Design Study of 5 DOF Robotic Manipulator (Kinematicaly)

Anurag Sharama

Abstract: - Robots are used in industries for fast, accurate, precise and mass production with in specified close tolerance limits. Robotic manipulator has rigid bodies i.e. links which is connected by articulations i.e. joints is segmented in to an arm which ensures mobility and rechability. This search ability is very much important in knowing the exact position and limit for placing the job or working piece either on working table or on conveyor belt. This can be easily done by forward kinematics to know min. to max. Workspace limit

Keywords:-Robot, DOF, manipulator, forward kinamatics, DH notations.

I. INTRODUCTION

Robots are reliable helping hand to human being and performs such type of difficult jobs which is next to impossible to human being. "Robot" which means servitude as forced work when word translated into English language it becomes Robot. The Number of indepent movements which an object perform in 3-D space is called degree of freedom (DOF). A rigid body has 6 independents movements. Three translations and three rotalations. The movement of manipulator is best described by denavit and Hartenberg (DH) notations. Manipular control requires both forward/direct and inverse kinematics.

II. METHODLOGY

The controlled movement of robots manipular is very essential for the completion of job/workpiece is at right time and right place and to avoid any incident or mis-happenening for robot and human being. For the given set of joint-link parameters, the process of finding end effector with respect to known parameter is called direct or forward kinematics. We have selected a 5 DOF model of manipulator for its study kinematicaly. We know all the values of link joint parameters. Then we form a kinematic relationship between adjacent links. The transformation matrices are formed. Further a overall homogenous transformation is formed.

III. FORWARD KINEMATICS

The forward kinematics is concerned with the relationship between the individual joints of the robot manipulator and the position (x, y and z) and orientation of the end-effector. Stated more formally, the forward kinematics is to determine the position and orientation of the end-effector, given the values for the joint variables of the robot.

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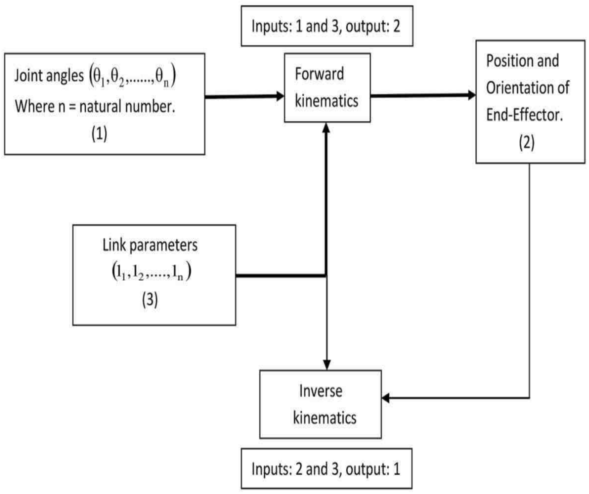
The joint variables are the angles between the links in the case of revolute or rotational joints, and the link extension in the case of prismatic or sliding joints.



Forward and Inverse Kinematics Scheme

The forward kinematics is to be contrasted with the inverse kinematics, which will be studied in the next section of this chapter, and which is concerned with determining values for the joint variables that achieve a desired position and orientation for the end-effector of the robot. The above mention theory is explained diagrammatically in figure above

Denavit-Hartenberg Notation (D-H notation)

A Robot manipulator with n joints (from 1 to n) will have n+1 links (from 0 to n, starting from base), since each joint connect to two links. By this convention, joint i connect link i-1 to link i. It is considered that the location of the joint i to be fixed with respect to link i-1. Each link of the robot manipulator is considered to be rigidly attached to a coordinate frame for performing the kinematics analysis. In particular, link i is attached to o_i $x_iy_iz_i$. It implies that whenever the robot executes motion, the coordinate of each point on the link i areconstant when expressed in the i^{th} coordinate frame. Furthermore when joint i actuate,link i and its attached frame o_i $x_iy_iz_i$, experience a resulting motion. The frame $o_0x_0y_0z_0$ is an inertial frame as it attached to the robot base. Now suppose, A_i is the homogeneous transformation matrix that express the position andorientation of o_i $x_iy_iz_i$ with respect to $o_{i-1}x_{i-1}y_{i-1}z_{i-1}$, where matrix A_i is not constant but varies as the configuration of the robot changes. Again the homogeneous transformationmatrix that expresses the position and orientation of $o_jx_jy_jz_j$ with respect to o_i $x_iy_iz_i$ is called, by convention, a global transformation matrix and denoted by T^i.

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Where, $T_j^i = A_{i+1}A_{i+2}...A_{j-1}A_j$ if $i < j$

$T_j^i = I$ if $i = j$

$T_j^i = \left(T_i^j\right)^{-1}$ if $j > i$

i	a_i	α_i	Q_i	Θ_i	q_i	c Θ_i	s_i	$s\alpha_i$	sαi
1	o	-90^0	d_1	Θ_1	Θ_1	c_1	s_1	O	-1
2	a_1	0^0	o	Θ_2	Θ_2	c_2	s_2	1	0
3	a_2	0^0	o	Θ_3	Θ_3	c_3	s_3	1	0
4	o	-90^0	o	Θ_4-90^0	Θ_4	s_4	$-c_4$	0	-1
5	o	0^0	d_6	Θ_5	Θ_5	c_5	s_5	1	0

$d_1 = 145$mm
$a_1 = 85$mm
$d_4 = 155$mm
$d_6 = 135$mm

S.No.	TYPE OF JOINT	RANGE OF ROTATION
1	ROTATING BASE Θ^1	O^0-180^0
2	ROTATING ELBOW Θ_2	O^0-150^0
3	ROTATING ELBOW Θ_3	O^0-150^0
4	ROTATING ELBOW Θ_4	O^0-150^0
5	ROTATING ELBOW Θ_5	15^0-48^0

$$^{O}T_1 = \begin{pmatrix} C_1 & O & S_1 & O \\ S_1 & O & C_1 & O \\ O & -1 & O & d_1 \\ O & O & O & 1 \end{pmatrix}$$

$$^{1}T_2 = \begin{pmatrix} C_2 & -S_2 & O & a_1C_2 \\ S_2 & C_2 & O & a_2S_2 \\ O & O & 1 & O \\ O & O & O & 1 \end{pmatrix}$$

$$^{2}T_3 = \begin{pmatrix} C_1 & -S_3 & O & a_2C_3 \\ S_3 & C_3 & O & a_2S_3 \\ O & O & 1 & O \\ O & O & O & 1 \end{pmatrix}$$

$$^{3}T_4 = \begin{pmatrix} S_4 & O & C_4 & O \\ -C_4 & O & S_4 & O \\ O & -1 & O & O \\ O & O & O & 1 \end{pmatrix}$$

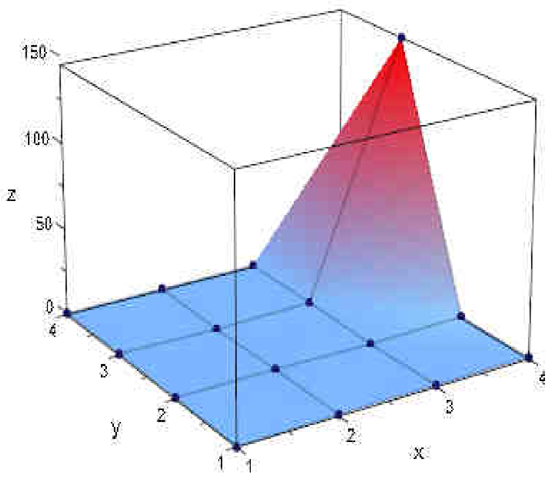
$$^{4}T_5 = \begin{pmatrix} C_5 & -S_5 & O & O \\ S_5 & C_5 & O & O \\ O & O & O & d_5 \\ O & O & O & 1 \end{pmatrix}$$

$$^{o}T_6 = T_1\,T_2\,T_3\,T_4\,T_5\,T_6 = \begin{pmatrix} n_X & o_X & n_X & p_X \\ n_Y & o_Y & a_Y & p_X \\ n_z & o_z & a_z & p_z \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

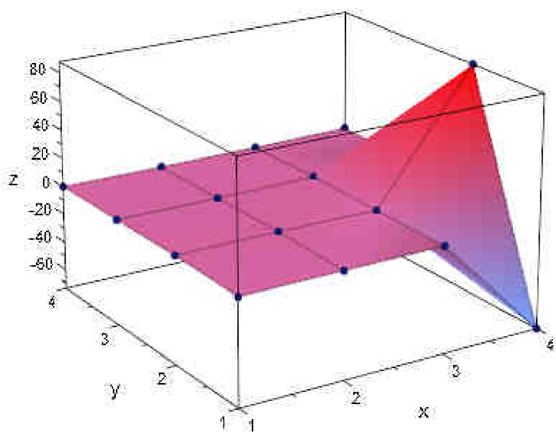
$$T\ home = \begin{pmatrix} 0 & 0 & 1 & a_1+a_2+d_6 \\ 0 & -1 & 0 & 0 \\ 1 & 0 & 0 & d1 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

IV. MUPAD GRAPHICS

```
(1)A:=[[-1,0,0,0],
[0,0,-1,0],
[0,-1,0,145],
[0,0,0,1]]:
plot(plot::Matrixplot(A))
```




```
(2)A:=[[-0.866,-0.5,0,-73.61],
[0.5,0.866,0,87.5],
  [0,0,1,0],
[0,0,0,1]]:
plot(plot::Matrixplot(A))
```



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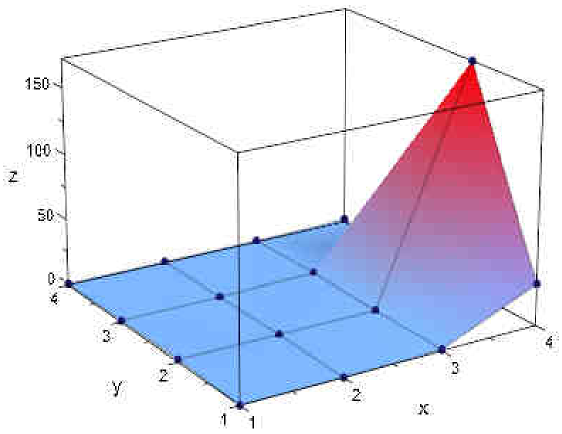
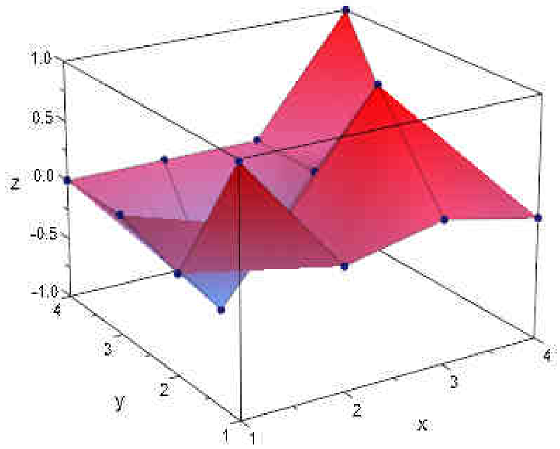
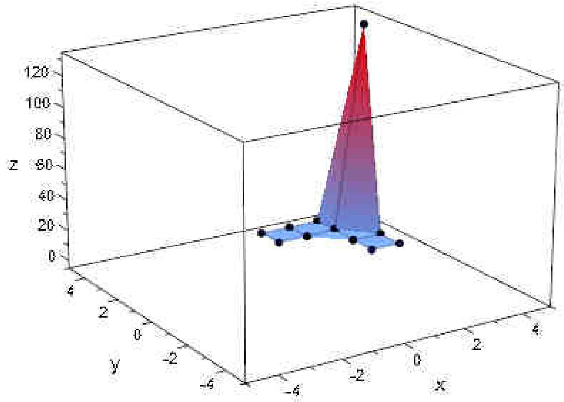
(3)A:=[[-1,-0.9848,0,30.38],
[0.9848,0.1736,0,172.34],
[0,0,1,0],
[0,0,0,1]]:
plot(plot::Matrixplot(A))



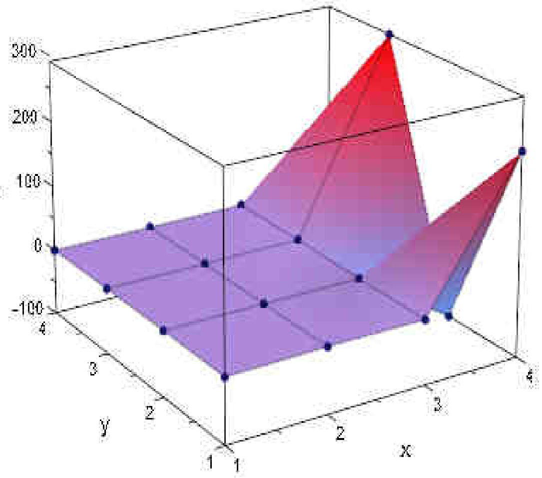
(4)A:=[[0.9848,0,0.1736,0],
[-0.1736,0,0.9848,0],
[0,-1,0,0],
[0,0,0,1]]:
plot(plot::Matrixplot(A))



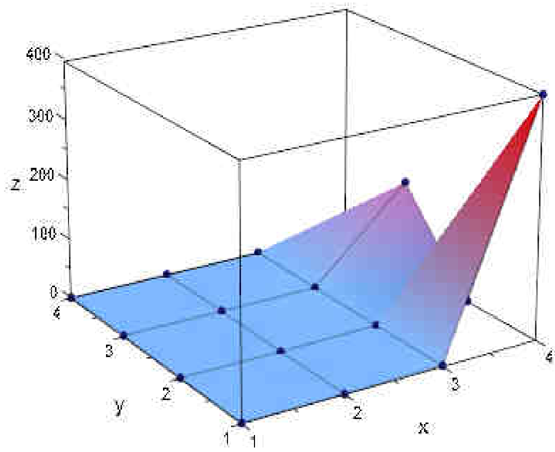
(5)A:=[[cos(x),-sin(x),0,0],
[sin(x),cos(x),0,0],
[0,0,1,135],
[0,0,0,1]]:
plot(plot::Matrixplot(A),x=15...48)



(6)A:=[[-0.8283,0.7220,-0.4637,210.9085],
[0.6590,0.1736,-0.7319,-98.8005],
[0.4946,0.6330,0.5955,290.8510],
[0,0,0,1]]:
plot(plot::Matrixplot(A))



(7) at home position
A:=[[0,0,1,395],
[0,-1,0,0],
[1,0,0,145],
[0,0,0,1]]:
plot(plot::Matrixplot(A))



IV. RESULT

The complete limit of work space for every joint is very essential so, we can come to know about the minimum and maximum work space limit. This data is very much important for designing and allotting joint parameters for performing the operation and location of work piece within the sufficient range of robotic manipulator. Through this study we know about each and every parameter.

V. CONCLUSION

5- DOF robot is generally used in industries especially automobile sector companies. Various joint parameters are very important in guiding a robotic manipulator to locate the position of action, perform the action / operation correctly and remove itself to a safe position without tool damage and were piece damage or go back to home position if required.

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The workspace is stipulated for every joint parameter for fast and accurate motion.

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