

**FORWARD KINEMATICS SOLUTION: VISUALIZATION OF
RHINO XR-3 ROBOT FOR 5 DEGREE OF FREEDOM**

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Bachelor of Mechatronic Engineering

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“I hereby declare that I have read through this report entitle “Forward Kinematics Solution: Visualization of Rhino XR-3 Robot for Five Degree of Freedom” and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Mechatronics Engineering”

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**FORWARD KINEMATICS SOLUTION: VISUALIZATION OF RHINO XR-3 ROBOT
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**A report submitted in partial fulfillment of the requirements for the degree of Bachelor
of Mechatronics Engineering**

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2010

I declare that this report entitle “Forward Kinematics Solution: Visualization of Rhino XR-3 Robot for Five Degree of Freedom” 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 and all my family

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ABSTRACT

This project is basically to develop software that will calculate the forward kinematics solution and visualize the final position of the Rhino XR-3 Robot with 5 degree of freedom (DOF). Initially, an algorithm is being developed to solve the forward kinematics problem. In order to know the final position of the robot, in this case the position of the gripper, the parameters of the robot needs to be applied. The parameters for this robot are the angle of rotation of the linkage between the arms of the robot and also the length between the joint. The final position of the robot can be obtained manually using conventional method. For this project, a software will be develop to solve the calculation faster than manual calculation and to review the final position of the robot. Both results obtain using the developed software and conventional method will be compared to make sure that the software can be used to solve the forward kinematics problem. The interface of the software needed user to insert desire value of *Theta* (θ) and the final position of the robot will be displayed. The visual aided in the interface will help user to know the exact position of the robot. Throughout this project, the method to solve the forward kinematics problem will be shown from developing the algorithm until the visualization of the final position of the robot.

ABSTRAK

Secara asasnya projek ini membangunkan perisian komputer yang akan menyelesaikan gerakan kinematik hadapan dan memaparkan kedudukan akhir robot Rhino XR-3. Pertamanya, satu algoritma dibuat untuk menyelesaikan permasalahan kinematik hadapan. Permasalahan kinematik hadapan ini diselesaikan untuk menentukan kedudukan dan pergerakan cekam dengan menggunakan perisian yang sesuai untuk robot Rhino XR-3. Proses yang terlibat ialah kawalan terhadap parameter iaitu sudut putaran bagi 3 paksi dan panjang antara titik paksi lengan robot. Permasalahan kinematik hadapan boleh diselesaikan dengan menggunakan kaedah konvensional dan secara manual. Untuk projek ini, satu perisian komputer telah dibangunkan untuk menyelesaikan perkiraan kinematik hadapan lebih cepat berbanding kiraan biasa dan kedudukan akhir robot akan ditunjukkan. Hasil kiraan menggunakan perisian yang dibuat akan dibandingkan dengan kiraan secara manual bagi memastikan perisian tersebut dapat digunakan untuk menyelesaikan masalah kinematik hadapan. Pengguna akan memasukkan nilai θ pada paparan muka perisian tersebut dan seterusnya kedudukan akhir robot akan dipaparkan. Dengan ini, pengguna akan mengetahui kedudukan sebenar robot dari nilai sudut yang dikehendaki mereka. Secara keseluruhannya, projek ini menerangkan bermula dari teknik, cara pengiraan dan kaedah penyelesaian sehingga kepada paparan kedudukan akhir robot.

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LIST OF ABBREVIATIONS

DH	-	Denavit Hartenberg
DK	-	Direct Kinematics
DOF	-	Degree of Freedom
GUI	-	Graphical User Interface
KAP	-	Kinematics Analysis Program

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CHAPTER 1

INTRODUCTION

The project entitle “Forward Kinematics Solution: Visualization of Rhino XR-3 Robot for 5 Degree of freedom” is a project to solve the forward kinematics problem and to visualize the final position of the Rhino XR-3 Robot. To achieve this goal, a software is developed to design a graphical user interface (GUI) with visualization of the final position of the robot. The first chapter will discuss the objective of the project, scope and the problem statement for this project.

1.1 Background

Kinematics is the science of motion which treats motion without regard to the forces that cause it [1]. In this project, forward kinematics concept was applied where Keith Peters stated that, Forward Kinematics (FK) deals with motion that originates at the base of the system and moves out to the free end [2].

Kinematics problem can be solved using conventional method where this method has a long calculation and a complex equation. This method was used for educational purpose all around the world. However, this method is not practical in industrial sector as the development of robotic sector and the complexity of the modern robot. The degree of freedom (DOF) of the robot will affect the calculation process. It takes a longer time to solve the problem if the robot has higher DOF. This project used Rhino XR-3 robot where it has 5 DOF.

Using a programming or software to solve the forward kinematics problem is well accepted nowadays as users can solved the problem in no time. For this project, a graphical user interface (GUI) for Rhino XR-3 robot will be develop with the visualization of the robot to show the final position of the robot.

1.2 Problem Statement

In industrial sector especially involved robotic application, there were several methods to solve the forward kinematics solution by using conventional method or using software. Usually user will used the conventional method to solve the forward kinematics problem. The complexity of formulation and computational burden make this method hard to be implemented in practice which also will waste a lot of time [10]. This method is a complex calculation that needs precision when working on kinematics solution. So, the more DOF is implemented, the longer and more complex the calculation would be.

It is also take a long time working on the forward kinematics solution using conventional method. As in industry and production sector, time is the most considerable thing of profit. The time taken solving the kinematics problem is increase with increasing the DOF of the robot.

Therefore, a new method to solve the kinematics problem especially the forward kinematics was created. Programming software was developed to calculate and solve this kinematics problem easier. The complexity of the calculation process and the time taken to solve the kinematics problem can be minimized. In addition to this software, it will show the final position of the robot in three dimensional (3D) views. This visualization will help user to know exactly the final position of the robot, from the origin.

1.3 Objective

The objectives of this project are to solve the forward kinematics problem and to visualize the final position of the Rhino XR-3 robot. The algorithm will be developed and tested with manual calculation before a software for the GUI is developed. The more specified objectives of this project are;

- a) To solve the forward kinematics solution manually.
- b) To develop an algorithm for forward kinematics solution.
- c) To develop the GUI for forward kinematics solution using Visual Basic software.
- d) To visualize the final position of the Rhino XR-3 robot using Solidwork software.

1.4 Scope

The scope of this project is to develop the programming software or GUI to solve the forward kinematics problem, only for Rhino XR-3 robot with 5 DOF. It cannot be applied to other robot model unless a modification was made to the software. The software will be develop based on the algorithm constructed that specified for 5 DOF. In this project, the software choose to develop the GUI is Visual Basic software.

The visualization of the robot will be in 3D view. The program will only view the Rhino XR-3 robot. The Solidwork software has been chosen to develop the 3D view. The scale of the robot will be exactly the same as the real Rhino XR-3 robot.

CHAPTER 2

LITERATURE REVIEW

In this chapter, a review of previous research project that are related with this project will be discussed. The review will include the previous research and studying in forward kinematic concept. The concept is including the D-H parameters and Rhino XR-3 Robot.

2.1 SIRF-Rhino (RhinoGUI)

The SIRF-Rhino is the example of Graphical User Interface (GUI) for Rhino XR-3 robot. This interface was developed by Venkatraghavan Gourishankar that applied the Rhino XR-3 robot to study the kinematics of the robot itself and to teach the beginner in robotics [3]. This GUI was able to perform kinematics routine and control the rhino robot in real time. This program was divided into two sections, RhinoGui and RhinoWhite. RhinoGui was designed such that the user can get a feel for kinematics of the 5-axis articulated Rhino robot while RhinoWhite was developed for demonstrating the basic trajectory planning method for the Rhino robot [3].

Figure 2.1 shows the interface of the RhinoGui. To use the forward kinematics option, simply choose the ‘forward kinematics’ button at the bottom of the interface. The plot of the robot configuration will change and the arm matrix configuration will change according to configuration setting by the user. The initial value of the joint angles represent by θ where the angle for each θ in degree was; $\theta_1 = 0^\circ$, $\theta_2 = -90^\circ$, $\theta_3 = 90^\circ$, $\theta_4 = 0^\circ$, and $\theta_5 = 0^\circ$. These values represent the home position of the Rhino XR-3 robot.

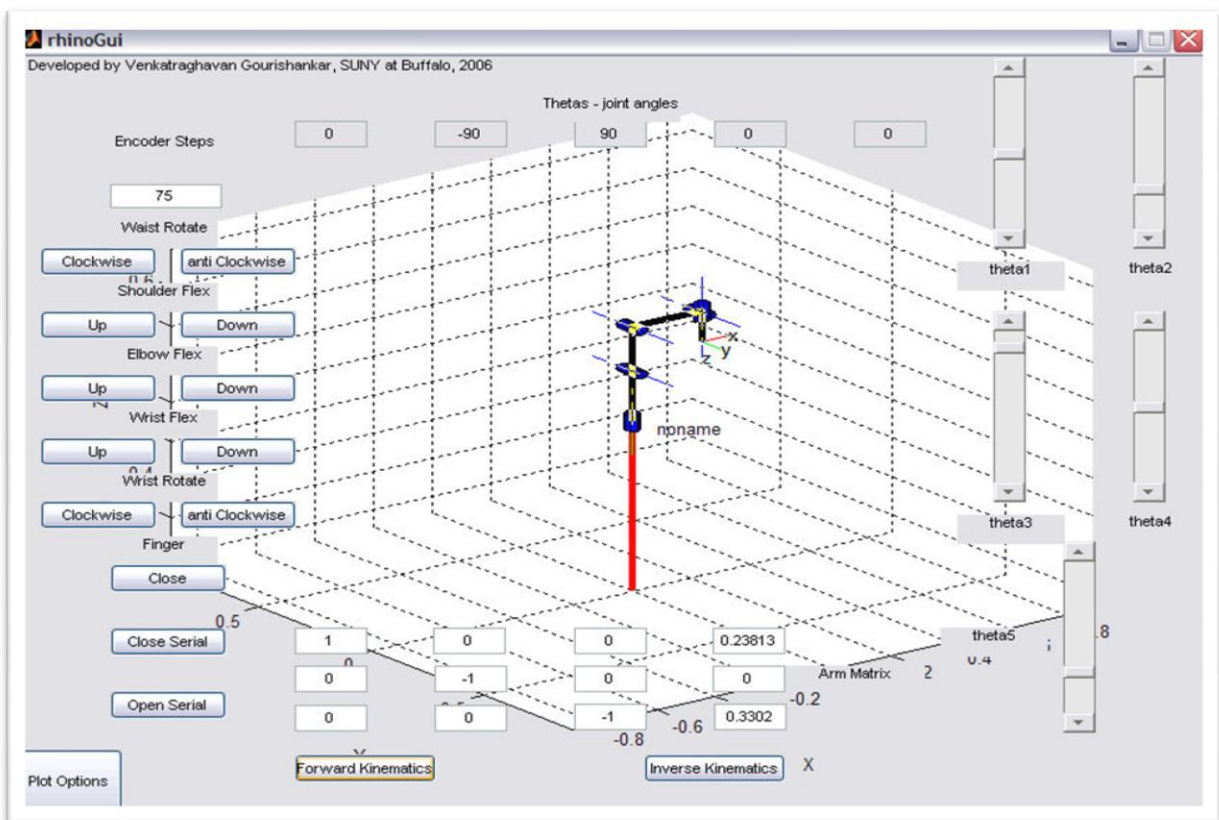


Figure 2.1: The RhinoGui Interface (robot at home position)

Since this program was developed through MATLAB, it can be used for all students in university, college and some high school to learn about kinematics especially forward kinematics. This program has user friendly interface that help new user and wanted to learn about robotic movement and kinematics.

2.2 RHINO XR-3 Robot

Rhino XR-3 robot is constructed out of 0.125 inch and 0.250 inch thick aluminum plate for years of trouble free service. It is powered by six PMDC servo motors with integral gearboxes and incremental encoders. The home position has microswitches on all axes and on the hand. It is easy to service and repair construction throughout. It is also a popular design with installations throughout the world [4].

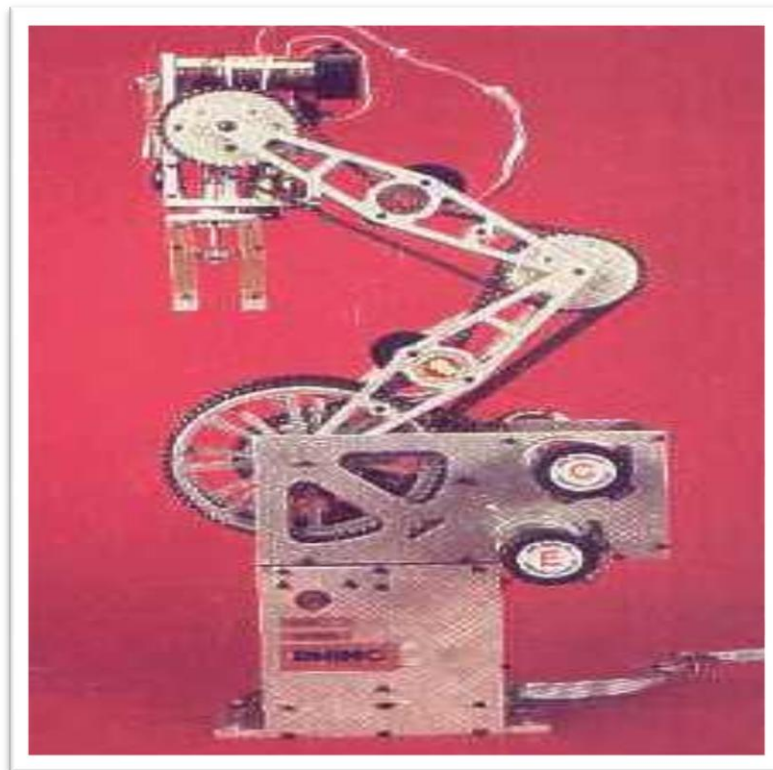


Figure 2.2: Rhino XR-3 Robot

Figure 2.2 show the example of Rhino XR-3 robot. This robot has used widely for educational purpose. It is easy to control as is have five DOF. This robot has simple design and user can easily determined the connection and joint between the connection points. This robot has electrical gripper at the end joint and has been classified as arm robot.

2.3 Denavit-Hartenberg (DH) Representation

Denavit-Hartenberg (DH) convention was introduced by Jaques Denavit and Richard S. Hartenberg [7]. It is a commonly used convention for selecting frames of reference in robotic applications. In this convention, each homogeneous transformation A_i is represented as a product of four basic transformations. Figure 2.3 show the example of Denavit Hartenberg assign frame.

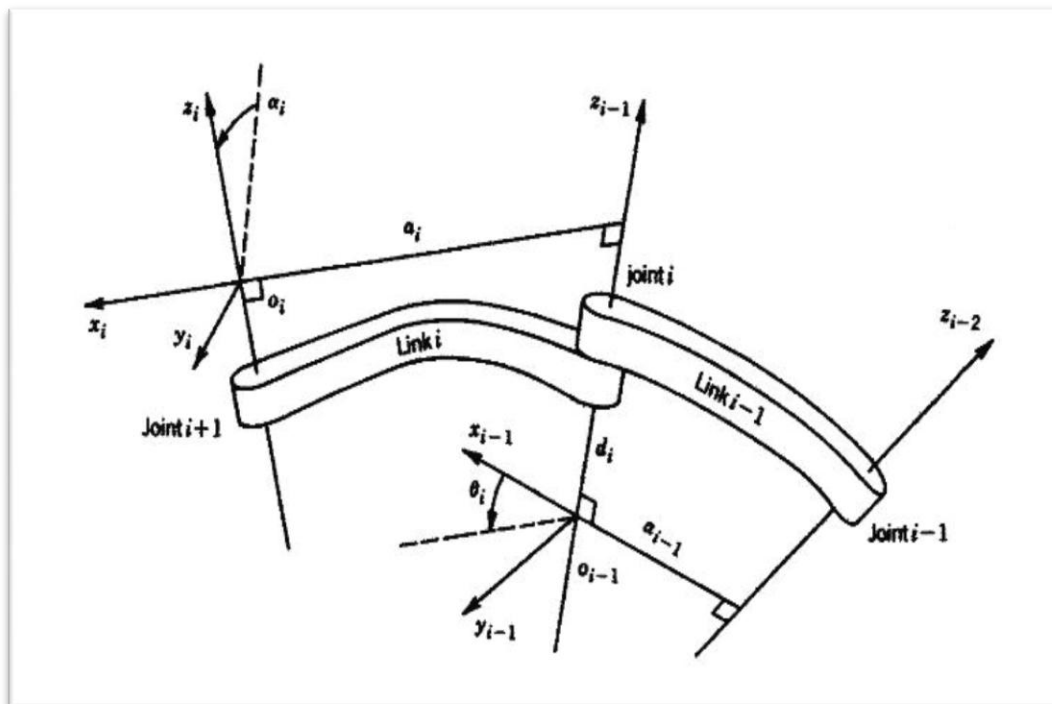


Figure 2.3: Denavit Hartenberg Frame Assignment

There were procedures based on the DH convention in the following algorithm for deriving the forward kinematics for any manipulator summarized below [5]:

Step 1 : Locate and label the joint axes z_0, \dots, z_{n-1} .

Step 2 : Establish the base frame. Set the origin anywhere on the z_0 -axis. The x_0 and y_0 axes are chosen conveniently to form a right-hand frame. For $i = 1, \dots, n-1$ perform Steps 3 to 5.

Step 3 : Locate the origin O_i where the common normal to z_i and z_{i-1} intersects z_i . If z_i intersects z_{i-1} locate O_i at this intersection. If z_i and z_{i-1} are parallel, locate O_i in any convenient position along z_i .

Step 4 : Establish x_i along the common normal between z_{i-1} and z_i through O_i , or in the direction normal to the $z_{i-1} - z_i$ plane if z_{i-1} and z_i intersect.

Step 5 : Establish y_i to complete a right-hand frame.

Step 6 : Establish the end-effector frame $o_n x_n y_n z_n$. Assuming the n -th joint is revolute set $z_n = a$ along the direction z_{n-1} . Establish the origin o_n conveniently along z_n , preferably at the center of the gripper or at the tip of any tool that the manipulator may be carrying. Set $y_n = s$ in the direction of the gripper closure and set $x_n = n$ as $s \times a$. If the tool is not a simple gripper set x_n and y_n conveniently to form a right-hand frame.

Step 7 : Create a table of link parameters $a_i, d_i, \alpha_i, \theta_i$.

a_i = Distance along x_i from O_i to the intersection of the x_i and z_{i-1} axes.

d_i = Distance along z_{i-1} from O_{i-1} to the intersection of the x_i and z_{i-1} axes

d_i is variable if joint i is prismatic.

α_i = The angle between z_{i-1} and z_i measured about x_i (see Figure 2.3).

θ_i = The angle between x_{i-1} and x_i measured about z_{i-1} (see Figure 2.3). θ_i is

variable if joint i is revolute.

Step 8 : Form the homogeneous transformation matrices A_i by substituting the above

parameters into equation 2.1.

Step 9 : Form $T_n^0 = A_1 \dots A_n$. This then gives the position and orientation of the tool

frame expressed in base coordinates.

The overall transformation is obtained by post multiplication of individual transformations:

$$T_i^{i+1} = Rot(z, \theta_i) Trans(0,0,d_i) Trans(0,0,a_i) Rot(x,\alpha_i) \quad (2.1)$$