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Inverse kinematics Solution of PUMA by using ANFIS Technique

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Abstract*: In this paper Inverse kinematics solution of the PUMA 560 is solved. In robotics the main problem is to find the inverse kinematics solution. Forward kinematics is calculated with the help of D-H (Denavit-Hartenberg) parameter method. Now a day's inverse kinematics is the area of research in robotics. In present paper, Inverse kinematics is calculated by mathematically and by ANFIS and then difference between the predicted value and deducted value is calculated. Workspace area of PUMA Robot is also shown in this paper.

Keywords: ANFIS, kinematics, Robotics arm, optimization, Robot manipulator, Neural networks, Fuzzy logic.

I. INTRODUCTION

With the advancement of technology robots play an important rolw in the Industry. PUMA robot used in different industries for safety reasons. It also increase the production in the industries. The efficiency and the accuracy of the industries also improve with the use of the robots[1]. Now a days, study of robotics is a new topic of research .This study of robotics is done with the help of kinematics, In robotics there are forward and inverse kinematics[11]. As the degree of freedom increase in the robot it's very difficult to find the solution of Inverse kinematics [12]. The forward kinematics is solved with the help of Denavit-Hartenberg (D-H) parameter. PUMA 560 is a six degree of freedom robots and each link is shown in the figure[4].

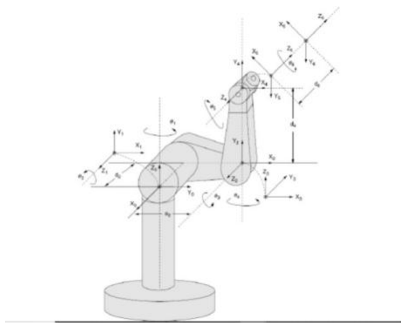

Figure1. Puma 560 robot[4]

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Many techniques are used to calculate the solution of inverse kinematics like algebraic, geometric and numerical method. In this paper the inverse kinematics solution is find out by the D-H parameter and code is written in the MATLAB , the same solution is find out by the applying the adaptive neuro fuzzy interface system(ANFIS)[3].

II. D-H PARAMETER

D-H parameters are nearly new to calculate the kinematics solution of the robots. There are the four parameters used in this which define the relationship between the joints[13].

The parameters are shown below in table. In forward kinematics the theta values are given and the values of x,y,z are find out. In each robot the first step is to find the forward kinematics using the table[5].

Table 1: DH Parameter of PUMA 560 Robot

Θi	α_i	d_i	a_i
90	-90	0	-160 to +160
0	0	149.09	-225 to 45
90	90	0	-45 to 225
0	-90	433.07	-110 to 170
0	90	0	-100 to 100
0	0	56.25	-266 to 266

$$T= T_1\, T_2= {}^0A_1\, {}^1A_2\, {}^2A_3\, {}^3A_4\, {}^4A_5\, {}^5A_6 = \begin{bmatrix} n_x & s_x & a_x & p_x \\ n_y & s_y & a_y & p_y \\ n_z & s_z & a_z & p_z \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$N_{x1}= C_1 [C_{23i}(C_4\, C_5\, C_6 - S_4\, S_6) - S_{23}\, S_5\, C_6] - S_1(S_4\, C_5\, C_6+ C_4\, S_6)$ (1)

$n_{y1}= S_1[C_{23i}(C_4\, C_5\, C_6 - S_4\, S_6) - S_{23}\, S_5\, C_6] + C_1(S_4\, C_5\, C_6+ C_4\, S_6)$ (2)

$n_{z1}= -S_{23}[C_4\, C_5\, C_6 - S_4\, S_6] - C_{23}\, S_5\, C_6]$ (3)

$s_{x1}= C_1[-C_{23}(C_4\, C_5\, C_6 + S_4\, S_6) + S_{23}\, S_5\, C_6] - S_1(-S_4\, C_5\, C_6+ C_4\, S_6)$ (4)

$s_{y1}= S_1[-C_{23}(C_4\, C_5\, C_6 + S_4\, S_6) + S_{23}\, S_5\, C_6] + C_1(-S_4\, C_5\, C_6+ C_4\, S_6)$ (5)

$s_{z1}= S_{23}[C_4\, C_5\, C_6 + S_4\, S_6] - C_{23}\, S_5\, C_6]$ (6)

$a_{x1}= C_1[C_{23}C_4\, S_5 + S_{23}\, C_5] - S_1S_4\, S_5$ (7)

$a_{x1}= S_1[C_{23}C_4\, S_5 + S_{23}\, C_5] - C_1S_4\, S_5$ (8)

$a_{x1}= -S_{23}C_4\, S_5 + C_{23}\, C_5$ (9)

$p_{x1}= C_1[d_6(C_{23}C_4\, S_5 + S_{23}\, C_5) + S_{23}\, d_4 + C_{23}\, a_3 + C_2\, a_2] - S_1(d_6\, S_4\, S_5 + d_2]$ (10)

$p_{y1}= S_1[d_6(C_{23}C_4\, S_5 + S_{23}\, C_5) + S_{23}\, d_4 + C_{23}\, a_3 + C_2\, a_2] + C_1(d_6\, S_4\, S_5 + d_2]$ (11)

$p_{x1} = d_6(C_{23}C_5 - S_{23}C_4S_5) + C_{23}d_4 - S_{23}a_3 - S_2a_2$ (12)

[16]

Inverse Kinematics

After finding the forward kinematics the next step is to calculate the IK. The x,y,z values are given and to find out the values of the different thetas. Inverse kinematics is a important thing in the robotics and to find the best theta values is a important thing[6][14].

$$\text{theta } 1 = tan^{-1}\frac{-P_x d_2 - ARM\ P_y\sqrt{P_x^2+P_y^2+d_2^2}}{P_y d_2 - ARM\ P_x\sqrt{P_x^2+P_y^2+d_2^2}}$$

(13)

all the possible values of the arm and the elbow is shown in Table 2

. $Sin(\theta_2)$= Sin α_1 Cos β_1 +(ARM1.ELBOW1) Cos α Sin β (14)

$Cos(\theta_2)$= Cos α Cos β - (ARM1.ELBOW1) Sin α Sin β (15)

$$\text{theta } 2_1 = tan^{-1}\frac{Sin(\theta_2)}{cos(\theta_2)}$$

(16)

$$R = \sqrt{P_x^2 + P_y^2 + P_z^2 - d_2^2}$$

(17)

$$\text{Cos}\varphi = \frac{a_2^2 + (d_4^2 + a_3^2) - R^2}{2\,a_2\sqrt{d_4^2 + a_3^2}}$$

(18)

$$Sin(\phi) = \text{ARM.ELBOW}\sqrt{1 - Cos^2\phi}$$

(19)

$$\text{Sin }\beta = \frac{d_4}{\sqrt{d_4^2 + a_3^2}}$$

(20)

$$\text{Cos }\beta = \frac{a_3}{\sqrt{d_4^2 + a_3^2}}$$

(21)

$Sin(\theta_3)$= Sin φ Cos β +Cos φ Sin β (22)

$Cos(\theta_3)$= Cos φ Cos β +Sin φ Sin β (23)

$$\text{theta } 3_1 = tan^{-1}\frac{Sin(\theta_3)}{cos(\theta_3)} \quad (24)$$

Table. 3 represent the wrist orientation.

$$\text{theta4} = tan^{-1}\frac{M(C_1 a_y - S_1 a_x)}{M(C_1 a_x C_{23} + C_{23} S_1 a_y - S_{23} a_z)}$$

(25)

theta5=

$$tan^{-1}\frac{(C_1 C_{23} C_4 - S_1 S_4)a_x + (S_1 C_{23} C_4 + C_1 S_4)a_y - C_4 S_{23} a_z}{(C_1 S_{23}\ a_x + S_1 S_{23} C_4\ a_y + C_{23} a_z}\ (26)$$

theta6=

$$tan^{-1}\frac{(-C_1 C_{23} C_4 - S_1 C_4)n_x + (-S_1 C_{23} S_4 + C_1 C_4)n_y - S_4 S_{23} n_z}{(-C_1 C_{23} C_4 - S_1 C_4)s_x + (-S_1 C_{23} S_4 + C_1 C_4)s_y - S_4 S_{23} s_z}$$

(27)

Table 2: Various arm configuration for joint 2

Arm Configuration	ARM	ELBOW	ARM.ELBOW
Port side and up	-1	+1	-1
Port side and down	-1	-1	+1
upRight and up	+1	+1	+1
upRight and down	+1	-1	-1

Table 3: Various Orientation for the wrist

Wriest Orientation	Ω= s.y5	Wrist	M= Wrist*Ω
Declining	≥0	+1	+1
Declining	<0	+1	-1
UP	≥0	-1	-1

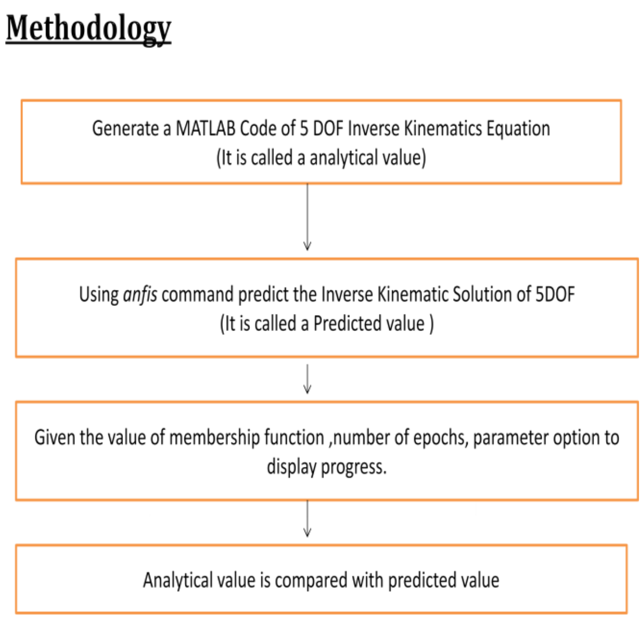
III. ADAPTIVE NUERO- FUZZY INTERFACE SYSTEM(ANFIS)

It is a rule based method also called a hybrid learning procedure; it is a amalgam of the neural network and the fuzzy logic.[7] This techniques discovered in 1990 based on Takagi–Sugeno fuzzy inference system.The fuzzy logic considered the imprecision and uncertainty while neural network give the sense of adaptability[8]. The training is done with the help of the input output datasets. The main objective of ANFIS is to built a model of robotics on which fuzzy rules are applied to get the input–output dataset[9].

Fuzzy interfece model approximate the data set consist of collection of input-output.Such models have a number of membership function with adjustable parameter[10]. The neuro adbative learning take place through input output dataset and using this database anfis construct a fuzzy interference structure whose parameters are adjusted with the backpropogation and least square method. The parameters of the membership function adjusted or changed as the learning process is going on.

IV. SIMULATION AND RESULTS

The methodoly used in this process is shown below. In this first the D-H parameter of the robot is used to calculate the Kinematics result of the robot. The matlab code is written for these equation and these values called the analytical values. Now using the anfis technique the solution of inverse kinematics is find out this value is called as predicted value. For anfis we given the value of membership function ,number of epochs ,and other parameter. Then the both values are compared.



Forward and Inverse kinematics equations can be solved by the mathematical equations with the help of DH parameters and then apply the ANFIS is used to find the predicted value, the difference between the predicted and deducted value is shown in the figure 3

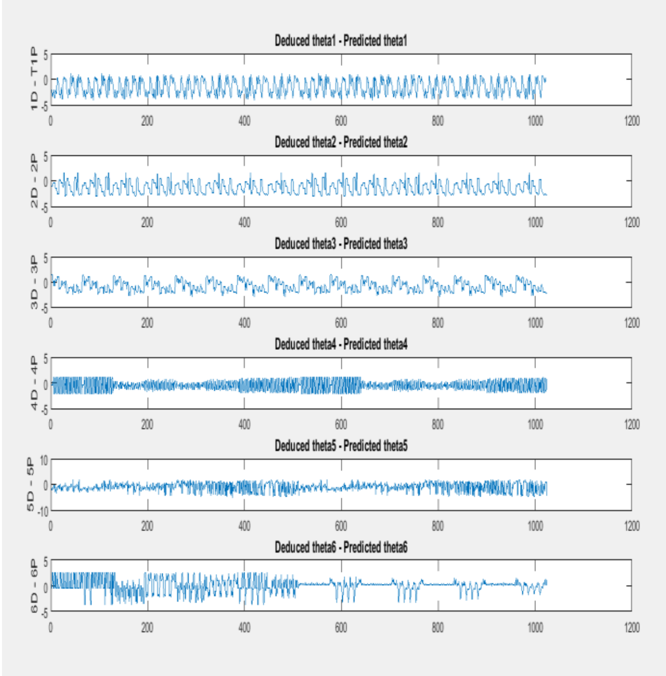


Figure3: Divergence of the predicted and analytical value

The ANFIS procedure followed is shown in figure 4.

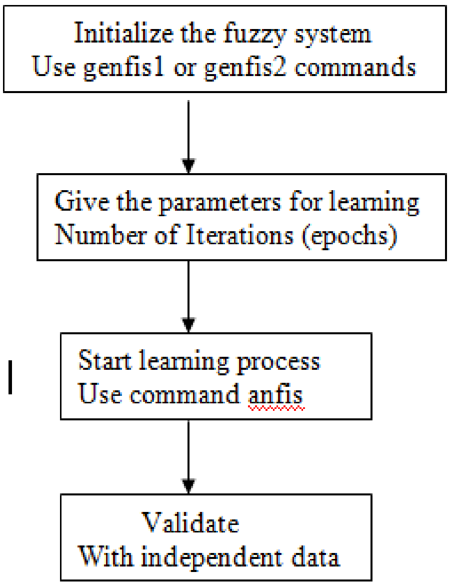
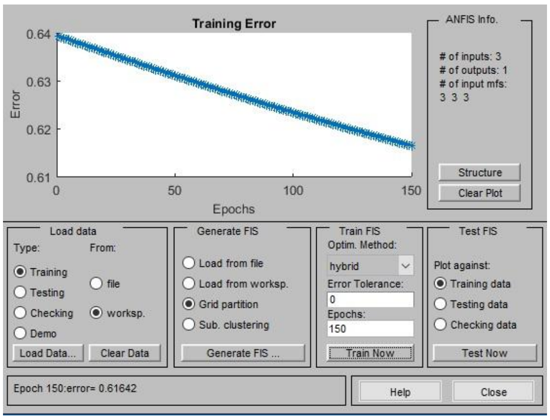
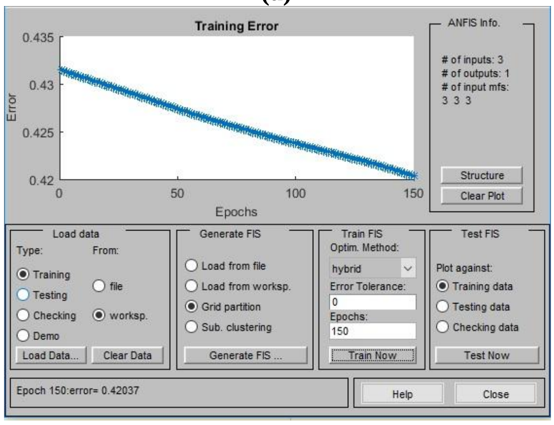


Figure 4: ANFIS Procedure

In figure 5 the ANFIS procedure is shown in which first we open anfis tool and intilize the fuzzy system then set the number of iteration and the input data is taken from the workspace and then start the learning process. The data is validate in the end. The figure 5 show the training of the six theta values by ANFIS network the co-ordinates will act as a input and the different theta values will act as a output. The membership function of the model is adjust so that it will give a best theta values as output.



(a)



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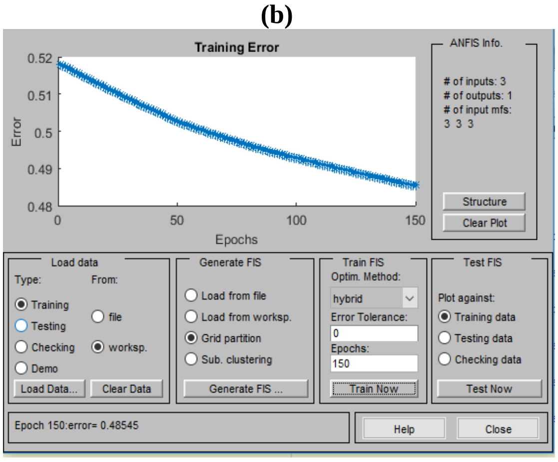

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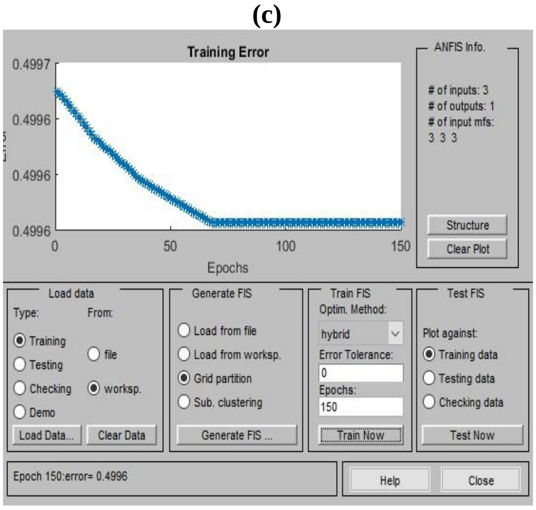

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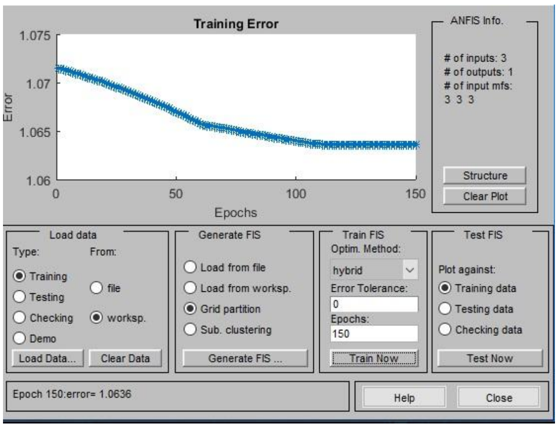
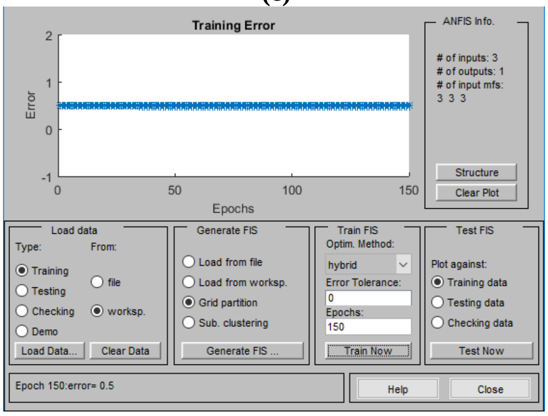


(e)



(f)

Figure 5: Training result of different theta(1to6) by ANFIS

The work space area of PUMA 560 arm) is shown below .The red star show the resolution and in this area the movement of the robot is fine and the resolution of the end effectors is maximum.

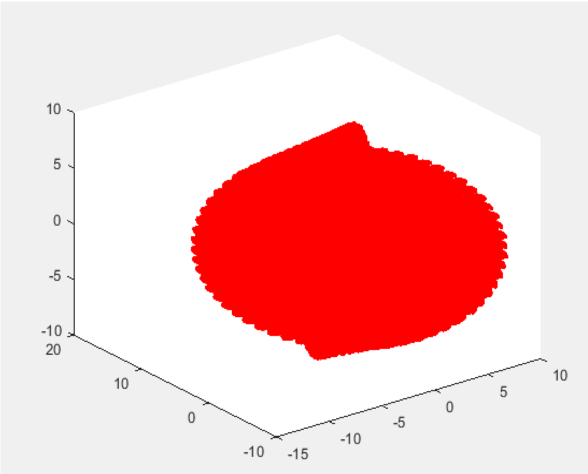


Figure 6. Workspace Area of PUMA 560

V. CONCLUSION

In this paper the solution of Inverse kinematics problem of PUMA robot is find out by by using ANFIS technique and joint angles are derived for the trajectory. The difference between the analytical and the predicted value is calculated and the results are acceptable. As compared to the other techniques this technique is acceptable and produces fast result of inverse kinematics. The workspace area of the end effector of a robot is also shown in a figure.

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