UNIVERSITI TEKNIKAL MALAYSIA MELAKA

5 DEGREE OF FREEDOM ROBOTIC ARM CALIBRATION ON 2-DIMENSIONAL AXIS COORDINATE

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Electronics Engineering Technology with Honours.

by

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FACULTY OF ELECTRICAL AND ELECTRONIC ENGINEERING TECHNOLOGY

2020

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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Tajuk: 5 DOF ROBOTIC ARM CALIBRATION ON 2-DIMENSIONAL AXIS COORDINATE

Sesi Pengajian: 2020

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APPROVAL

This report is submitted to the Faculty of Electrical and Electronic Engineering Technology of Universiti Teknikal Malaysia Melaka (UTeM) as a partial fulfilment of the requirements for the degree of Bachelor of Electronic Engineering Technology with Honours. The member of the supervisory is as follow:

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ABSTRAK

Pada era permodenan ini, hamper semua industri yang melibatkan pekerja menggunakan sebarang bentuk mesin. Penggunaan mesin dan robot dapat memudahkan sesuatu kerja membuatkan pekerja dan syarikat dalam menggunakan robot dalam bidang kerja mereka. Lengan robot yang mempunyai lima darjah kebebasan digunakan sebagai wacana dalam melaksanakan kaedah yang telah dicadangkan. Dalam projek ini, penentukuran pergerakan lengan robot dilakukan dengan menggunakan kaedah kinematic songsang melalui proses pengekodan yang dijalankan. Hal ini menjadikan lengan robot tersebut berjaya dikawal untuk bergerak ke koordinat yang telah ditentukan . Input kepada kod yang telah ditulis merupakan koordina yang telah ditentukan dengan jarak yang specifik dan telah disebut di dalam tesis ini. Dapatan daripada projek ini kemudiannya dianalisis menggunakan kaedah ANOVA. Dapatan kajian menunjukkan bahawa tiada perbezaan yang ketara atau signifikan berdasarkan analisis statistik kepada dua set data. Tuntasnya, ketepatan lengan robot dapat ditunjukkan melalui kajian ini.

ABSTRACT

Nowadays, almost all working industries use some kind of machineries. Its convenience attracts worker and companies to be involved in making and proper use of robotics. A five degree of freedom robotic arm was used as the platform to put in proposed method in effect. In this project, calibration of robotic arm movement was used by implementing inverse kinematics in the coding. Due to the implementation, the robotic arm was successfully controlled to move at certain predetermined coordinate. The input to the coding were predetermined coordinates with specific distance mentioned in this thesis between them. The result was later analysed using ANOVA method. The result indicated that there were no significant difference between two sets of data which concludes that the accuracy of the robotic arm was apparent.

DEDICATION

This thesis is dedicated to my parents for their unwavering support financially and emotionally. They have given their all to raise me although I was such a troublemaker. Leaving previous studies to pursue this one must have cost a fortune to them. Seeing where I am right now after four years of gruelling experience of blood, sweat, and tears, I am forever grateful that I have made it this far.

This thesis is dedicated to my supervisor, Mr Ahmad Sayuthi bin Mohamad Shokri, which without his continued support and counsel. Without his reprimanding, I could not have completed this thesis.

I dedicate this project to all my friends in BEEZ who have been giving me moral support throughout this project and I am blessed to have them beside me and without their guide, I could not have completed this project. Being the first batch of a new program felt like being a lab rat, although I must say I had so much fun learning in class with them. Alas, our very last semester in UTeM was spent without their giggle and wittiness in class due to worldwide pandemic. Hopefully, all of us would have a bright future and career ahead albeit the predicament we must face in the working world.

ACKNOWLEDGEMENTS

First and foremost, I thank Allah (SWT) for letting me live to see this thesis through. I am forever indebted to my supervisor, Mr Ahmad Sayuthi bin Mohamad Shokri for his unwavering support, encouragements, and patience through this process. I hope you find some kind of satisfaction in this modest paper. Thank you so much!

I am very fortunate and grateful to Dr Zanariah binti Jano, my co-supervisor for providing readership and ideas, paramount to the realization of this thesis. Thank you for your support and helpful suggestions, I will be forever thankful to you.

Not least of all, I owe so much to my whole family for their undying support, their unwavering belief that I can achieve so much. Unfortunately, I cannot thank everyone by name because it would take a lifetime but, I just want you all to know that you count so much. Had it not been for all your prayers and benedictions; were it not for your sincere love and help, I would never have completed this thesis.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Machines has been a valuable tool and its development go hand in hand with the rise of human civilisation. As a product of human's innovation, its purpose is to increase effectiveness and work efficiency that are either routine or too difficult for a human to do by hand. A common robotic machinery used in industry such as automation; is the robotic arm. A robotic arm can be programmed and manipulated to do specific task more efficiently than a human. This reduced the manpower needed greatly and resources and time efficient.

Robotic arms had clear advantages when compared to a human arm. Robotic arm machines will not be affected by fatigue and can be used in a wide variety of settings. Regardless of these benefits, a robotic arm is a complex machine that is challenging to control with linear-based controller. For the machine to have an autonomous operation, the controller used must be able to sense its current state and decide its next action just like a human would.

Nowadays, the lifting can be used for technology. The robotic arm is used for many industrial applications, from welding, to painting and drilling. The human-like dexterity is the one the industry is seeking to replace human labour. The 5-DOF robotic arm delivers fast, accurate, and repeatable movement. Equipped with 3 high torque servo motors and 3 high speed servo motors, both are metal geared servo motor, for accurate and durable movement control.

1.2 Problem Statement

Movement control is major to numerous robot application and could cause a troublesome issue. Robotic tasks are getting more complex thus, an intelligent and simpler controller is due to be designed and analysed to control the performance of the robot arm. The problem statement of this project are as follows:

i. Some tasks are repetitive in nature or hazardous for a human worker. Therefore, a robot arm is used in the worker's place.

ii. Autonomous robot can be inaccurate in its movement without presence of sensors.

iii. Errors would limit robot arm movement accuracy without proper calibration.

1.3 Research Objectives

The robot arm needs to be able to perform precise movement in doing tasks. To achieve this aim, these are the objectives of this project:

i. To design and implement inverse kinematics in robot movement control.

ii. To calibrate robot movement to point at 2-dimensional axis coordinate.

iii. To analyze robot movement on 2-dimensional axis coordinate.

1.4 Scope of Project

This project revolves around these following scopes:

i. Calibrate robot arm movement to reach designated coordinate.

ii. Controlling joint movement of DOF robot arm using inverse kinematics.

iii. Analyze the accuracy of robot arm using 2D axis coordinate.

CHAPTER 2

LITERATURE REVIEW

2.1 Literature background

Machines used to be manually controlled by the worker until the advancement of technology enables machines to be controlled by a program (Ligutan et al., 2018). Errors can be reduced or removed altogether using calibration process (Marwan et al., 2017).

Kinematics parameter error directly affect accuracy of robot movement. Errors in the kinematic parameters consist of errors in the geometric parameters and zero errors in the robot joints (Mustafa et al., 2008). In order to realise the right position power, the geometric parameter errors and zero errors need to be compensated (Qian et al., 2018). Kinematic calibration is an efficient way to improve the accuracy of the end-effector coordinate by improving the accuracy of the kinematic model (Qian et al., 2018).

There are several places in the workspace where the errors of the kinematic parameter have little effect on the errors of the end-effector location, while the impact of the noise of the measurement sensors on the precision of the measurement of the error is greatly increased (Cai et al., 2012). Therefore, by choosing the end-effector positions with significant position errors in the workspace as the measurement positions, the precision of error measurement can obviously be increased. The inputs are the predetermined coordinate from user (Bennett & Hollerbach, 1991).

Robotic arm control with uncertain kinematics could be a problem due to the coupled nonlinearities of the grasped robot arm and internal force produced by grasped objects (Yang et al., 2019). A fuzzy logic feedback control system should be able to control the angle position of a flexible robotic arm (Jalani & Jayaraman, 2018). Vibrations that were emanated from a rotary flexible robotic arm will be dampened when a certain angle position is reached (Jalani & Jayaraman, 2018).

2.2 Kinematics

By describing the relationship between joint configurations and a functioning reference frame, Kinematics describes the rigid body motion of the robotic manipulator. The forward kinematics (FK) solution maps the joint angles in the working reference frame to an end effector position and orientation. A provided end effector position and orientation are mapped by the IK solution to a set of joint angles.

The mapping in one direction or the other could be mathematically trivial depending on the robot configuration, or there may be several solutions or no closed form solution at all. The FK is needed for the calibration of cinematics, while the IK is required for advanced control algorithms and direct motion planning for the workspace.

Joint Axis	θ_{offset}	d	a	α
1	0	$0.205m$	0	$-\frac{\pi}{2}$
2	$-\frac{\pi}{2}$	0	$0.350m$	π
3	$-\frac{\pi}{2}$	0	0	$-\frac{\pi}{2}$
4	0	$0.305m$	0	$\frac{\pi}{2}$
5	0	0	0	$-\frac{\pi}{2}$
6	0	$0.075m$	0	0

Figure 2.1 Example of nominal DH parameter.

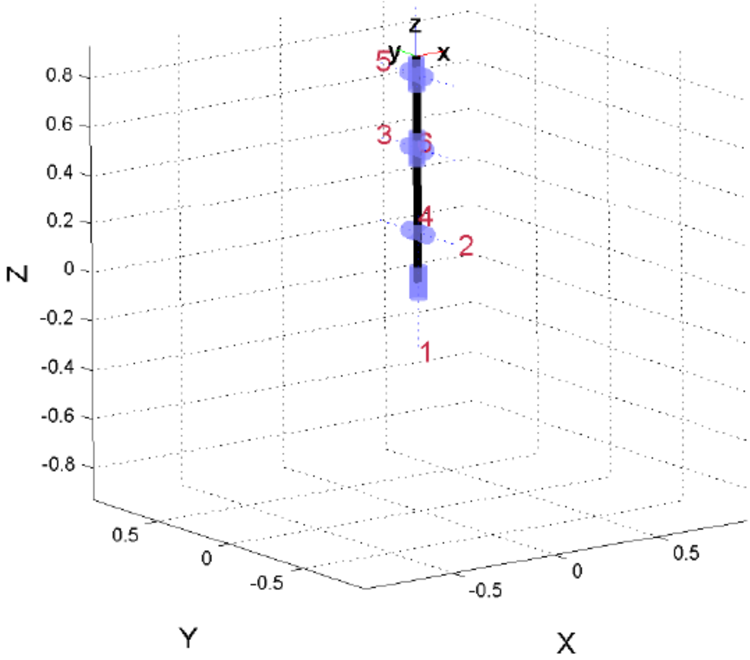

Figure 2.2 Configuration diagram

2.3 Forward Kinematics

It is possible to derive the FK in a number of ways, each with benefits and drawbacks, but they all begin with a parameterization for the positions and orientations of the joints. One parameterisation used in research and industry is Denavit-Hartenberg (DH) parameters. Throughout this research, standard DH parameters have been used to make more direct comparisons to other research in the field. With µ the input variable for revolute joints and d the input variable for translational joints, the DH parameters are *µ, d, a,* and *Ɵ*.

The DH parameters describe the transformation in the kinematic chain from one joint coordinate system to the next joint, µ defines rotation between the z-axis, d defines the distance between joints along the z-axis, a defines the distance between joints along the x-axis, and ® defines the angle between the z-axes of the joint.

2.4 Inverse Kinematics

For fast direct workspace trajectory solutions and advanced control algorithms like impedance control, the IK (inverse kinematics) will be appropriate. Given a particular robot end effector position and orientation, the inverse kinematics issue is to solve for the joint angles. This solution uses a homogeneous transformation matrix as an input for simplicity of implementation along with an optional "previous angles" vector that will allow the return of a single solution closest to the previous angles vector for easier trajectory implementation in the vector norm sense.

Table 2.1 Example of inverse kinematics solution joint angles

	Solution 1	Solution 2	Solution 3	Solution 4	Solution 5	Solution 6	Solution 7	Solution 8
θ_1	1.191	-1.951	1.191	-1.951	1.191	-1.951	1.191	-1.9506
θ_2	0.717	1.130	0.717	1.130	-1.130	-0.717	-1.130	-0.717
θ_3	2.081	2.081	2.081	2.081	-2.081	-2.081	-2.081	-2.0807
θ_4	-0.566	0.715	2.575	-2.427	-2.427	2.575	0.714	-0.567
θ_5	1.634	2.186	-1.634	-2.186	2.186	1.634	-2.186	-1.634
θ_6	0.938	-1.699	-2.203	1.443	-1.699	0.938	1.443	-2.203
Topology	111	110	011	010	101	100	001	000

2.5 Degree of Freedom

Degree of freedom is simply represented by the number of joints or ways the robotic arm can move (Farah, 2017). More specifically, it is directly related to the independent position variables of the robot. Abad et al. (2018) said ‘the robotic arm is an open kinematic chain because each joint position is defined by a single variable and the number of degrees equals the number of joints”. A joint of a robotic arm resembles a joint of the human body in which it gives a DOF motion to the robot. Each joint has two links which are rigid components known as input link and output link that form a chain when attached by joints. There are mainly two types of joints which are rotary joints and sliding joints. As it is indicated by the name itself, the sliding joint allows linear motion along its axis while the rotary joint gives relative rotation when joined by two links.

2.6 Control System

Open-loop (OL) and closed-loop (CL) control system are generally used to control and adjust the robotic arm. Although these control systems are mostly used, CL control system has the upper hand in controlling robot arm as it is a more complete system.

The output signal is returned as feedback after the controller has sent the signal to the motor to specify the current state of the motor. Some functions of the robot arm are provided by the control system, for instance, the ability to move within its vicinity and storing data given by the movement of the robot arm.

2.7 Fuzzy Logic Controller

Fuzzy logic has multiple values, which grants intermediate values to be defined between typical values such as high/ low, true/false, etc. This type of logic is created for the program to have human-like thinking and decision-making (Ayas & Altas, 2017). These notions can be mathematically processed by computers. The first fuzzy logic work was about mimicking a human operator for a steam engine and boiler using the IF-THEN rule (Mendel, 1995). It is commonly known as ‘Mamdani controller’, that is obtained through experimentation by the control engineer to give out the appropriate output (Dulaidi, 2014).

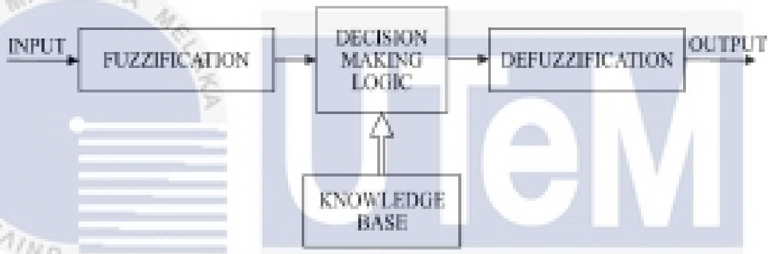

Figure 2.3 Fuzzy controller block diagram.

2.7.1 Fuzzy set

A set that is not crisp and defined accurately is called a fuzzy set. It contains values with only partial membership degree (Bingül & Karahan, 2011). Fuzzy sets are different than a classical set and the difference is used to comprehend what fuzzy set is. A classical set includes or excludes any give elements. Figure 2.2 can be used as an example to differentiate between the two sets.

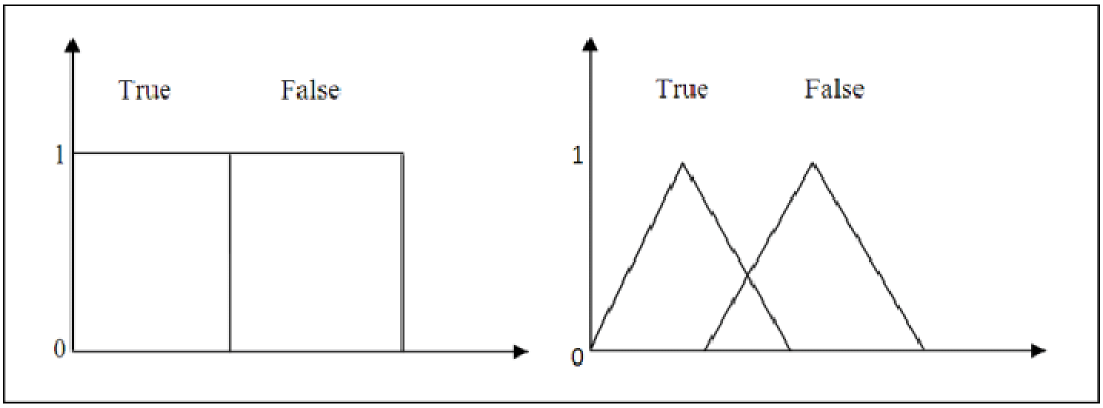

Figure 2.4 Representation of classical set (left) and fuzzy set (right).

As shown in the diagram above, there is clear boundary for the classical set while for fuzzy set, there is overlay of values between TRUE and FALSE. When the truth of a statement becomes a matter of degree (Mendel, 1995), the advantage is the ability to answer a simple question with a vague answer. This is precisely how human think, and now it can be done by machines and computers.

2.7.2 Fuzzy Logic Control

The base of a fuzzy controller is a linguistic description for making appropriate action for a given state. Fuzzy logic controller structure has input interface, linguistic description, and output interface (Shamsulkamar, 2014). The input and output interface handles fuzzification and defuzzification as well as normalization, scaling, smoothing and quantization. The inference mechanism based on the linguistic description will emulate human decision-making and applying on how to control the robot arm.