ANFIS Based Forward and Inverse Kinematics of Six Arm Robot Manipulator with Six Degree of Freedom

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Abstract— *The forward and inverse kinematics of six arm robot is difficult task. But now a day many of researchers developed many ways to determine it. In this paper we use robotics tool box in mat lab in order to find forward and inverse kinematics of six arm robot. First in this paper developed D-H parameter, then make programming according to it. Next step choose joint angle first link to last link and determine its position vector with the help of forward and inverse kinematics of robot. After that validate the data come from robotics tool box by another tool box of matlab called adaptive neuro fuzzy interference system (ANFIS). First in validation step train the network with hundred position vector and joint angle. Then validate ten points and calculate error by norm command in mat lab between validate data and initial data of robotics.*

Keywords— *Forward kinematics, Inverse kinematics, Neural network, Robotics, ANFIS, DOF.*

I. Introduction

As strange as it might seem, there really is no standard definition for a robot. However, there are some essential characteristics that a robot must have and this might help you to decide what is and what not a robot is. It will also help you to decide what features you will need to build into a machine before it can count as a robot. Then robot can be defined as: “A robot is the device which perform human like function.”

According to American society of robotics the definition of robot is: “An industrial robot is reprogrammable, multifunctional manipulator, design to move material, parts, tool and specific devices through variable programmed motions for performance of variety of tasks.”
Modern robot manipulators and kinematic machine in general, are typically constructed by connecting different joints together using rigid links. First link of robot is generally fixed. A number of links are attached according to the manner of desired output by a set of joints. The kinematics of a robot manipulator describes the relationship between the motion of the joints, momentum, of a manipulator and resulting motion of the rigid bodies that form the robot. Most of the modern manipulators consist of a set of rigid links connected together by a set of joints. Although joint mechanism can be used to connect the links of a robot, traditionally the joints were chosen from revolute, prismatic, helical, cylindrical, spherical and planar joints. This paper looks at consist with revolute joints.

The forward and inverse kinematics problem for a serial-chain manipulator is to find the values of the joint angle given and find the position orientation of the end-effector relative to the base by D-H parameter’s. D-H parameter defines the robot in three dimensional spaces. There are many solutions to solve the inverse kinematics problem, such as geometric, algebraic, and numerical iterative, FABRIC etc. methods. In this paper the forward and inverse kinematics of six arm robot done with the help of robotics tool box.

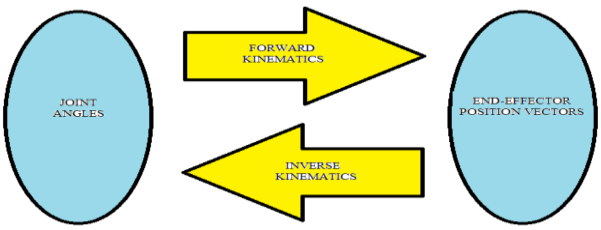


Fig. 1 Relationship between Joint variable and end effector position

The major role in the field of robotics was played by Denavit and Hartenberg in 1955 who gave position vectors of robot manipulator at various joint angles. On the basis of DH parameter in 2008 Sreenivas Tegomurtula, Subhas Kak gave Inverse kinematics of robotics by using neural network at same time Srinivasan Alavandar, M.J. Nigam gave Nero fuzzy based approach for inverse kinematics solution of industrial robot manipulator. FABRIC which is a fast iterative solver for the inverse kinematic problem given by Andeas Aristidou & joan Lasenby in 2011. 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.

II. 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 to last link 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.

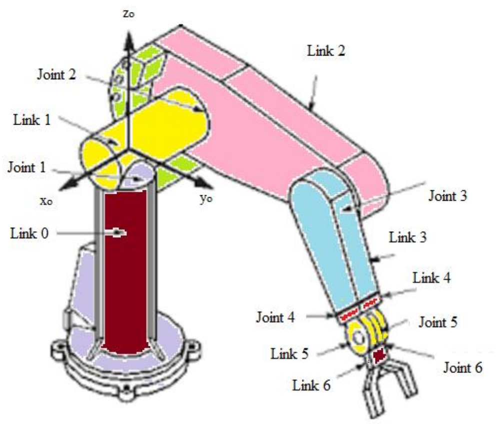


Fig. 2 A six arm Robot

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 program. The Denavit- Hartenberg (DH) convention and methodology is used to derive its forward kinematics.

Table I: 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_3	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 0T6 with respect to base. 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.

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

$$\begin{bmatrix} Cos\theta i & -Sin\theta i\ Cos\alpha i & Sin\theta i\ Cos\alpha i & ai\ Cos\theta i \\ Sin\theta i & Cos\theta i\ Cos\alpha i & -Cos\theta i\ Sin\alpha i & ai\ Sin\theta i \\ 0 & Sin\alpha i & Cos\alpha i & di \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (1)$$

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.

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

Robotics tool box has been made by Peter I. Corke CSIRO Manufacturing Science and Technology Pullenvale, AUSTRALIA, 4069 in year 2002. D-H parameter showing above table no.2.
First step write startup_rvc on the screen of matlab toolbox and start the robotics toolbox. Make a program according to the D-H parameter and then gives some joint angle in increasing manner shown in table no. 2.

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

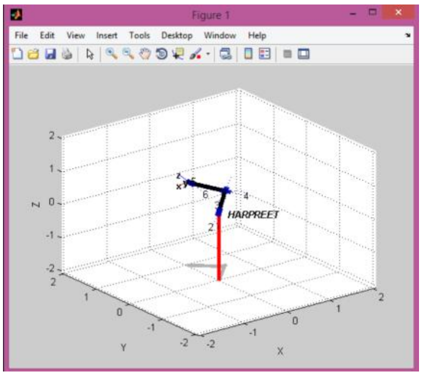


Fig. 3 (a)

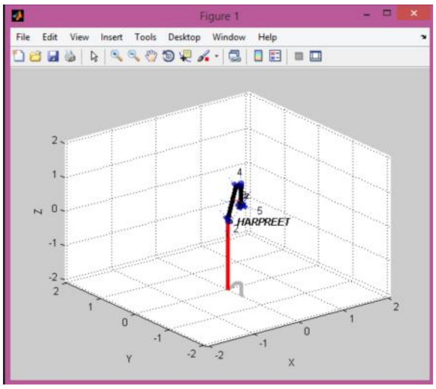


Fig. 3 (b)

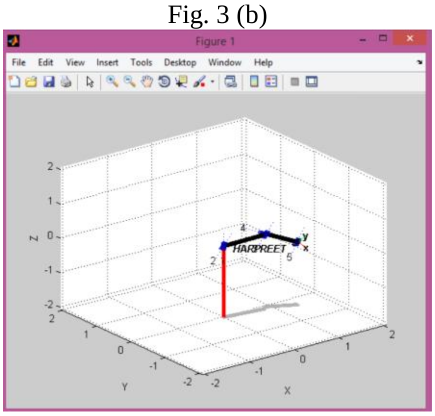


Fig. 3 (c)

Fig. 3 3D images of Robot

We can find position vectors as shown in table no. 3.

Table 3: Position Vectors

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

Pz	0.589809	0.640441	0.670239	0.547294	0.47014	0.583373	0.63309	0.594521	0.594089	0.611022

III. VALIDATE DATA WITH THE HELP OF ANFIS

A. Introduction of ANFIS

System modelling based on conventional mathematical tools (e.g., differential equations) is not well suited for dealing with ill-defined and uncertain systems. By contrast, a fuzzy inference system employing fuzzy if then rules can model the qualitative aspects of human knowledge and reasoning processes without employing precise quantitative analysis. This fuzzy modelling or fuzzy identification, first explored systematically has found numerous practical applications control prediction and inference .However, there are some basic aspects of this approach which are in need of better understanding. More specifically:

1. No standard methods exist for transforming human knowledge or experience into the rule base and database of a fuzzy inference system.
2. There is a need for effective methods for tuning the membership functions (MF's) so as to minimize the output error measure or maximize performance index.

In this perspective, the aim of this thesis is to suggest a novel architecture called Adaptive-Network-based Fuzzy Inference System, or simply ANFIS, which can serve as a basis for constructing a set of fuzzy if-then rules with appropriate membership functions to generate the stipulated input-output pairs [13, 21].
Step how to apply ANFIS:-
Step 1 start mat lap and write anfisedit on the command window of matlab.
Step 2 In second step train network with 100 position vector for first joint angle and give input position from table number 3 vector after that we get output in the term of joint angle. ANFIS output for joint angle 1 show below.
Step 3 same procedure repeat with all remaining position vector and get corresponding joint angle show in table no. 4

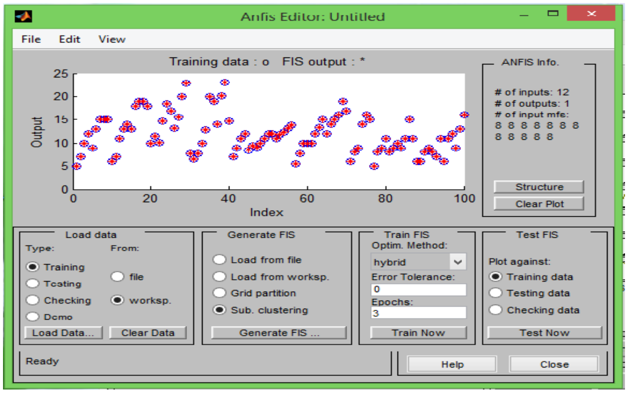


Fig. 4

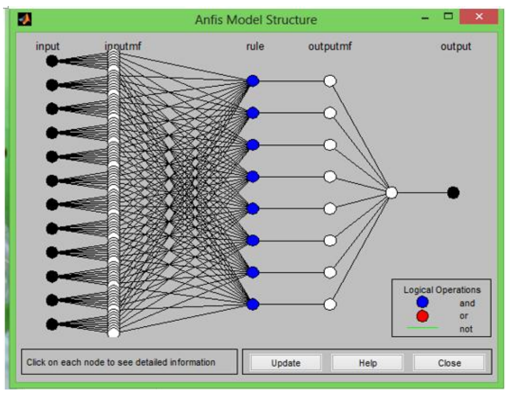


Fig. 5

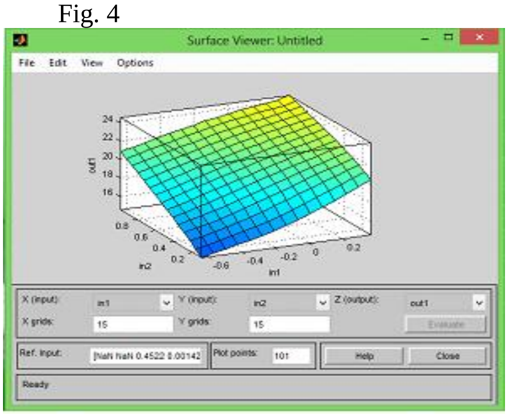


Fig. 8

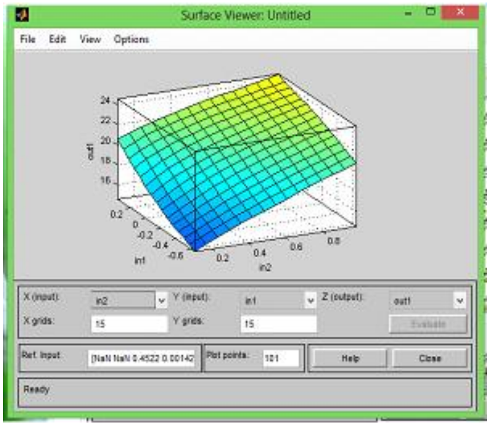


Fig. 6

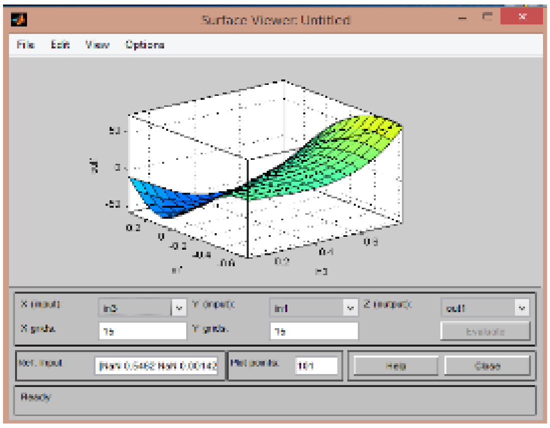
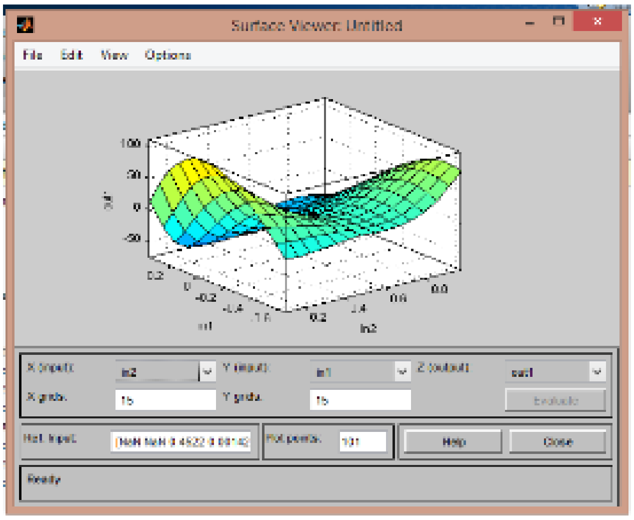


Fig. 9



Output joint angles from ANFIS shown in Table 4.

Table 4: Output Joint Angles from ANFISFig. 7

Joint Angles	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
θ_1	12	10.2	6.8	11	14.1	11	7	8.94	11	9.88
θ_2	17.9	14.2	11.3	18.9	23.9	19.1	14.1	16	15.8	15.1
θ_3	22.6	16.8	22.4	29.1	28.8	20.6	20.2	26.3	26.2	26
θ_4	32.3	20.3	30.3	39	43.6	28.9	23.4	36.2	36.4	36.6
θ_5	42.8	27	38.2	44	48.6	30.9	35.2	43.9	45.9	39.4
θ_6	49.7	37	48.5	50.1	51.7	40.1	49.4	52	49.8	49.9

IV. CONCLUDING REMARKS

In this paper, we considered the problem of forward and inverse kinematics of six arm robot with six degree of freedom. In this study, the inverse kinematics solution using ANFIS for a 6-DOF Robot manipulator is presented. The difference in position vectors (table no. 4) deduced and predicted with ANFIS model in robotics toolbox for a 6-DOF Robot manipulator (table no. 3), it clearly depicts that the proposed method results with an acceptable error 0.030. The modelling efficiency of this technique was obtained by taking 10 end-effectors position vector coordinates as input parameters to our ANFIS network which gives the same output as predicted in robotics toolbox. Also, the ANFIS model used with a smaller number of iteration steps with the hybrid learning algorithm. Hence, the trained ANFIS model can be utilized to solve complex, nonlinear and discontinuous kinematics equation for a complex robot manipulator; thereby, making ANFIS and robotics toolbox an alternative approach to deal with inverse and forward kinematics of the robot.

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