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A Review Paper on Analysis and Simulation of Kinematics of 3R Robot with the Help of RoboAnalyzer

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***Abstract* -Robot kinematics the basis of robotics research, provides the basis for robot path planning and motion control. The paper focuses on D-H method for the forward kinematics analysis and inverse kinematics analysis for robot, and establishes the kinematics model and at last, the paper uses the RoboAnalyzer as the simulation software for the simulation of forward and inverse kinematics and also to illustrate and prove the correctness and rationality of the models.**

Keywords—robot, kinematics, simulation, D-H method.

I)INTRODUCTION

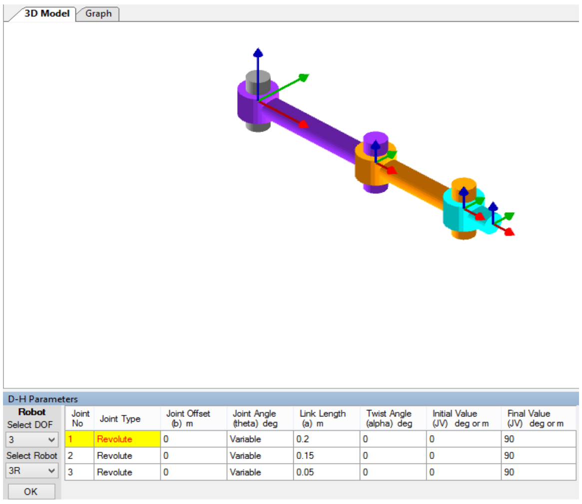
With the advancement of industrial automation, the robot which has become indispensable and cheap labor in the area of research and production. Robot kinematics is now a days the basis of robotics research, and it also shows the relative relationship between the end pose of robot and robot kinematics parameters, which acts as the basis of robot's control study [1]. Analysis of robot kinematics is the base of robot technology research and the key feature to study robot path planning and also motion control [2]. The D-H method is used to establish the relation between forward and inverse solution so as to study the robot kinematics in the robot kinematics model. In order to analyze the kinematics and build a relationship between the end effector and its parameter's, we use the homogenous coordinate transformation matrix proposed by Denavit Hartenberg [3]. The robot kinematics includes forward as well as inverse kinematics which are described as follows.

II)DENAVIT-HARTENBERG PARAMETERS

Denavit Hartenberg parameters are generally used to represent the architecture of industrial robots . It generally forms the basis for performing kinematic and dynamic analyses of robots. It consists of a set of four DH parameters is used to represent the position and orientation of a robot-link with respect to its previous link. The four parameters are associated with a particular convention for attaching reference frames to the links of a spatial kinematic chain, or robot manipulator so as to standardize the coordinate frames for spatial linkages [6][7]. These includes:

a) Joint offset (d) : length of intersections of common normal on joint axis
b) Joint angle (θ) : angle between the orthogonal projections of the common normal to the plane normal to the joint axes.
c) Link length (a) : measured as the distance between the common normal to the axis.
d) Twist angle (α) : the angle between the orthogonal projections of the joint axes onto a plane normal to the common normal.

And θ and α are variables if joint is revolute and prismatic respectively.



III)FORWARD KINEMATICS

In forward or direct kinematics, the joint positions, also called the angles and displacement of the revolute joints and the prismatic joints respectively, are prescribed. The user has to find the configuration or the transformation of end-effector consisting its position and orientation.

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(a)Analysis of robot forward kinematics :

The relation between adjacent links of a robot is described using the homogeneous coordinate transformation matrix, in which we first establishes the coordinate system of each robot joint, and then gets the homogeneous coordinate transformation matrix according to the conversion in the coordinate system[8].

T-Transformation matrix;

${}^{0}_{n}A$ – Homogeneous equation

T = ${}^{0}_{n}A = {}^{0}_{1}A\ {}^{1}_{2}A \ldots {}^{3}_{2}A$

T = $\prod_{i=1}^{n} {}^{i-1}_{i}A$

Parameters characteristics:

θ_i = Rotation around z_{i-1} axis

d_i = Translation along z_{i-1} axis

a_i = Translation along x_i axis

α_i = Rotation around x_i axis

The transformation matrix is multiplied among each of the robot link to get the transformation matrix and shows that the robot's end coordinate is relative to the base coordinate.

T = ${}^{0}_{3}A = {}^{0}_{1}A\ {}^{1}_{2}A\ {}^{2}_{3}A$

$$A = \begin{matrix} C\theta_i & -C\alpha_i S\theta_i & S\alpha_i S\theta_i & a_i C\theta_i \\ \theta_i & C\alpha_i C\theta_i & -S\alpha_i C\theta_i & a_i S\theta_i \\ 0 & S\alpha_i & C\alpha_i & d_i \\ 0 & 0 & 0 & 1 \end{matrix}$$

Subtituting the values of i=0,1,2,3 and then finding ${}^{0}_{1}A,\ {}^{1}_{2}A,\ {}^{2}_{3}A$ from the above equation we get:-

$$T = \begin{matrix} n & o & a & P \\ 0 & 0 & 0 & 1 \end{matrix}$$

Where,

n, o, a = the orientation of co-ordinate system and

P = position.

$$P = \begin{matrix} P_x \\ P_y \\ P_z \end{matrix}$$

In terms of angles $\theta_{1,}\theta_{2,}\theta_3$

$$P_x = a_2C\theta_1C\theta_2 + a_3C\theta_1C\theta_2C\theta_3 - a_3C\theta_1S\theta_2S\theta_3$$

$$P_y = a_2S\theta_1C\theta_2 + a_3S\theta_1C\theta_2C\theta_3 - a_3S\theta_1S\theta_2S\theta_3$$

$$P_z = a_2S\theta_2 + a_3C\theta_3 + a_3C\theta_3S\theta_2 + d_1$$

IV)INVERSE KINEMATICS

Inverse Kinematics (IKin) consists of determination of the joint variables corresponding to the end-effector's orientation and position. The solution to the problem is to transform the motion specifications of the end-effector in the operational space into the corresponding joint space motions. There may not be any results or may be multiple results possible for the end effector's orientation and position.

(a) The analysis of robot inverse kinematics :

In the inverse kinematics of the robot , the known end pose of robot to solve each joint angle, and the solving methods of the problems are different. Among the various methods, the most widely used method because of its quick calculating speed and high efficiency is Closed Method [4].The algebraic method, which refers that the inverse transformation matrix of each joint pre-multiplies both its ends of equation set, and also separates the joint variables, and then solve each joint variable value's according to the equal elements of both end of the matrix.

To find the value of $\theta_1, \theta_2, \theta_3$ based on the values of P_x, P_y, P_z.

$$\theta_k = F_k(P_x, P_y, P_z)$$

T = ${}^{0}_{n}A = {}^{0}_{1}A\ {}^{1}_{2}A\ {}^{2}_{3}A$

$$\frac{1}{{}^{0}_{1}A}\frac{1}{{}^{1}_{2}A}T = {}^{2}_{3}A$$

Putting the values and matching column of each side we get:-

For θ_1,

$$\frac{\sin\theta_1}{\cos\theta_1} = \frac{P_y}{P_x} = \tan\theta_1$$

$$\theta_1 = \tan^{-1}\frac{P_y}{P_x}$$

For $\theta_{2,}$ We have:-

a= $P_xC\theta_1 + P_yS\theta_1$

b= $P_z - d_1$

c= $aC\theta_2 + bS\theta_2$

$$\cos\theta_2 = \frac{1-u^2}{1+u^2}$$

$$\sin\theta_2 = \frac{2u}{1+u^2}$$

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Then ,

$$\tan\theta_2 = \frac{2u}{1-u^2}$$

$$\theta_2 = \tan^{-1}\frac{2u}{1-u^2} \qquad \text{where , } u = \tan\frac{\theta_2}{2}$$

For θ_3 ,

$$\tan\theta_3 = \frac{-aS\theta_2 + bC\theta_2}{a\theta_2 + bS\theta_2 - a_2}$$

$$\theta_3 = \tan^{-1}\frac{-aS\theta_2 + bC\theta_2}{a\theta_2 + bS\theta_2 - a_2}$$

V)ROBOANALYZER

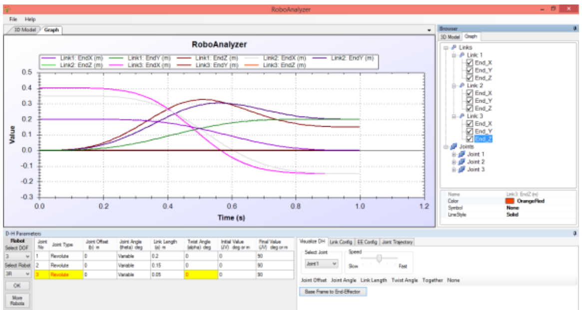
The RoboAnalyzer is a 3D Model Based Robotics Learning Software that has been developed for students to automatically. The software is simple and convenient for operation, and generates the corresponding simulation graphics so as to easily understand the operations and functions of robot intuitively [5].

FEATURES OF ROBOANALYZER : RoboAnalyzer is used to perform kinematic and dynamic analyses of serial chain manipulators. Main features of RoboAnalyzer Software are as follows:

- DH Parameter Visualization,
- Forward Kinematics,
- Inverse Kinematics,
- Inverse Dynamics,
- Forward Dynamics,
- Motion Planning .

SIMULATION USING ROBOANALYZER

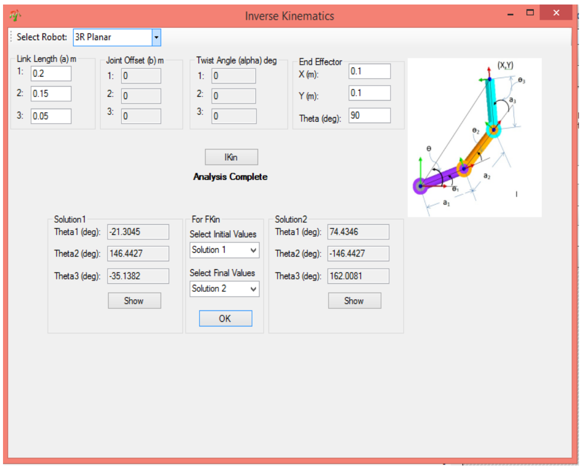
(a) Forward kinematics simulation :
Each joint angle of robot and its corresponding joint angle of one pose is plugged into the simulation software for solving the matrix of robot end pose.
From the initial position to the end position, the simulation time is designed as 1s and the simulation step number is taken to be 100.



learn the concepts of Robotics and has been developed using OpenTK and Visual C#. RoboAnalyzer[9] takes DH parameters of aserial manipulator and generates a 3D model of the robot as per the requirements. The 3D viewing window has various features like zoom, pan and tilt with the help of which 3D model can be viewed from various angles. The simulation parameters are set and then the forward kinematics (FKin) analysis and Inverse kinematics (IKin) analysis are performed. The minimum requirements for a system to assist the RoboAnalyzer software includes 1.5 GHz processor, 512 MB RAM memory, Windows XP/Vista/7 as the operating systems.

RoboAnalyzer by default shows a robot model (2-R) which users can select from the options given and thus can modify the Denavit-Hartenberg (DH) parameters and hence the robot model updates

(b)The inverse kinematics simulation :
The inverse kinematics the process of using the known robot end position is used to solve the value of each joint angle .



VI)CONCLUSION

The kinematics of the 3R robot forms the basis of robot research, and so the paper analyzes the kinematics of the robot manipulator with different link lengths, and also establishes robot kinematics model using D-H model, and the positive and inverse solution of the running model is analyzed with the help of roboanalyzer. Finally, the simulation software to illustrate the problems in the robot kinematics models are used which are difficult to understand, and hence the correctness of the model is verified.

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