ANFIS Based Forward and inverse Kinematics of Robot Manipulator with five Degree of Freedom

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***Abstract* - The forward and inverse kinematics of five arm robotics difficult task. Nevertheless now each day many of researchers developed many ways to determine it. In this paper we use anfis algorithm in matlab in order to find forward and inverse kinematics of five arm robot. First in this paper developed D-H parameter, then make programming according to it. Next step choose joint angle first connect to last link and determine its position vector with assistance from forward and inverse kinematics of robot. Next 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, Robotics, ANFIS, DOF, Denavit-Hartenberg representation**

I. INTRODUCTION

As strange as it can seem, there really isn't any standard definition for a robot. However, there are several essential characteristics a robot should have and this could allow you to decide what's and what not really a robot is. It will even allow you to decide what features you will have to build into a machine before it could 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 maneuver material, parts, tool and specific devices through variable programmed motions for performance of number of tasks. Modern robot manipulators and kinematic machine in general, are generally 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 couple 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. The majority of the modern manipulators consist of a couple of rigid links connected together by a couple of joints. Although joint mechanism can be utilized 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 positioning orientation of the end-effector relative to the beds base by D-H parameter's. D-H parameter defines the robot in three dimensional spaces. There are numerous solutions to fix the inverse kinematics problem, such as for instance geometric, algebraic, and numerical iterative etc. methods. In this paper the forward and inverse kinematics of five dof robot arm done with assistance from anfis tool box.

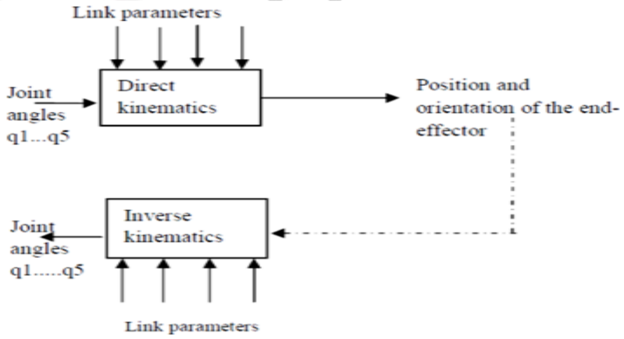

Figure 1: Forward and Inverse Kinematics Model

Kinematics

It's the branch of classical mechanics that describes the motion of bodies (objects) and systems (groups of objects) without consideration of the forces that cause the motion. Kinematics is the task of calculating the positioning in space of the final outcome of a linked structure, given the angles of most of the joints. This technique can be extremely useful in robotics. You could have a computerized arm which must seize an object. If the program knows where to be honest

1. Forward Kinematics

The forward kinematics is worried with the relationship between the patient joints of the robot manipulator and the career (x, y and z) and orientation (Φ) of the end-effector. Stated more formally, the forward kinematics is to ascertain the career and orientation of the end-effector, given the values for the joint variables (Θ_i , a_i , d_i , α_i) of the robot. The joint variables are the angles involving the links in case of revolute or rotational joints, and the web link extension in case of prismatic or sliding joints. The essential concept of forward kinematic animation is that the positions of particular parts of the model at a specified time are calculated from the career and orientation of the item, along with any info on the joints of an articulated model. So for example if the item to be animated is a supply with the shoulder remaining at a fixed location, the precise location of the tip of the thumb could be calculated from the angles of the shoulder, elbow, wrist, thumb and knuckle joints. Three of those joints (the shoulder, wrist and the base of the thumb) have multiple level of freedom, which must be studied into account. If the model were an entire human figure, then your precise location of the shoulder would also have to be calculated from other properties of the model.

2. Inverse Kinematics

It'll enable us to calculate what each joint variable must be if we desire that the hand be located at particular point and have a specific position. The positioning and orientation of in conclusion effector relating with the bottom frame compute all possible sets of joint angles and link geometries which may be properly used to attain the given position and orientation of in conclusion effector [20].

Degrees of freedom (DOF)

The Degree of freedom, or DOF, are an essential term to understand. Each degree of freedom is a joint on the arm, a spot where it may bend or rotate or translate. You can typically identify the number of quantities of freedom by the number of actuators on the robot arm. When creating a robot arm few quantities of freedom is allowed for the applying, because each degree requires a motor, often an encoder, and exponentially complicated algorithms and cost [24].

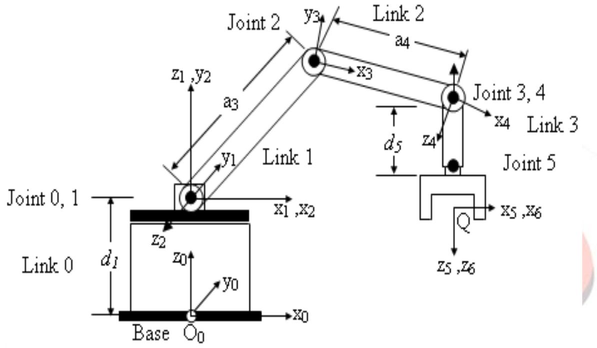

Fig 2: 5DOF Robot Arm Frame Assignment

Table 1: The D-H parameters of the 5 DOF robotic Arm

Frame	Θ_i	D_i(mm)	a_i(mm)	α_i(degree)
O_0-O_1	Θ_1	120	68.75	-90
O_1-O_2	Θ_2	0	160	0
O_2-O_3	-90 +Θ_3	0	0	-90
O_3-O_4	Θ_4	137.75	0	90
O_4-O_5	Θ_5	0	0	-90
O_5-O_6	0	113.21	0	0

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, beginning base), since each joint connect to two links. By this convention, joint i connect link i -1to link i. It is recognized as that the located area of the joint i to be fixed with respect to link i -1. Each link of the robot manipulator is regarded as being rigidly attached to a coordinate frame for performing the kinematics analysis. Specifically, link i is attached to $o_i\ x_i\ y_i\ z_i$.It shows that whenever the robot executes motion, the coordinate of each point on the link i are constant when expressed in the i^{th} coordinate frame. Furthermore when joint i actuate link i and its attached frame $o_i\ x_i\ y_i\ z_i$, experience a resulting motion. The frame $o_0\ x_0\ y_0\ z_0$ is really a inertial frame because it attached to the robot base.

The 5 degrees of freedom robotic arm's end-effector position in Cartesian space could be directly linked to its link lengths and joint angles by the following equations:

$$^{i-1}t_i = \begin{bmatrix} c\theta i & -s\theta ic\alpha i & s\theta is\alpha i & aic\theta i \\ s\theta i & c\theta ic\alpha i & -c\theta is\alpha i & ais\theta i \\ 0 & s\alpha i & c\alpha i & di \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (1)$$

$$T_e = \begin{bmatrix} n_x & o_x & a_x & p_x \\ n_y & o_y & a_y & p_y \\ n_z & o_z & a_z & p_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (2)$$

Where, $n_x = C_{12}C_{345}$, $n_y = S_{12}$, $n_z = C_{12}$, S_{345},$o_x = S_{12}$,C_{345},$o_y = -C_{12}$, $o_z = S_{12}S_{345}$,, $a_x = S_{345}$, $a_y = 0$, $a_z = -C_{345}$, $p_x = S_{12}d_5+C_{12}a_4C_{34}+C_{12}a_3C_3$ $p_y = -C_{12}d_5+S_{12}a_4C_{34}+S_{12}a_3C_3$, $p_z = a_4S_{34}+a_5S_5+d_1$,

where, $C_i = \text{Cos}(\Theta_i)$, $S_i = \text{Sin}(\Theta_i)$, $C_{23} = \text{Cos}(\Theta_2 + \Theta_3)$ and $S_{23} = \text{Sin}(\Theta_2 + \Theta_3)$.

$$\theta_1 = a\tan 2(p_x, p_y)$$

$$\theta_2 = A\tan 2(S_2, C_2)$$

$$\theta_3 = A\tan 2(S_3, S_4)$$

$$\theta_4 = \theta_{234} - \theta_3 - \theta_2$$

$$\theta_5 = A\tan 2(S_5 - C_5)$$

II. RESULTS

Forward kinematics of robotic arm

In this section of the research paper the graphical plots of predicted positon vectors versus actual position vectors that is px ,py and pz for the 5-DOF redundant manipulator is carried out. The error iterations versus training iterations of these position vectors are also calculated in this paper. The graphs obtained from this position vectors are shown below:

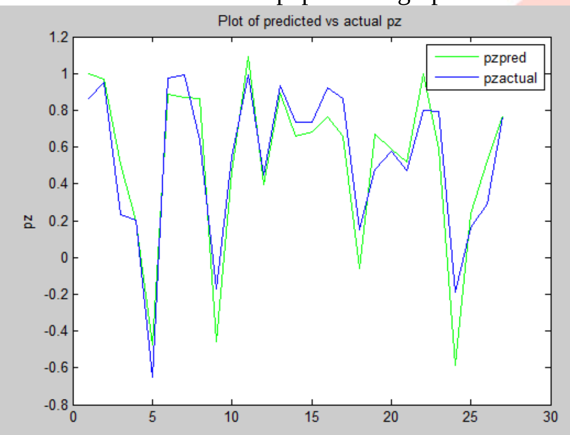

Fig. 3(a)

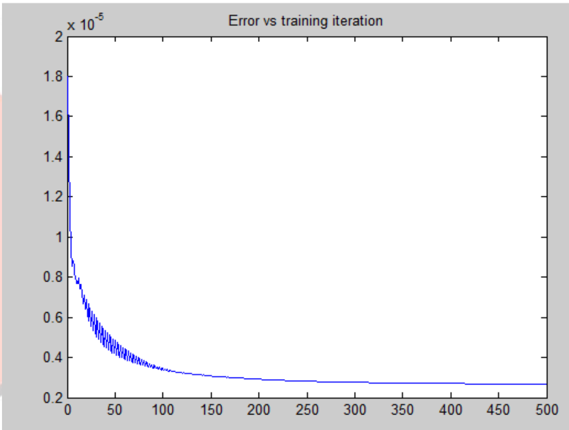

Fig. 3(b)

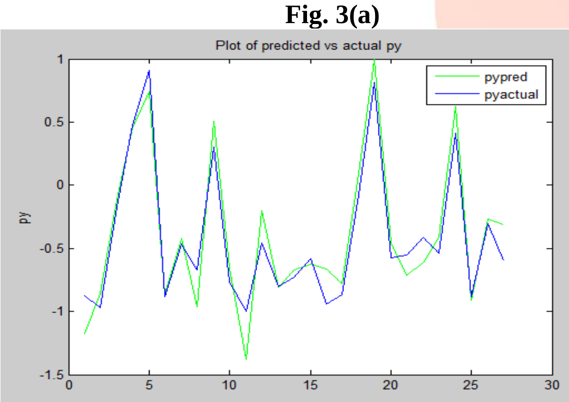

Fig .3(c)

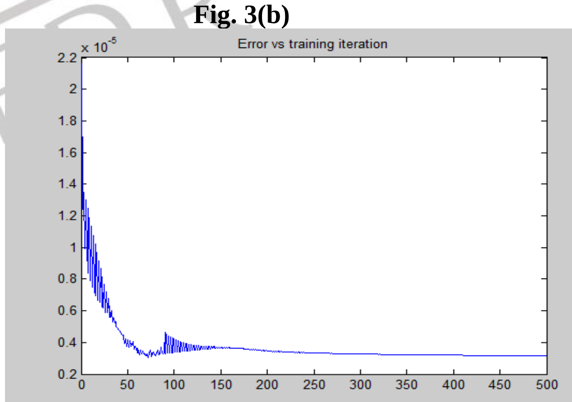

Fig. 3(d)

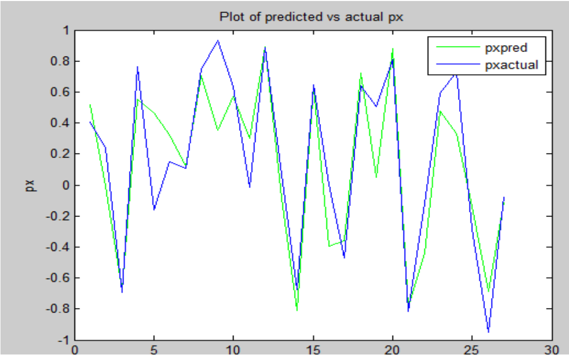

Fig. 3 (e)

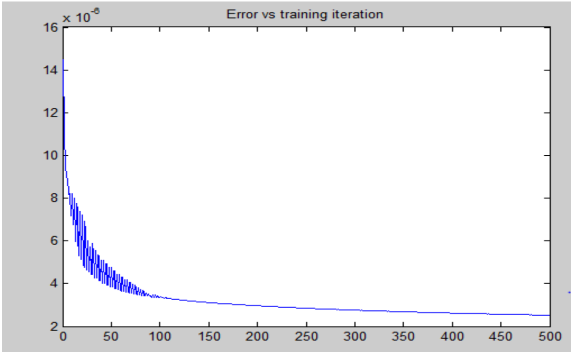

Fig.3 (f)

Fig 3 (a), (b), (c), (d), (e), (f) plot of predicted versus actual pz ,py , pz position vectors of robotic arm and their error versus training iterations respectively.

Inverse Kinematics of robotic arm

In this section of the research paper the graphical plots of predicted thetas versus actual thetas that is theta1, theta2, theta3, theta4, theta5 for the 5-DOF redundant manipulator is carried out. The error iterations versus training iterations of these thetas are also calculated in this paper. The graphs obtained from this position vectors are shown below:

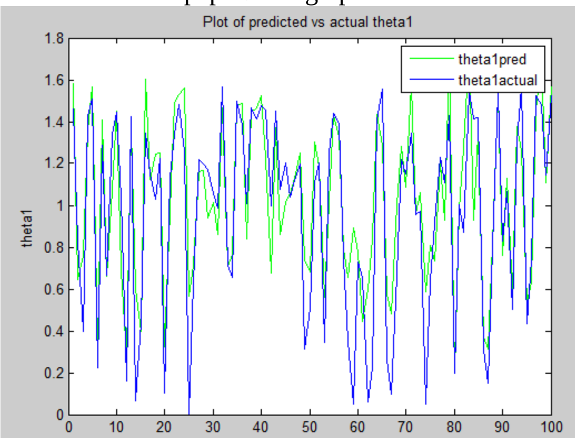

Fig. 3(g)

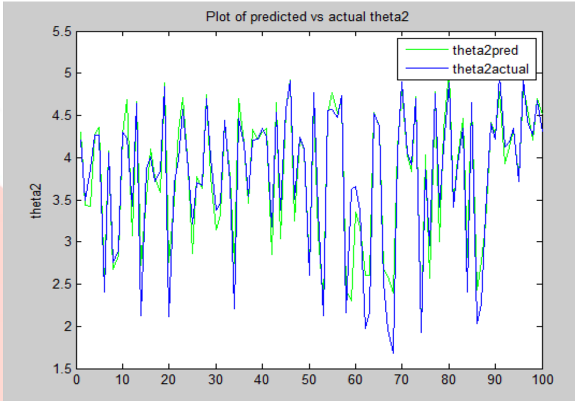

Fig. 3(h)

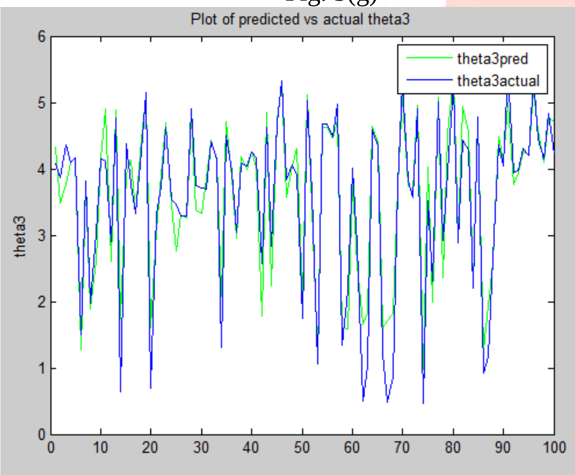

Fig. 3(i)

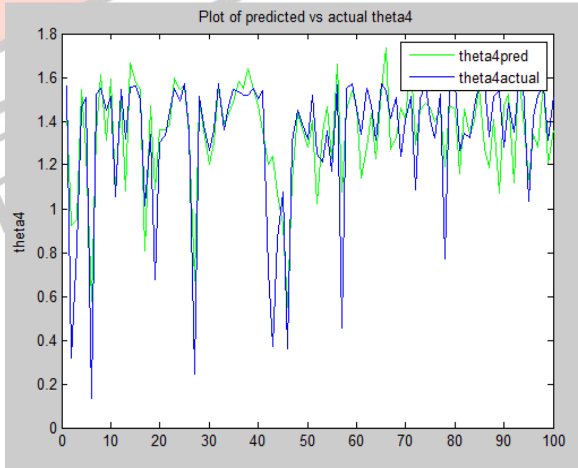

Fig. 3(j)

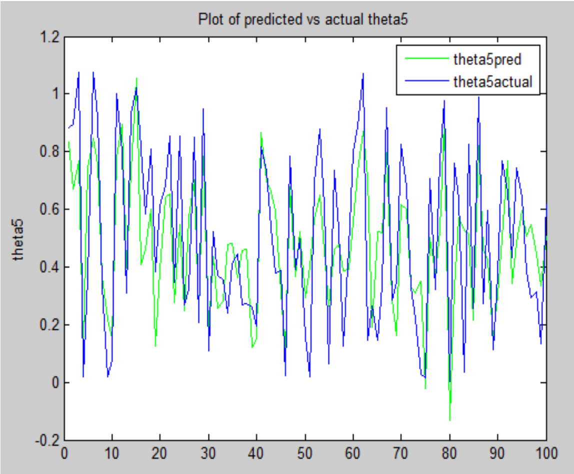

Fig. 3(k)

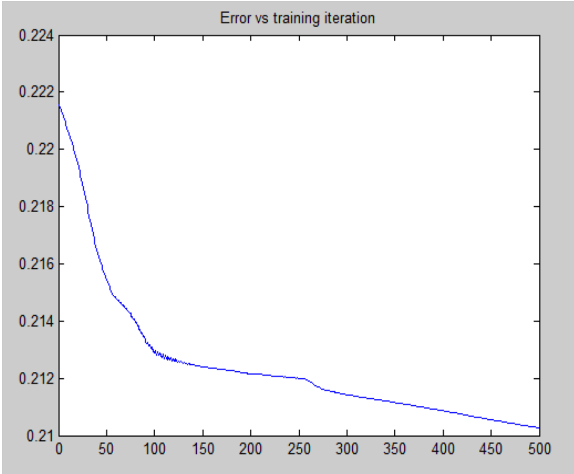

Fig. 3(l)

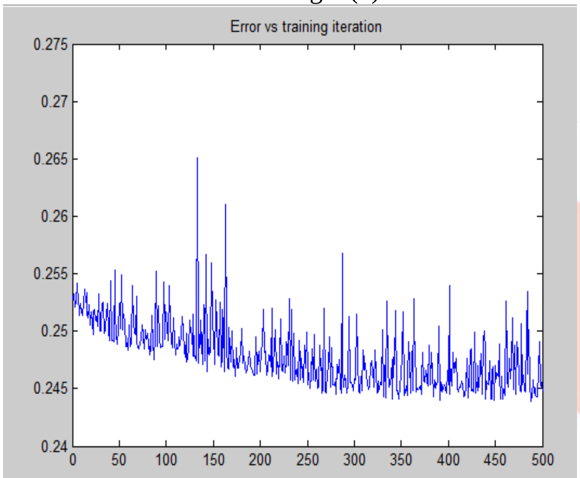

Fig. 3(m)

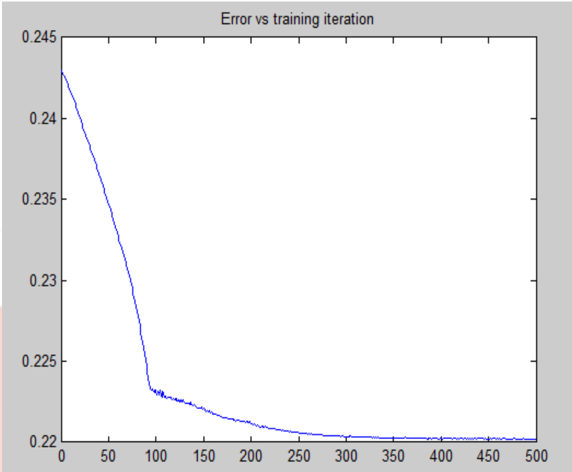

Fig. 3(n)

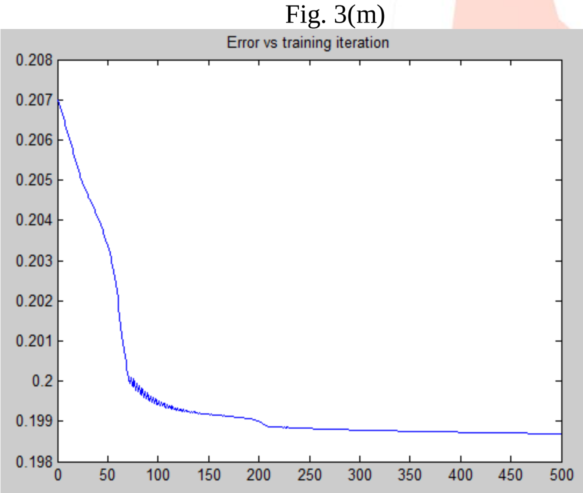

Fig.3 (o)

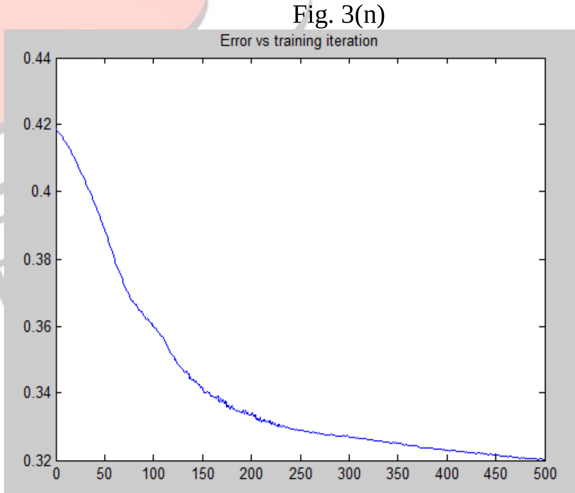

Fig. 3(p)

Fig. 3 (g), (h), (i), (j), (k), (l), (m), (n), (o), (p) plot of predicted versus actual theta1, theta2, theta3, theta4 and theta5 of robotic arm and their error versus training iterations respectively.

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