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Modelling and Control of 5DOF Robot Arm using ANFIS Toolbox

Payal Agnihotri, Banga VK, Gurjeet Singh ER

Dept. of Electronics and Communication Engineering, Amritsar College of engineering and technology, Amritsar, India

ABSTRACT: In this paper modelling and control of 5 level of freedom robotic arm is presented. It provides forward and inverse kinematics is derived based on Denavit-Hartenberg (DH) representation and ANFIS toolbox. The key objective of the paper is definitely to model the robotic arm by using D-H parameters. The kinematics problem is defined as the transformation from the Cartesian space to the joint space and vice versa. This paper aims to model the forward and inverse kinematics of a 5 DOF Robotic Arm for easy pick and place application. An over-all D-H representation of forward and inverse matrix is obtained.

KEYWORDS: Forward Kinematics, Inverse Kinematics, Robotic Arm, Levels of Freedom (DOF), Denavit-Hartenberg Representation, ANFIS toolbox

I. INTRODUCTION TO ROBOTICS

A robot manipulator comprises a serial chain of rigid links connected to each other by revolute or prismatic joints. A revolute joint rotates in regards to a motion axis and a prismatic joint slide along a motion axis. Each robot joint location is usually defined relative to neighboring joint. The relation between successive joints is described by 4*4 homogeneous transformation matrices that have orientation and position data of robots. The amount of those transformation matrices determines the quantities of freedom of robots. The merchandise of those transformation matrices produces final orientation and position data of a n quantities of freedom robot manipulator [1-6]. Robot control actions are executed in the joint coordinates while robot motions are specified in the Cartesian coordinates. Conversion of the career and orientation of a robot manipulator end-effector from Cartesian space to joint space, called as inverse kinematics problem. Inverse kinematics is of fundamental importance in calculating desired joint angles for robot manipulator design and control. For a manipulator with n amount of freedom, at any instant of time joint variables is denoted by $qi = q(t), i = 1,2,3,\ldots,n$ and position variables $xj = x(t)$, $j= 1, 2, 3, \ldots, m$. The relations between the end-effector position x(t) and joint angle q(t) can be represented by forward kinematic equation, $x(t) = f (q (t))$ (1) where f is just a nonlinear, continuous and differentiable function. On one other hand, with the given desired end effect or position, the problem of finding the values of the joint variables is inverse kinematics, which can be solved by, $q (t) = f\ 0(x(t))$ (2) Solution of (2) is not unique as a result of nonlinear, uncertain and time varying nature of the governing equations the schematic representation of forward and inverse kinematics. The different techniques used for solving inverse kinematics can be classified as algebraic, geometric and iterative. The algebraic methods do not guarantee closed form solutions. In the event of geometric methods, closed form solutions for the very first three joints of the manipulator must exist geometrically. The iterative methods converge to just a single solution depending on the kick off point and won't work near singularities. If the joints of the manipulator are more complicated, the inverse kinematics solution by using these traditional methods is a time consuming. As a result of presence of non-linearity, complexity, and transcendental function in addition to singularity issue in solving the inverse kinematics, various researchers used different ways like iteration, geometrical, closed-form inverse solution, redundancy resolution as discussed in above theory. But some researchers also adopted methods like algorithms, neural network.Neuro fuzzy in recent year for solving the non-linear equation arises in different area such as in mechanical engineering. To overcome this drawback, various author adopted Neuro fuzzy method like Adaptive Neuro-Fuzzy Inference System (ANFIS). This is often justifying as ANFIS combines the main advantage of Adaptive Neural networks and fuzzy logic [7] technique with no

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some of their disadvantage. The Neuro fuzzy system are must widely studied hybrid system now a days, as because of the advantages of two very important modeling techniques i.e. Neural networks and Fuzzy logic are for solving computational problems which may be reduced to finding inverse kinematics.

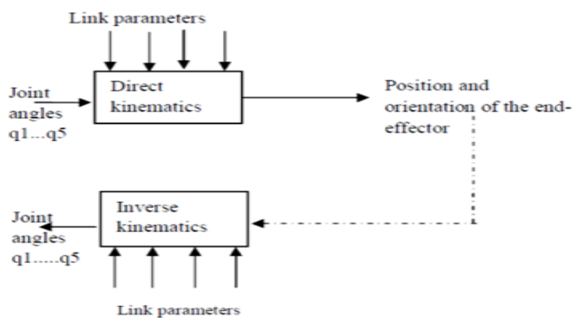

Figure 1: Forward and Inverse Kinematics Model

II. KINEMATICS

It is 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 procedure of calculating the positioning in space of the final outcome of a linked structure, given the angles of all of the joints. This technique can be extremely useful in robotics. You may have a computerized arm which must seize an object. If the software knows where to be honest in terms of the shoulder, it really must calculate the angles of the joints to attain it. The simplest application of kinematics is for particle motion, translational or rotational [8]. Another amount of complexity arises from the introduction of rigid bodies, which are collections of particles having time invariant distances between themselves. Rigid bodies might undergo translation and rotation or a combination of both. A more difficult case is the kinematics of something of rigid bodies, which might be linked together by mechanical joints. It is of two types [9-11].

- Forward Kinematics
- Inverse Kinematics

The kinematics solution of any robot manipulator includes two sub problems forward and inverse kinematics. Forward kinematics will determine where in fact the robot's manipulator hand will be if all joints are known whereas inverse kinematics will calculate what each joint variable must certainly be if the required position and orientation of end-effector is determined. Hence Forward kinematics is defined as transformation from joint space to Cartesian space whereas Inverse Kinematics is defined as transformat ion from Cartesian space to joint space. General methods do exist for solving forward kinematics [5-8]. For the investigation work, 5 DOF Robotic Arm was selected. It is a vertical articulated robot, with five revolute joints. It has a stationary base, shoulder, elbow, tool pitch and tool roll. This simple block diagram indicates the partnership between direct and inverse kinematics problem as shown in Figure 1. The objective in this paper is to provide an analytical solution for the forward and inverse kinematics of 5 DOF Robotic Arm, to analyze the movement of arm from one point in space to another point [12-15].

III. DEGREE OF FREEDOM (DOF)

The degree of freedom or DOF, certainly are a critical term to understand [16]. Each amount of freedom is a shared on the arm, a spot where it may bend or rotate or translate. You are able to typically identify the number of quantities of freedom by the number of actuators on the robot arm [17-23]. When developing a robot arm few quantities of freedom is allowed for

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the application, because each degree needs a motor, often an encoder, and exponentially complicated algorithms and cost [24]. Because of the presence of non-linearity, complexity, and transcendental function as well as singularity issue in solving the inverse kinematics, various researchers used different methods like iteration, geometrical, closed-form inverse solution, redundancy resolution as discussed in above theory.

IV. ARTIFICIAL NEURAL NETWORK

Artificial neural network (ANN) is really a parallel-distributed information processing system. This technique comprises operators interconnected via one-way signal flow channels. ANN stores the samples with a distributed coding, thus forming a trainable nonlinear system. It provides hidden layers involving the inputs and outputs. A synthetic neural network is designed to mimic the characteristics of the human brain and contains an accumulation of artificial neurons. An adaptive network is really a multi-layer feed-forward network through which each node (neuron) performs a particular function on incoming signals. The design of the node functions can vary from node to node. Within an adaptive network, you will find two kinds of nodes adaptive and fixed. The big event and the grouping of the neurons are influenced by the overall function of the network. The network applies many different minimal squares method and a corner propagation gradient descent method for training FIS membership function parameters to emulate certain training data set. The machine converges when exercising and checking errors are within an acceptable bound. A straight back propagation neural network with sigmoidal activation function is employed to resolve inverse kinematics problem. Firstly, some points in the task degree of manipulator are taken fully to utilize within the cubic path likely to generate the ($\theta 1$, $\theta 2$, $\theta 3$) joint angles in accordance with different (x, y, z) Cartesian coordinates. These values were recorded in a written report to create the educational pair of the neural network. We obtained the angles ($\theta 1$, $\theta 2$, $\theta 3$) from the certain cubic by sampling 6000 for orbit trajectory certain job. The robot manipulator arm has 5 joints,[25] which mean the robot has 5DOF. The kinematics robot manipulator is derived by utilizing Denavit-Harterberg (DH) representation. In this convention, each homogeneous transformation Ai is represented as a product of four basic transformations.

$Te = R_Z (\Theta i)\ D_Z (di)\ D_X(ai)\ R_X(\alpha i)$

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

Where,

$$
\begin{aligned}
\theta_1 &= a\tan 2(p_x, p_y) \\
\theta_2 &= A\tan 2(S_2, C_2) \\
\theta_3 &= A\tan 2(S_3, S_4) \\
\theta_4 &= \theta_{234} - \theta_3 - \theta_2 \\
\theta_5 &= A\tan 2(S_5 - C_5)
\end{aligned}
$$

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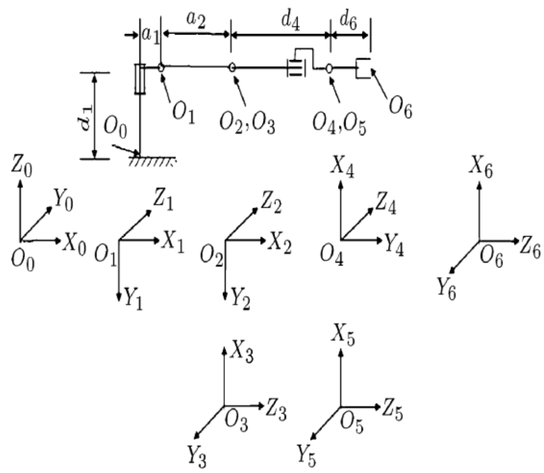

Figure 2: DOF Robot Arm coordinate FrameAssignment

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

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

I. Method useful for modeling of 5 DOF Robotic Arm

A. ANFIS Toolbox:

The proposed work is dependant on finding finding the value of inverse kinematics solutions. In the MATLAB we use ANFIS tool to obtain the inverse kinematics solution of 5 DOF robotic arm. Artificial Neuro-Fuzzy Inference Systems (ANFIS) is a class of adaptive networks that are functionally equivalent to fuzzy inference systems. ANFIS represent Sugeno e Tsukamoto fuzzy models and it works on the hybrid learning algorithm. The fuzzy logic are little used in limnology, and almost completely ignored by classical statistics textbooks, and by standard statistical packages. The only pre-requisite is to possess use of the MATLAB basic package in addition to the MATLAB Fuzzy Logic Toolbox, but no expertise with this software is required. we wrote codes in MATLAB language, to make the most of the ANFIS functions within the MATLAB Fuzzy Logic Toolbox. The acronym ANFIS derives its name from adaptive neuro-fuzzy inference system. Utilizing a given input/output data set, the toolbox function anfis constructs a fuzzy inference system (FIS) whose membership function parameters are tuned using either a straight back propagation algorithm alone, or in combination with a least squares form of method. This allows your fuzzy systems to learn from the data they're modeling. The basic structure of the sort of fuzzy inference system that individuals have seen so far is a product that maps input characteristics to input membership functions, input membership function to rules, rules to a couple of output characteristics, output characteristics

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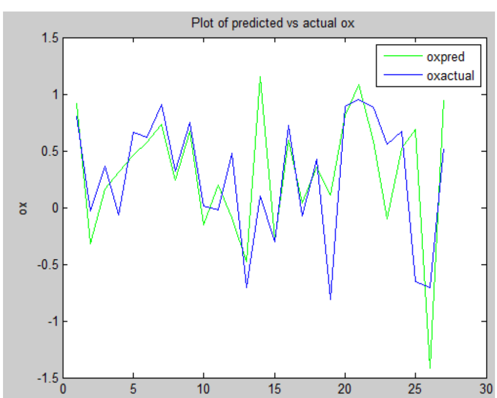
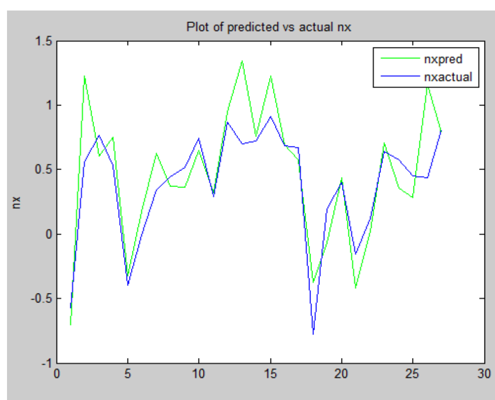
to output membership functions, and the output membership function to a single-valued output or a decision associated with the output. We have only considered membership functions which were fixed, and somewhat arbitrarily chosen. Also, we have applied fuzzy inference to modelling systems whose rule structure is essentially predetermined by the user's interpretation of the characteristics of the variables in the model. In this section we discuss the utilization of the function anfis and the ANFIS Editor GUI in the Fuzzy Logic Toolbox. These tools apply fuzzy inference techniques to data modelling. As you have seen from the other fuzzy inference GUIs, the form of the membership functions is dependent upon parameters, and changing these parameters will change the form of the membership function. Rather than just considering the data to choose the membership function parameters, we will see how membership function parameters may be chosen automatically using these Fuzzy Logic Toolbox applications.

B. Model Learning and Inference through ANFIS:

The basic idea behind these neuro-adaptive learning techniques is very simple. These techniques provide a way for the fuzzy modeling procedure to learn information regarding a data set, to be able to compute the membership function parameters that best allow the associated fuzzy inference system to track the given input/output data. This learning method works similarly to that particular of neural networks. The Fuzzy Logic Toolbox function that accomplishes this membership function parameter adjustment is called ANFIS. The anfis function may be accessed either from the command line, or through the ANFIS Editor GUI. Considering that the functionality of the command line function anfis and the ANFIS Editor GUI is similar, they're used somewhat interchangeably in this discussion, until we distinguish them through the description of the GUI.

V. RESULTS





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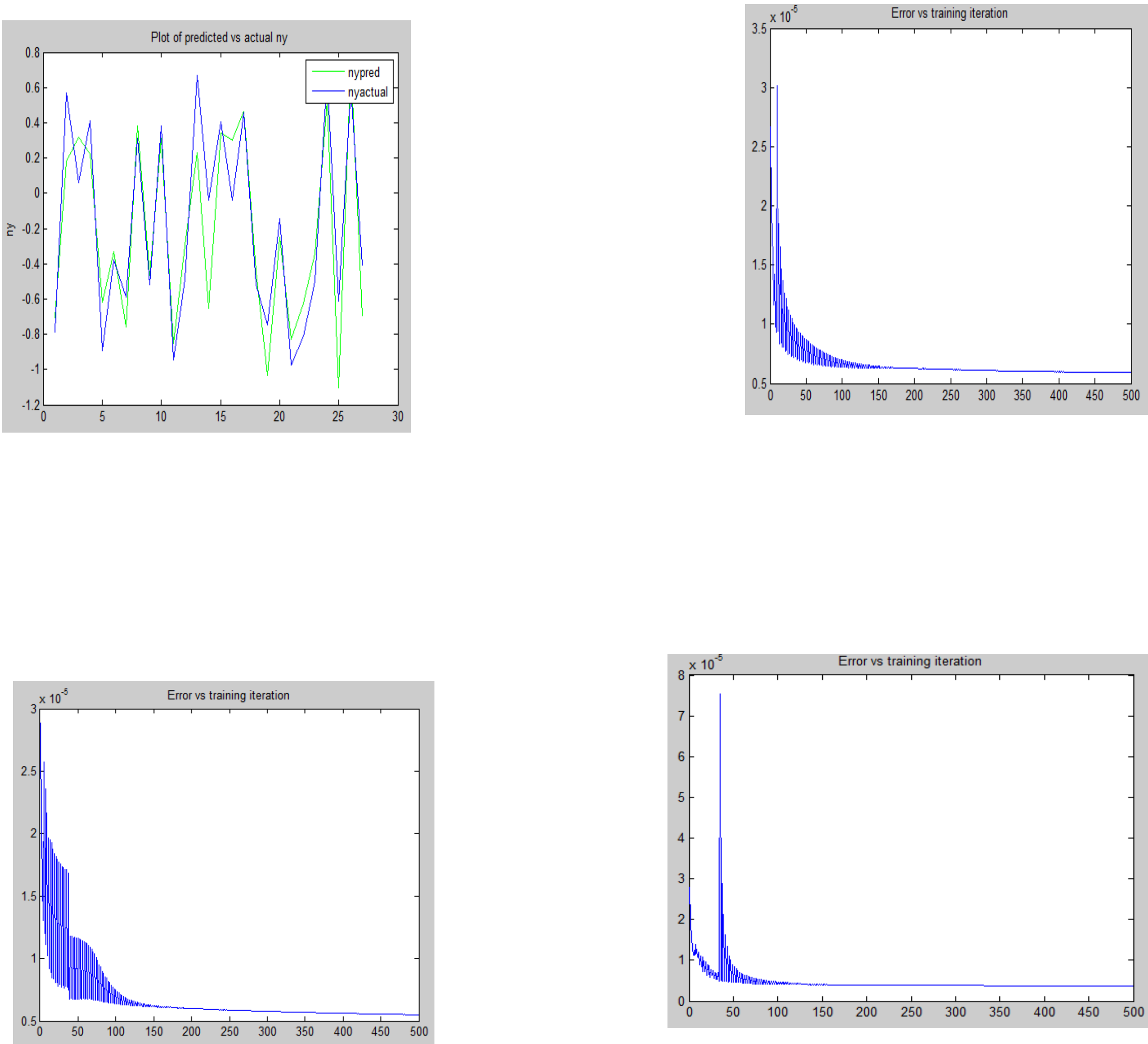

Figure 3: Graph of predicted data vs actual data of o_x,n_x,$n_y$and their error vs training iterations respectively

The difference in data actual and the datapredicted with ANFIS trained for two and three degree of freedom planar manipulator clearly depicts that the proposed method results in an acceptable error. Also the ANFIS converges with a smaller number of iteration steps with the hybrid learning algorithm. Hence trained ANFIS can be utilized to provide fast and acceptable solutions of the inverse kinematics thereby making ANFIS as an alternate approach to map the inverse kinematic solutions.Other techniques like input selection, tuning methods and alternate ways to model the problem may be explored for reducing the error further.

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VI. CONCLUSION

In this paper, complete analytical solution to the forward and inverse kinematics of 5 DOF Robotic arm is discussed. The forward kinematic analysis of 5 DOF roboti carm is investigated. A strategy based on geometric projection was done to resolve the inverse kinematics of 5 DOF robotic arm. A review from various kinematic modeling methods has been taken using denavit-hartenberg representation. ANFIS toolbox is used to find the training iterations.

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