Non-Linear Modelling and Performance analysis of Robotic arm using Fuzzy based control system

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***Abstract*— Modelling and control of 6 degree of freedom (DOF) robot arm is the aim of this thesis. The main objective of this is to control a robot arm using fuzzy logic controller (FLC) to acquire the desired position. FLC is applied to handle the nonlinearity in the robot manipulators. The performance of FLC is then compared with well known conventional controller, Proportional integral derivative (PID). The comparison between the PID controller and FLC results in terms of overshoot, time response and steady-state error specifications. Based on simulation results, FLC gives better results than classical PID controller in terms of overshoot, time response and steady-state error. Through this study it is proved that the FLC is more efficient in the time response behavior than the PID controller.**

I INTRODUCTION

Industrial robot manipulator field is one of the interesting fields in industrial, educational and medical applications. Research in control the motion and movement of industrial robot was the most concentrate field during recent year. Due to advance computer and visualization technology, robotic manipulator study are divided in two categories, mathematical modeling and computer modeling of the manipulator and the actuators, which includes an analysis for the forward kinematic, the inverse kinematic and modeling the direct current motor.

This study is focus on modeling an industrial robot manipulator and designing controller for the motion of the industrial robot manipulator meet the requirement of the desired trajectory or desired angle.

Robot manipulator is classified as a complex system due to nonlinear systems. Proportional Integral Derivative (PID) controller may be the most widely used controller in the industrial and commercial applications for the early decades, however, PID does not give optimal performance due to the nonlinear elements. Fuzzy logic controller (FLC) was found to be an efficient tool to control nonlinear systems.

II PROBLEM STATEMENT

Motion control is fundamental to many robotics applications, and is known to be a difficult problem. Execution in real world environments is confounded by noisy sensors, approximate world models and action execution uncertainty. A practical and mathematical model of industrial robot required many equations and consumed much time when it comes to design and experiment a real model. It has been proved that the benefit of design an industrial model in computer simulation had reduced the cost and time in designing and simulates an industrial robot. The complexity of the robotic tasks is getting more and more advanced, so an intelligent, robust, computationally simple and easy to implement controller must be designed and analyzed to optimize and maximize the performance of industrial robot.

The problem statements of this study are:

i. Robot system and its mathematical modeling is very complex system, a computer software simulation is the easiest method to model a real robot without writing a code/programming and derive mathematical equation.
ii. Performing an experiment a behavior and mechanism of a real robot may damage the robot and required lot of money, a robot modeling and computer simulation required to reduce the cost and time to study a robot system.
iii. PID controller is not sufficient to obtain the desired tracking control performance because of the nonlinearity of the robot manipulator, so nonlinear controller such as Fuzzy Logic is required to minimize and counter the nonlinearity issue.
iv. Conventional controller has issued in handling the time response, overshoot and steady-state error of a robot manipulator, this issue can be mitigate using nonlinear controller.

III METHODOLOGY

One of the drawbacks for using the PID control techniques is that, they are not sufficient to obtain the desired tracking control performance because of the nonlinearity of the robot manipulator. Hence, a lot of time is required to tune the PID parameters. On the other hand, other techniques are used to overcome the previous problem, such as fuzzy controller that emulates human operation.

FLC is an emerging technique in control systems. It is considered as intelligent controller. Many studies show that the fuzzy controller (FC) performs superior to conventional controller algorithms. Zadeh did the main idea of FLC and fuzzy set theory. Mamdani and his colleagues have done a pioneering research work on FLC in the for engine steam boiler. The benefit of FLC is obvious when the controlled process is too complicated to be analyzed using PID controller or when the information about the controlled system does not exist.

FLC is classified into two categories: the first, involves the fuzzy logic system based on a rule based on expert system, to determine the control action. The second used FL to provide online adjustment for the parameters of the conventional controller such as the PID control. This method attempts to combine the merits of FL with those control techniques to expand the capability of linear control technique to handle the nonlinearity in the physical system. Fuzzy supervisory is used to reduce the amount of tuning the PID controller with a fuzzy system. It is considered as an attractive method to solve the nonlinear control problems, one of the advantages of fuzzy supervisory that the control parameters changed rapidly with respect to the variation of the system response.

The fuzzy supervisor operates in a manner similar to that of the FLC and adds a higher level of control to the existing system. Fuzzy supervisory is hybrid between the PID controller and FLC that designed to overcome the problem of tuning PID in nonlinear systems using FLC as an adaptive controller. The basic structure of FSC resembles the structure of PID controller, but the controlled parameter of PID controller depends on the output of the fuzzy controller.

IV SYSTEM SETUP

The servomotor was controlled using an PIC microcontroller board. The microcontroller was used to interface the servomotor with Matlab / Simulink environment.

The microcontroller utilizes a series of square pulses to control the position of the servomotor. The width of the pulses corresponds to the reference angle of the servomotor. When the reference angle is input into the servomotor, the embedded servo controller computes the control input needed to track the reference angle, and applies the appropriate voltage to the motor.

Fig. 1 illustrates the block diagram of the entire system while, Fig. 2 shows a photograph of the hardware setup.

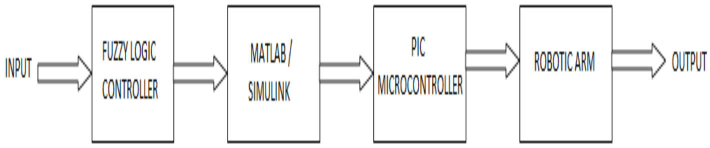

Fig.1 : Block diagram

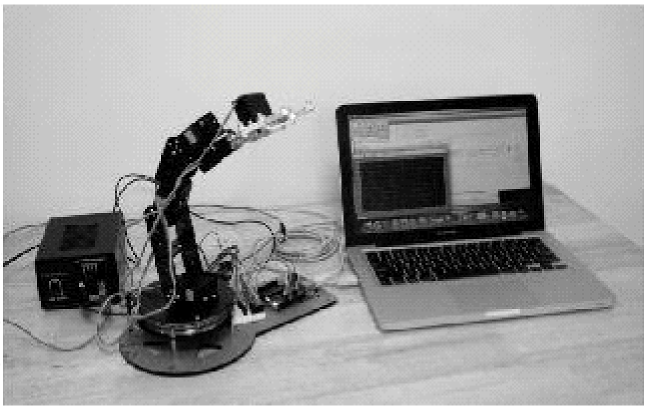

Fig.2: Hardware setup

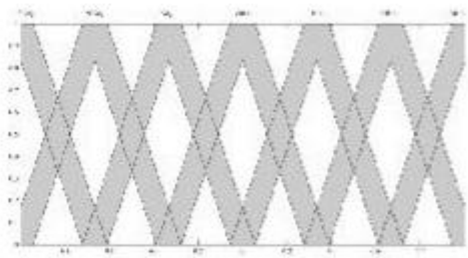

Fig.3: Design Fuzzy Controller

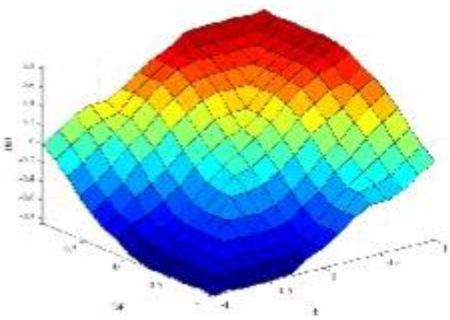

Fig.4: Surface Viewer

V DEFUZZIFICATION METHODS

Centroid: The centroid type-reducer combines all the rule-output type-2 fuzzy sets by finding their union. Finding the union of fuzzy sets requires computing the join of their secondary membership functions. This method involves an enormous amount of computation, as the centroid and membership computations have to be repeated numerous times.

Center-of-sums: The center of sums type-reducer combines the type-2 rule output sets by adding their secondary membership functions.

Height: The height type-reducer replaces each type- 2 output set by a type-2 fuzzy set whose y-domain consists of a single point . This single point is chosen to be the point having the highest primary membership in the principal membership function of the output set. The point having maximum membership in the lth output set and are associated withThis method requires the least computational complexity.

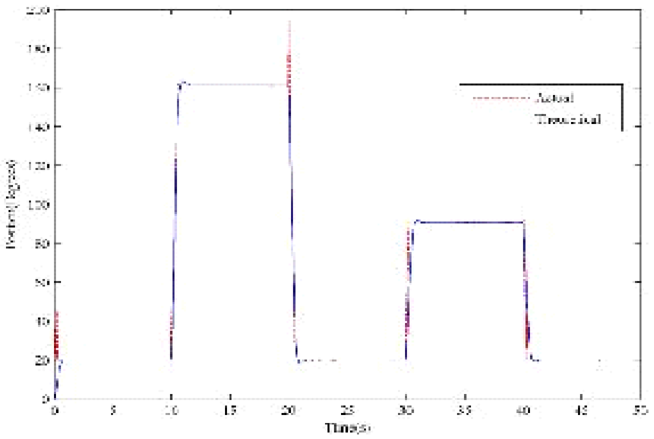

Fig.5: Actual measured output vs theoretical estimated response

VI RESULTS AND DISCUSSION

A closed loop PI-controlled system was set up and the PI controller was tuned using the Ziegler-Nichols method followed by hand tuning. The tuned gains were:

$$Kp = 1, Ki = 1.5$$

The tuned gains of the PI controller were then used to compute the gains of the fuzzy logic controller. The execution time of each defuzzification method was recorded as well. The execution time is the average total amount of time taken by the controller to compute the output at a single point. The computer used in this work has an Intel i3 M380, 2.53 GHz processor and 3 GB of RAM.

Table I : depicts the IAE, as well as the execution time for each defuzzification method. The performances of all the methods are plotted.

Defuzzifcation Method	IAE	Execution Time
Centroid	381.0	0.00703 s
Center of Sums	402.35	0.00683 s
Height	387.4	0.00553 s
Center of Sets	382.65	0.00829 s

Table I : IAE & Execution time of different defuzzification methods

VII CONCLUSION

Real-time implementation of the FLPIC to control the position of a DC servomotor, which controls a robotic arm was successfully done. Different defuzzification methods were tested. The tests revealed the superiority of the Centroid method over the other methods. Overall,FLPIC showed much improved performance over the conventional PI controller, as well as the PID controller. This improvement is evident when handling uncertainty and impression induced in the system by means of noise and sudden disturbances.

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