubungan yang dipacu oleh penggerak selari telah dibangunkan dan disimulasikan dengan menggunakan simulator robot dinamik. Semua sifat-sifat kinematik dan dinamik ditunjukkan untuk menghubungkan kehadiran alam sekitar dengan pengolah. Dari hubungan ini, algoritma kawalan daya telah diteroka, dengan membandingkan prestasi model robot melalui tempoh masa dan ketepatan apabila rujukan kuasa yang berbeza telah diberikan . Algoritma kawalan daya telah dibahagikan kepada dua jenis iaitu kawalan otot bebas dan kawalan otot pengesan hujung pengolah. Keputusan menunjukkan kenaikan rujukan kuasa akan menjadikan daya yang dikenakan kepada pengesan hujung pengolah dan otot meningkat. Sementara itu, untuk kawalan otot pengesan hujung pengolah, keputusan menunjukkan daya maksimum digunakan untuk robot meningkat jika daya rujukan meningkat tetapi melalui ini ia juga akan menambah baik masa untuk setiap daya yang dikenakan pada otot menjadi stabil.

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l_{m1}	-	Shoulder mono-articular muscle
l_{m2}	-	Elbow mono-articular muscle
l_{m3}	-	Biar-articular muscle
F_{lm1}	-	Force applied at shoulder mono-articular muscle
F_{lm2}	-	Force applied at elbow mono-articular muscle
F_{lm3}	-	Force applied at biar-articular muscle
F_{endy}	-	Force applied at end effector in y-direction
F_{endx}	-	Force applied at end effector in x-direction
F_{ref}	-	Force reference at muscle
$F_{ref(endy)}$	-	Force reference at end effector in y-direction
$F_{ref(endx)}$	-	Force reference at end effector in x-direction
t	-	Time
s	-	Second
N	-	Newton

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CHAPTER 1

INTRODUCTION

1.1 Introduction

In this chapter, the purpose of this research will be described. Begin with the current issues in the real world environment and then the problem statement for this research will be translated. The objectives of the research are made to overcome the problem statement. The scopes of the research are defined to make the limitation of the research.

1.2 Motivation

Nowadays, robot have been widely used in industrial environment because it capability to do work that dangerous to human. Moreover, robot can do task without getting tired. With this, the production of the product will be more consistent and the quality of the product will be improved. This is proven by Robotics Industries Association (RIA) where the overall industrial robot order from all over the world was increased by 49 percent during 2005. Most of the order was coming from Asian nation such as China, Malaysia, Philippines, Indonesia, Singapore and India with about 125 percent of industrial robot order [21]. For example, the plant at PROTON SDN. BHD. TANJUNG MALIM operate on 60 percent automation with a total of 180 robots, of which 138 units are employed in the Body Shop, 31 units in the Paint Shop and 11 units in the Trim & Final Assembly. Overall automation levels of each shop are body 60%, Painting 32% and final assembly 2% [1].

Generally, most industrial robot use position control scheme to control the robot movement. Theoretically, the position control scheme is a method of control where the robot tool follows a prescribed trajectory in space which has been pre-programmed or “taught” before run-time. However, for some applications, it is more important to precisely control the force applied by end-effectors rather than controlling the robots positioning to produce a better product. Furthermore, by using position controlled robot system in industry will endanger humans or objects surrounding it during operation. This is because when position control scheme is being used, the robot will follow the instruction in the program until it completes its task regardless of its surrounding. This can cause injury or harm to anything within its working space.

This have proven when there are workplace accident in 2009 at Golden State Foods bakery in California that caused by worker’s lack of precaution. According to the inspection report. “At approximately 7:55 a.m. on July 21, 2009, Employee #1 was operating a robotic palletizer for Golden State Foods, Inc., a food processor and packager for fast food restaurants. She entered the caged robotic palletizer cell while the robotic palletizer was running. She had not de-energized the equipment. Her torso was crushed by the arms of the robotic palletizer as it attempted to pick up boxes on the roller conveyor. She was killed.” [21].

Lately, researches focus on new methods to control the robot which is force control method. Through this method, the problem that was caused by position control method can be solved. However, force control method is still new and has many shortages in terms of robot control static and dynamic characteristics. Because of this problem, the force control method is still on early development and not widely used in industrial environment.

1.3 Problem Statement

Generally, force control scheme is a method where force at end-effectors is being controlled and this will decide its next movement, either it need to stop, continue, or do next task that have programmed to the robot. To make the robot works perfectly, the robot controller algorithm for force control method is more complex compared to the position control method.

This is because by using force control method, it will consider the surrounding environment before the controller makes decision on the robots next move. Compared to position control method, it only considers the position on the end-effectors of the robot without considering the surrounding environment. So, the complex controller needs to be developed to make sure the robot work perfectly and is safe to its surrounding.

Furthermore, to make a force control method work, there are several important variables that need to be considered. One of the important variables is the force axis that applies to the robot end-effector. This can be either or a combination of X-axis, Y-axis and Z-axis if the robot is modelled in 3 Dimensions. Other important variable for the robot to function well is the rotational angle or displacement of the joint compared to the previous joint. For example, if the robot is two-link robot and have two degree of freedom, there e are two angles that need to be considered which is the rotational angles or displacement between base of the robot and first joint of the robot, and rotational angles or displacement between first and second joint of the robot. Figure 1.0 show the three link robot with it variables.

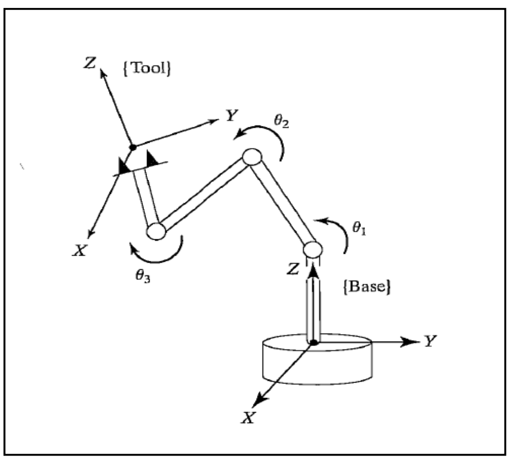

Figure 1.1: 3 Link robot with variables [22]

Lastly, to develop the force control method it requires the fundamental engineering knowledge. One of the engineering knowledge that needs to be considered is the mathematical relations between torque and forces. This fundamental knowledge is important where it will be used to determine the force at muscle and end-effectors. Knowledge on torque is needed to determine the torque that will be applied to each joint. Virtual work theory also needs to be considered because the purpose of force control method is to use it for industrial environment and household. Thus, the specific force control algorithm needs to be developed to make sure the robot can work properly.

In response to this problem, this research purpose is to study and develop the way to control the robot by using force control. This research will also consider the performance of the robot when using force control method.

1.4 Objective

The objectives were refined and developed to be more specific achievable. As such, these achievable objectives for this research are:

1. To design two-link musculoskeletal manipulator driven by linear actuator using robotics dynamics simulator.
2. To derive force control algorithm based on virtual work principle and simulate two-link musculoskeletal manipulator with force control algorithm using robotics dynamics simulator.
3. To analyse and compare the relationship between speed and accuracy from force control data in term of force tracking.

1.5 Scope

Research scope are the limitations for each research that have been conduct. One of the scope for this research is the modelling of two-link musculoskeletal will be represented in the form of two dimension modelling. This two-link musculoskeletal manipulator will be modelling in rigid form two-link manipulator and the length of each arm joint will be 0.4m.

Another scope that have been set for this research is the centrifugal/coriolis force (C terms) is being neglect and force that will be apply to the linear actuator and end-effector of the robot will be in range of 0 Newton to 100 Newton. This tracking force is applied to the end-effectors of the manipulator, where the direction of the force is considered in one direction only.

Lastly, this research will conduct using robot software simulator which is ROCOS software, where the time taken for the robot manipulator end-effector to achieve the desired force when it make a contact with the wall will be considered. Other than that, this research also will consider the accuracy of the robot manipulator to maintain the desired force at end-effector when it make a contact with the wall.

1.6 Organization of Report

This report is organized as follows; Chapter 2 describes about the literature review where some of previous work that related to this research have been review. Chapter 3 is a methodology for the research. In this chapter, the method to complete this research have been described. Chapter 4 is mention about the result and analysis for this research where it show the result from the independent muscle control and end effector muscle control simulation. Lastly, chapter 5 is described about the conclusion and recommendation for this research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will provide the review from previous research that is related to this research. There are previous researches on force control robot manipulator using different controller type and experiment design to obtain the accurate and fast settling time force at robot end-effectors. Other than that, the industrial robot, rigid-flexible manipulator, musculoskeletal manipulator and robotic experiment are discussed in this chapter.

2.2 Robot

There are plenty type of robot have been proposed by researcher to test and improved the robot performance by applied force control method. Some of research was applied to actual robot and some of research was on robot manipulator. Some of robot type that have been proposed by researcher is:

- Industrial robot.
- Rigid-flexible robot manipulator.
- Musculoskeletal robot manipulator.

2.2.1 Industrial Robot

Industrial robot as defined by ISO 8373 is an automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes, which may be either fixed in place or mobile for use in industrial automation applications.

One of the common industrial robot that have been widely use in research is KUKA robot. Basically, KUKA is derived from the initial letters of the company name “Keller und Knappich Augsburg” where this company is focusing in develop and produce an automation industrial robot [2].

Nowadays, KUKA company already have develop many industrial robot for many industry sector such as automotive manufactures, food and beverages, rubber and plastics, metal products, automotive suppliers, wood and furniture, and lastly foundry sector[2]. One research that have been done by [3] is using a 6 DOF KUKA KR210 industrial robot with an ATI DELTA force sensor. 6 DOF KUKA KR210 is a industrial robot arm with high payload and often used for grinding purpose [2].

Figure 2.1: KUKA KR 210 [2]