Inverse Kinematics of Robot Manipulator with 5 Degree of Freedom based on ANFIS Toolbox

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Abstract— In this paper, while using capacity of Adaptive Neuro-Fuzzy Inference Method (ANFIS) to master via instruction facts, you possibly can develop prediction of Inverse Kinematics of 5-degree of flexibility (DOF) manipulator in this function. Soon after researching the end result, it can be concluded that the couples capacity of Adaptive Neuro-Fuzzy Inference Method (ANFIS) is very useful because this method comes with a normal figure work with mix of Nerve organs Multilevel and also fluffy reasoning. This Productivity of ANFIS may be concluded by seeing the symptoms plan, continuing plan and also normal possibility plan. This particular existing examine with applying different nonlinear products with the prediction from the Inverse kinematics of 5-degree of freedom robotic manipulator will offer an invaluable way to obtain info with regard to different products. On this document all of us use anfis formula with matlab and discover forwards and also inverse kinematics of all 5 dof robotic arm.

Key words: Forward kinematics, Inverse Kinematics, Robotics, ANFIS, DOF, Denavit-Hartenberg Representation

I. INTRODUCTION

A robot manipulator is composed of a serial chain of rigid links connected to each other by revolute or prismatic joints. A revolute joint rotates about 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 number of those transformation matrices determines the degrees of freedom of robots. The product of these transformation matrices produces final orientation and position data of a n degrees of freedom robot manipulator. Robot control actions are executed in the joint coordinates while robot motions are specified in the Cartesian coordinates. Conversion of the position 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 degree of freedom, at any instant of time joint variables is denoted by qi = q(t), i = 1;2;3; :::;n and position variables xj = x(t), j = 1;2;3; :::;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 a nonlinear, continuous and differentiable function.

On the 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 due to 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 case of geometric methods, closed form solutions for the first three joints of the manipulator must exist geometrically. The iterative methods converge to only a single solution depending on the starting point and will not work near singularities. If the joints of the manipulator are more complex, the inverse kinematics solution by using these traditional methods is a time consuming. Due to the presence of non-linearity, complexity, and transcendal 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. 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 can be justify as ANFIS combines the advantage of Adaptive Neural networks and fuzzy logic technique without having any of their disadvantage. The neuro fuzzy system are must widely studied hybrid system now a days, as due to the advantages of two very important modelling technique i.e. Neural networks and Fuzzy logic. And this technique for solving computational problems which can be reduced to finding inverse kinematics.

II. FORWARD AND INVERSE KINEMATICS OF FIVE ARM ROBOT

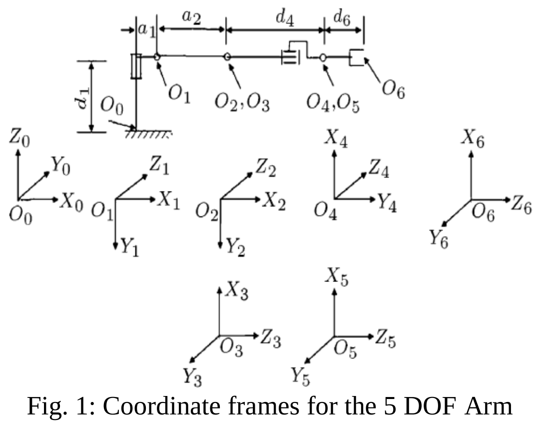

Fig. 1: Coordinate frames for the 5 DOF Arm

In this paper we are using five link robot shown in fig. 1. 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.

III. ANFIS ARCHITECTURE

ANFIS stands for adaptive neuro-fuzzy inference system developed by Roger Jang. It is a feed forward adaptive neural network which implies a fuzzy inference system through its structure and neurons. He reported that the ANFIS architecture can be employed to model nonlinear functions identify nonlinear components in a control system. It is a hybrid neuro-fuzzy technique that brings learning capabilities of neural networks to fuzzy inference systems. It is a part of the fuzzy logic toolbox in MATLAB R2013a software of Math Work Inc. The Fuzzy Inference System (FIS) is a popular computing frame work based on the concepts of fuzzy set theory, fuzzy if-then rule, and fuzzy reasoning. It has found successful application in a wide variety of fields, such as automatic control, data classification, decision analysis, expert system, time series prediction, robotics, and pattern recognition. The basic structure of a FIS consists of 3 conceptual components: a rule base, which contains a selection of fuzzy rules: a database, which define the membership function used in fuzzy rules; a reasoning mechanism, which performs the inference procedure upon the rules and given facts to derive a reasonable output or conclusion. The basic FIS can take either fuzzy input or crisp inputs, but outputs it produces are almost always fuzzy sets. Sometime it is necessary to have a crisp output, especially in a situation where a FIS is used as a controller. Therefore, method of defuzzification is needed to extract a crisp value that best represent a fuzzy set. For solving the Inverse Kinematics of 5-DOF manipulator used in this work Sugeno fuzzy inference system is used, to obtain the fuzzy model. The Sugeno FIS was proposed to develop a systematic approach to generate fuzzy rules from a given input and output data set. The typical fuzzy rule in a Sugeno fuzzy model for three inputs used in this work for both the manipulator has the form:

If x is A, y is B and z is C, then z = f (x, y, z), where A, B, C are fuzzy sets in the antecedent, while z = f(x, y, z) is a crisp function in the consequent. Usually, f (x,y,z) is a polynomial in the input variables x, y, and z but it can be any function as long as it can appropriately describe the output of the model with the fuzzy region specified by antecedent of the rule. When f (x,y,z) is a first order polynomial, the resulting FIS is called first order Sugeno fuzzy model. The coordinates and the angles obtained from forward kinematics solutions are used as training data to train ANFIS network with the triangular membership function with a hybrid learning algorithm. For solving the inverse kinematics equation of 5-DOF Redundant manipulator, in this work, considers the ANFIS structure with first order Sugeno model containing 343 rules. For the neuro-fuzzy model used in this work, 1024 data points analytically obtained using forward kinematics, of which 776 are used for training and the remaining 248 are used for testing (or validating). Training of ANFIS is usually performed by using ANFIS editor GUI of MATLAB [64]. The ANFIS Editor GUI window displays the four main sub displays. These are 1. Load data, 2. Generate FIS, 3. Train FIS and 4. Test FIS.

IV. TOOLBOX STRUCTURE

The ANFIS toolbox is shown as:

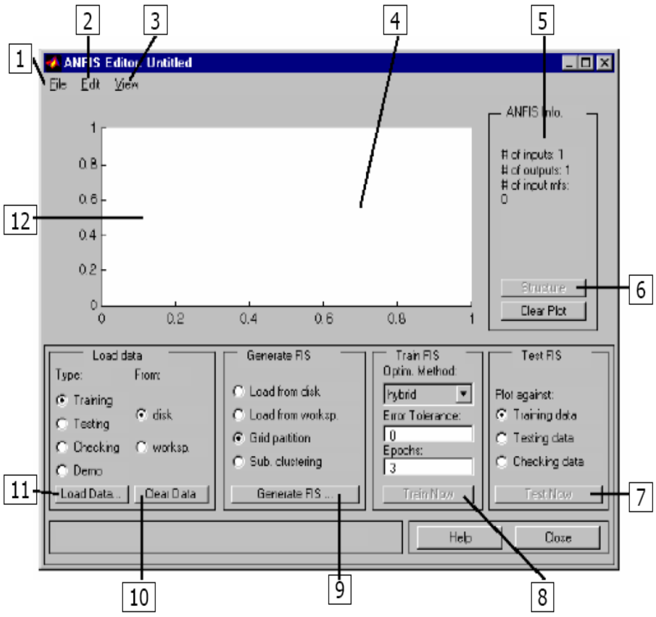

Fig. 2: ANFIS Architecture Tool Box Structure

1) Load or save a fuzzy Sugeno system, or open new Sugeno system.
2) Undo.
3) Open or edit a FIS with any of the other GUIs.
4) Plot region.
5) Status of the number of inputs, outputs, input membership functions, and output membership functions.
6) After you generate or load a FIS, this button allows you to open a graphical representation of its input/output structure.
7) Test data against the FIS model. The plot appears in the plot region.
8) Train FIS after setting optimization method, error tolerance, and number of epochs. This generates error plots in the plot region.
9) Load FIS or generate FIS from loaded data using your chosen number of MFs and rules or fuzzy.
10) Clear Data unloads the data set selected under Type: and clears the plot region.
11) Load either training, testing, or checking data from disk or workspace, or load demo data. Data appears in the plot region.
12) Testing data appears on the plot in blue as **. .**; Training data appears on the plot in blue as **o o;** Checking data appears on the plot in blue as **++;** FIS output appears on the plot in red as ******

V. STRUCTURE IDENTIFICATION

In this section we explain how to use a graphical user interface included in the MATLAB Fuzzy Logic Toolbox to solve the structure identification. The main thing is how many MFs are necessary for each input variable?

1) Launch MATLAB and type anfis edit. A graphical interface to work with ANFIS starts.

2) Click Load data…with the Training option active. Load the Main data file (e.g. Data.dat). The output variable appears plotted on the screen.
3) Click Generate FIS…with the Grid partition option active.

   A new window appears. In the Input MF Type box choose gaussmf, and in the Output MF Type box choose constant. In the Number of Input MFs box type a number of membership functions for each input separated by a space (e.g. start with 2 2). Here the inputs are ordered as in our files. Click OK. A graphical diagram of the generated zero order Sugeno type model is available clicking the button Structure.
4) Set the Optim. Method to hybrid, and the error tolerance to 0. Write a number of epochs for the training process (e.g.50). Click Training Now. A picture of the evolution of the Mean Square Error between modeled and observed values is displayed. If evidence exist that more epochs will significantly decrease the Error, click the Train Now button again.
5) When a reasonably stable Error value is achieved, click Test Now with the Training data option active. Record the Average Testing Mean Square Error displayed in the box at the bottom of the window, and also the total number of epochs used to achieve a stable Error value.
6) Repeat steps (iii) to (v) with different number of Input MFs, until a decision can be taken. This step includes some subjectivity, because in addition to the Mean Square Error, the total number of parameters should also be considered as a criterion. Each gaussian MF has two parameters, and the total output parameters are the product of the number of MF in each input. Total number of parameters should not exceed 1/6 the number of cases present in the Main data file.

VI. RESULT AND DISCUSSION

In this section of the thesis the surface plots, the residual plots and the normal probability plots for the 5-DOF redundant manipulator is carried out. The surface plots obtained for this type of manipulators explains the efficiency of the ANFIS methodology. The plots obtained by comparing the predicted data from the ANFIS and the analytical data show that, the data predicted using ANFIS methodology deviate very less from the analytical data. The last section of this chapter is concluded with obtaining the normal probability plots. The details of the plots are explains in the following section.

A. 3-D Surface Viewer Analysis

In this section the 3-D surface plots, obtained for the 5-DOF Redundant manipulator is discussed. The surface plot dispaly both the connecting lines and faces of the surface in color. The surf command in MATLAB tool is use to create the 3-D surface plots of the matrix data. The surface plot explains the relation between the output and two inputs.

1) 3-D Surface plots obtained for all joint angles of 5-DOF Redundant manipulator

Figures 15-19 show surface plot of five ANFIS networks relating inputs with joint angles of 5-DOF Redundant manipulator.

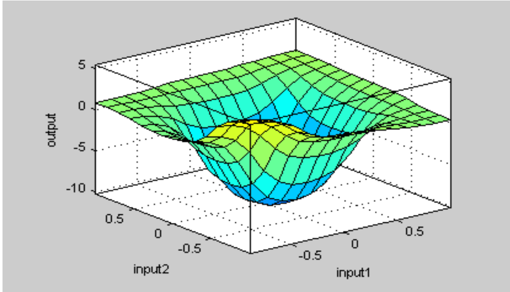

Fig. 1: Surface plot for θ_1

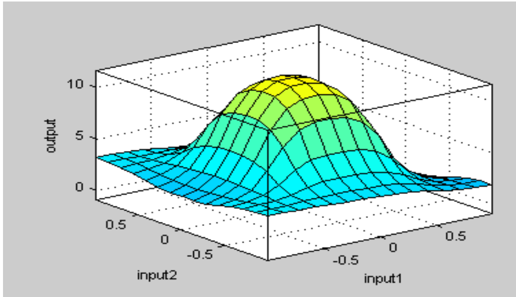

Fig. 2: Surface plot for θ_2

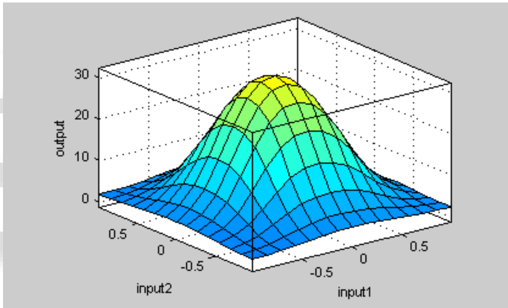

Fig. 3: Surface plot for θ_3

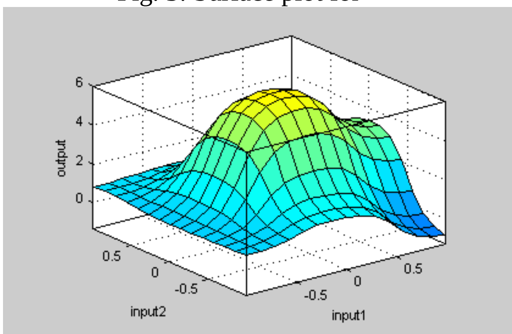

Fig. 4: Surface plot for θ_4

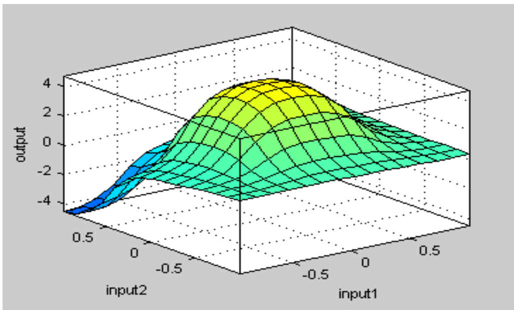

Fig. 5: Surface plot for θ_5

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