

Forward and inverse Kinematics Solution for Six DOF with the help of Robotics tool box in matlab

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ABSTRACT

Robot is the main part of flexible manufacturing system. Robotics is the vast field in which we can easily calculate the joint angles and position vectors of robot up to 3 degree of freedom. But in case of 6-arm robot to find joint angles and position vectors we need robotics toolbox in matlab. In this paper we find the position vectors of robot by forward kinematics and joint angles by inverse kinematics in matlab with the help of robotic toolbox.

Keywords: Forward kinematics, Inverse kinematics, Degree of freedom, Robotics.

1. INTRODUCTION

Robotics tool box is developed by Peter I. Corke CSIRO Manufacturing Science and Technology Pullenvale, AUSTRALIA, 4069 in year 2002. Robotics toolbox released in mat lab 7.1 provides many functions which are useful in robotics including kinematics, dynamics, and trajectory generation etc [7]. The Toolbox is useful for simulation as well as for analysing the results of experiments with real robots. The Toolbox is representing the kinematics and dynamics of robot manipulators [14]. Robot objects can be created by the user for any robot manipulator and a number of examples are provided for learning like Puma 560 and Stanford arm. The Toolbox also provides homogeneous transformations and unit-quaternions which are necessary to represent 3-dimensional positions and orientation of robot. With the help of robotics toolbox in matlab we can find out our data in which we have given the different angles and for which we get the different position vectors [19].

The inverse kinematics (IK) problem for a robot manipulator is to find the values of the joint angles given in the position and orientation of the end-effector relative to the base. There are many solutions to solve the inverse kinematics problem, such as geometric, algebraic, and numerical hit and trial, iterative, FABRIC methods [20]. The inverse kinematics solution is a major problem in robotic research area.

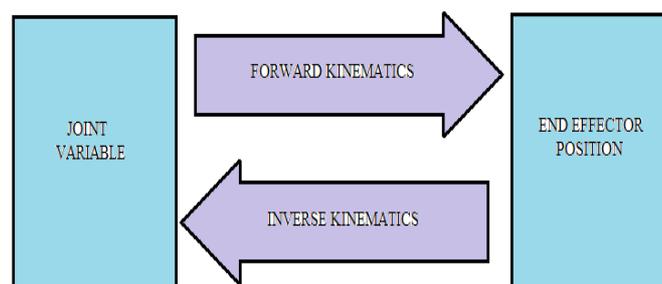


Figure 1 Relationship between Forward and Inverse kinematics

The conversion of the position and orientation of the robot manipulator end-effector from Cartesian space to joint space is called inverse kinematics problem. This relationship between forward and inverse kinematics is illustrated in Fig. 1. There are traditional methods to find inverse and forward such as algebraic solutions, geometric solutions and iterative solutions. However, these methods are time-consuming and suffer from numerical problems. Furthermore, if the joint structure of robot manipulator is more complex, inverse kinematics solution also is more difficult [13].

D-H parameters given by Denavit Hartenberg in 1955 who give as position vectors of robot manipulator at various joint angles [19]. Serdar Kucuk and Zafer Bingul gives the introduction of Forward and Inverse Kinematics of robot manipulator December 2006 in this paper he introduce D-H parameter [1]. On the basis of DH parameter in 2008 Sreenivas Tegomurtula, Subhas Kak gives Inverse kinematics of robotics by using neural network at same time

Srinivasan Alavandar, M.J. Nigam gives Nero fuzzy based approach for inverse kinematics solution of industrial robot manipulator Inverse kinematics solution for robot manipulator based on neural network joint subspace given by Y Feng, W.Yao-Nan & Y. Yi-min in 2012. Artificial neural network solution for planer parallel manipulator passing through the similar configuration given by Ammar H Elsheikh, Ezzat A Shoaib and Elwahed M Asar in 2013.

2. FORWARD AND INVERSE KINEMATICS OF SIX ARM ROBOT

In this paper we are using six link robot shown in fig. 2. In order to find relation between first link and last link we fixed the base (first link). This can be obtained from the description of the coordinate transformations between the coordinate frames attached to all the links and forming the overall description in a recursive manner. For this purpose, the position and orientation of the rigid body is useful for obtaining the composition of coordinate transformations between the consecutive frames. As a first step, this method is to be derived to define the relative position and orientation of two successive links. The problem is to define two frames attached to two successive links and make the coordinate transformation between them. It is convenient to set some rules for the definition of the link frames [3,6,8,12].

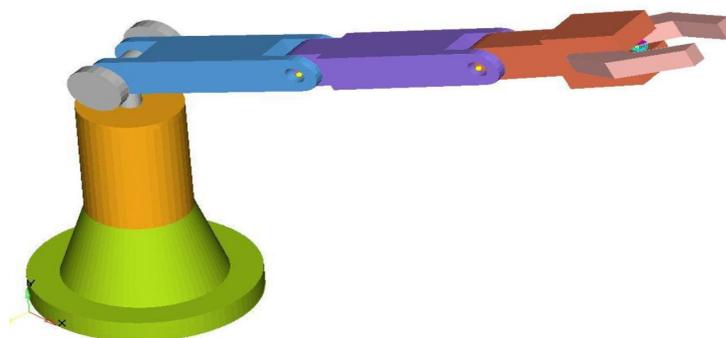


Figure 2 A six arm Robot

The DH parameters corresponding to this six arm robot manipulator are shown in Table 1. Here θ_i is the joint angle, d_i is joint offset, a_i is link length, and α_i is the twist angle. The limits of each of the joint angles have also been given in the table and these limits are also used in the matlab programming. The Denavit- Hartenberg (DH) convention and methodology is used to derive its forward kinematics [1,17].

Table 1: D-H Parameters

Joint Angle	Joint offset (d_i)	Link Length (a_i)	Twist Angle (α_i)	Angle limits
$\theta_1 + \pi/4$	0	0	$-\pi/6$	-185 to 185
$\theta_1 + \pi/3$	0.5	0.699	0	-155 to 35
θ_2	0.0948	0.0948	$\pi/2$	-130 to 154
$\theta_4 + \pi/3$	0.68	0	$-\pi/2$	-350 to 350
θ_5	0	0	$\pi/2$	-130 to 130
θ_6	0.853	0	0	-350 to 350

The process of calculating the position and orientation of the end effectors with given joint angles is called Forward Kinematics analysis. Forward Kinematics equations are generated from the Transformation matrixes and the forward kinematics solution of the arm is the product of these six matrices identified as OT_6 with respect to base as shown in equation no.1. The first three columns in the matrices represent the orientation of the end effectors, whereas the last column represents the position of the end effectors normal orientation and approach matrix [7, 15].

$$\begin{bmatrix} n_x & o_x & a_x & p_x \\ n_y & o_y & a_y & p_y \\ n_z & o_z & a_z & p \\ 0 & 0 & 0 & 1 \end{bmatrix} =$$

$$\begin{bmatrix} \cos\theta_i & -\sin\theta_i \cos\alpha_i & \sin\theta_i \cos\alpha_i & a_i \cos\theta_i \\ \sin\theta_i & \cos\theta_i \cos\alpha_i & -\cos\theta_i \sin\alpha_i & a_i \sin\theta_i \\ 0 & \sin\alpha_i & \cos\alpha_i & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (1)$$

Compare the normal orientation and approach matrix with homogenous transformation matrix. The manual solution of this matrix is difficult and the chances of increment of error is high. Same method is used on matlab in the term of programming with the help of robotics tool box, which is developed by Peter I. Corke CSIRO Manufacturing Science and Technology Pullenvale, AUSTRALIA, 4069 in year 2002 [7].

3.FORWARD AND INVERSE KINEMATICS OF SIX ARM ROBOT WITH THE HELP OF ROBOTICS TOOLBOX IN MATLAB

Forward and inverse of robot can be done with the help of robotics tool box which has been made by Peter I. Corke CSIRO Manufacturing Science and Technology Pullenvale, AUSTRALIA, 4069 in year 2002. First write start up_rvc on the screen of matlab toolbox and start the robotics toolbox [7,17]. Make a program according to your motion and D-H parameter showing above table no.1.The Toolbox provides functions for manipulating and converting the data types such as in Table no. 2. Given below the ten joint angle matrix and their corresponding ten position vectors for each input are shown [1].

Table 2: Input Joint Angles

Joint angle	1	2	3	4	5	6	7	8	9	10
θ_1	12	10	7	11	14	11	7	9	11	10
θ_2	18	15	11	19	24	19	14	16	16	15
θ_3	22	17	21	29	33	21	21	26	26	25
θ_4	32	20	32	39	43	29	24	36	36	36
θ_5	43	28	39	44	49	31	35	44	46	40
θ_6	50	38	47	50	51	40	49	52	50	50

Joint angle of any robot shows the current position of a robot at any certain position according to the DH parameter and every robot joint have fixed joint limits. We can change the joint angle and corresponding output will change according to the given input. If your given input crosses the limit forward kinematics is possible but inverse kinematics is not possible. It means the output is not real. Some positions of robot are shown in Fig. 3 according to given angle.

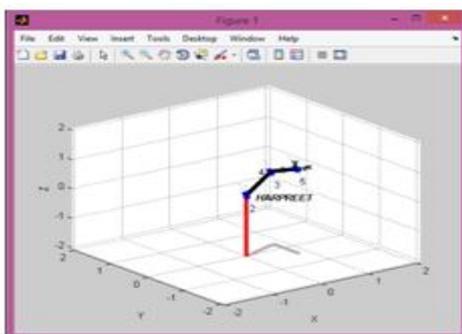


Figure 3 (a)

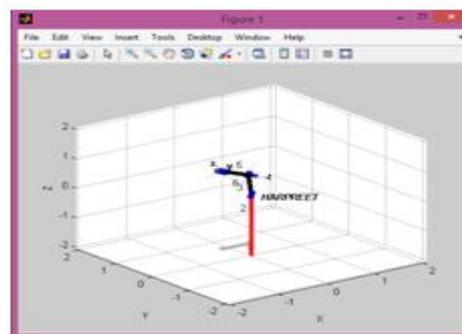


Figure 3 (b)

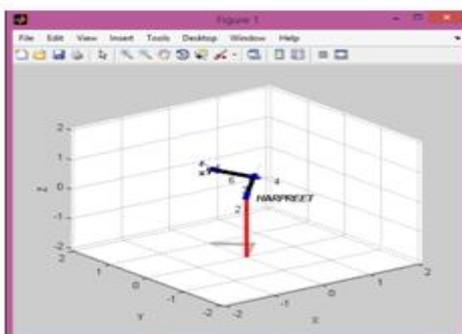


Figure 3 (c)

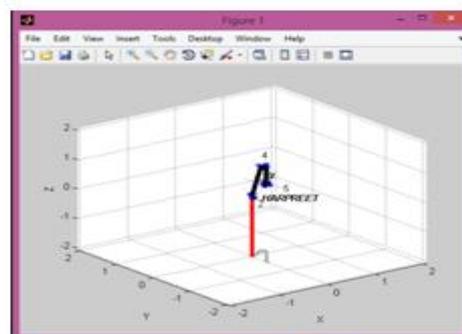


Figure 3 (d)

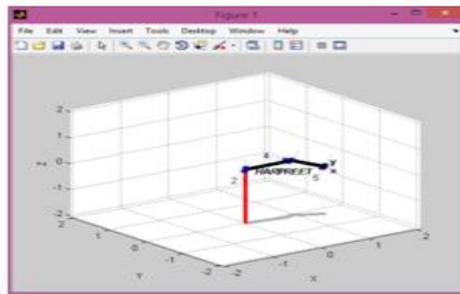


Figure 3 (e)

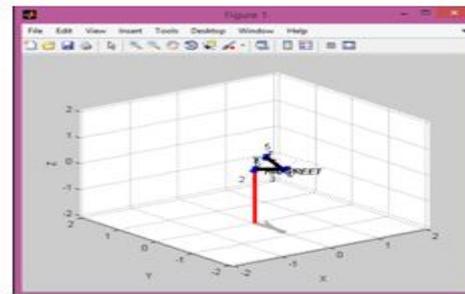


Figure 3 (f)

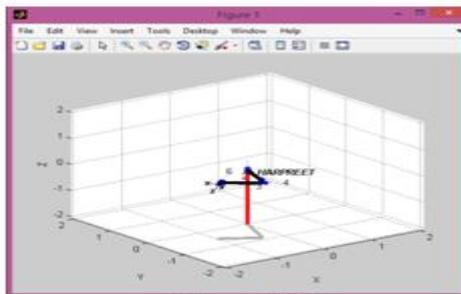


Figure 3 (g)

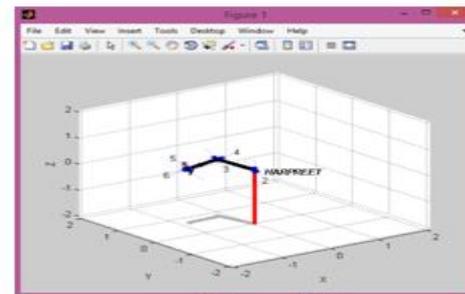


Figure 3 (h)

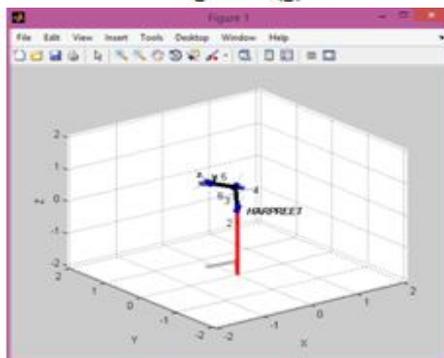


Figure 3 (i)

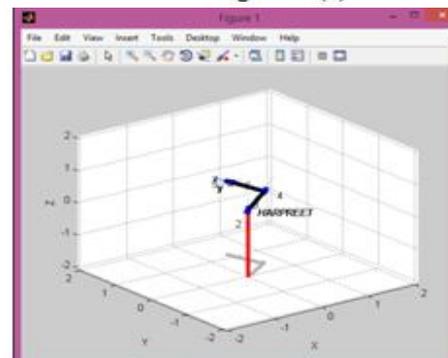


Figure 3 (j)

Figure 3 (a-j) Different Positions of Robot in 3-D

The output or position vectors of the robot according to the given joint angles are given in Table no. 3

Table 3: Output or position vectors of the robot corresponding to ten joint angles

Position vector	1	2	3	4	5	6	7	8	9	10
N _x	-0.43418	0.022283	-0.26918	-0.52539	-0.62439	-0.21337	-0.1646	-0.46334	-0.49907	-0.42181
N _y	0.660197	0.901223	0.766799	0.532454	0.342944	0.822721	0.798967	0.598272	0.602553	0.635403
N _z	0.612883	0.432783	0.582717	0.663671	0.701798	0.52688	0.578409	0.653751	0.622785	0.646791
O _x	-0.14155	-0.45013	-0.39482	-0.01246	0.246665	-0.3387	-0.36397	-0.12357	-0.08996	-0.20652
O _y	-0.72191	-0.37749	-0.63973	-0.78473	-0.76592	-0.56815	-0.59422	-0.77413	-0.75083	-0.76194
O _z	0.677357	0.809249	0.65944	0.619711	0.593737	0.749993	0.717235	0.620852	0.654346	0.613838
A _x	0.889634	0.892683	0.878441	0.850771	0.74114	0.91638	0.916752	0.877524	0.861881	0.88285
A _y	0.20734	-0.21284	-0.05256	0.317318	0.543835	-0.01843	-0.09246	0.206877	0.270538	0.125345
A _z	0.406892	0.397259	0.474952	0.418925	0.393643	0.399885	0.388609	0.432612	0.428918	0.45262
P _x	1.216677	1.183993	1.204717	1.257786	1.227498	1.217917	1.219845	1.252104	1.242704	1.241114
P _y	0.299788	0.125816	0.044102	0.3736	0.587547	0.269554	0.093132	0.238598	0.28533	0.224835
P _z	0.589809	0.640441	0.670239	0.547294	0.47014	0.583373	0.63309	0.594521	0.594089	0.611022

Similarly if we use position vectors as input then similar joint angles can be obtained as output in inverse kinematics and we get again same joint angle show in table no. 4.

Table 4: Output or position vectors of the robot corresponding to ten joint angles

Joint angle	1	2	3	4	5	6	7	8	9	10
θ_1	12	10	7	11	14	11	7	9	11	10
θ_2	18	15	11	19	24	19	14	16	16	15
θ_3	22	17	21	29	33	21	21	26	26	25
θ_4	32	20	32	39	43	29	24	36	36	36
θ_5	43	28	39	44	49	31	35	44	46	40
θ_6	50	38	47	50	51	40	49	52	50	50

4. RESULT AND CONCLUSION

In this paper, we considered the forward and inverse kinematics in six arm robot manipulator. We have presented different methods for finding multiple solutions for a given end-effector position (as in the example like algebraic, geometrical FABRIC etc). All methods show end effector position but it is limited to 2 or 3 degree of freedom system of robot. But forward and inverse kinematics of robot with the help of robotics tool box in mat lab is able to find end effector positions of large number of degree of freedom system of robot. In this we find end effector positions of six arm or six degree of freedom robot. by this method we can also find the position of intermediate links position vectors as well as joint angles at any position of robot. By using this method we can also make three dimensional view of robot, and also control the time, movement of robot of initial position to end position of end effector.

5. FUTURE SCOPE

Robotics tool box in mat lab is not only limited to forward and inverse kinematics of robot by which we can make controller of robot, can calculate link length and link weight, link momentum, link velocity, maximum limits of robot etc the data come from robotics tool box you can validate in different tools of mat lab like artificial neural network (ANN), articulated neuro fuzzy interference system (ANFIS) etc.

REFERENCES

- [1] Serdar Kucuk and Zafer Bingul Forward and Inverse Kinematics December 2006.
- [2] Joan Q Gan, Eimei Oyama, Eric M Rosales & Huoheng hu a complete analytical solution to the inverse kinematics of the pioneer 2r robotic arm Cambridge journals 7 may 2004.
- [3] LORENZO SCIAVICCO & BRUNO SCILIANO a solution algorithm to the inverse kinematics problem for redundant manipulator IEEE Journal of Robotics and Automation, Vol. 4 no.4 august 1998.
- [4] Li – Chun Tommy Wang & Chi Cheng Chen a combined optimization method for solving the inverse kinematics problem for mechanical manipulator IEEE Transaction on Robotics and Automation Vol. 7 No. 4 august 1991.
- [5] Kesheng Wang Efficient inverse position transformation for TR400S robot manipulator Modeling identification and Control, 1989, Vol.10 No. 2 101-113 9 feb. 1989.
- [6] Ziauddin ahmad & Allon Guez On the solution of inverse kinematics problem IEEE 1990.
- [7] <http://www.petercorke.com/robot> Robotics toolbox for Mat lab Release 9.0
- [8] Jianxin XU, Wei Wang & Yuanguang SUN two optimization algorithms for solving inverse kinematics with redundancy South China University of Technology and Academy of Mathematics and Systems Science, CAS and Springer-Verlag Berlin Heidelberg 2010.
- [9] B Purmus, H. Temurtas & A. Gan An inverse kinematics solution using practical swarm optimization 6th International Advanced Technologies Symposium (IATS'11), 16-18 May 2011, Elazığ, Turkey.
- [10] Ali T hasan & M.A.A. Al Assadi Performance prediction network for serial manipulator inverse kinematics solution passing through singular configuration Advanced Robotics System International 2010.
- [11] Adrew A. Goldenberg, B. Benhabib, & Robert G. Fenton a Complete Generalized Solution to the Inverse Kinematics of Robots IEEE JOURNAL OF ROBOTICS AND AUTOMATION, VOL. RA-1, NO. 1, march 1985.
- [12] Himanshu Chaudhary and Rajendra Prasad Intelegent Inverse kinematics control of scrobot- ER plus robot manipulator International Journal of Advances in Engineering & Technology, Nov 2011.
- [13] Mustafa Jabbar Hayawi analytical inverse kinematics algorithm Of A 5-DOF robot arm Journal of education of college no.4 vol.1 march./2011.

- [14]S. V. Shah ,S.K Saha, J.K Dutt Denavit-Hartenberg Parameterization of Euler Angles Journal of Computational and Nonlinear Dynamics 2012.
- [15]Harvey Lipkin a note on D-H notation on robotics ASME 2005.
- [16]Dr. Anurg Verma¹, Mehul Gor² forward and inverse kinematics of 6DOF arc welding robot International Journal of Engineering Science and Technology Vol. 2(9), 2010, 4682-4686.
- [17]Tadeusz szkodny Forward and inverse kinematics of IRb-6 manipulator Pergamon 1995.
- [18]Federico Thomas solved problem of robot kinematics by using robotics toolbox Barcelona, April 2nd, 2012.
- [19]www.robotshop.ca www.robotshop.us history of robotics.
- [20]Andreas Aristidou & Joan Lasenby FABRIC :- A fast iterative solver for the inverse kinematic problem ELSEVIER 9 may 2011.

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