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FUZZY CONTROL FOR NONLINEAR CONTROL SYSTEM

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Abstract

The problem of solving nonlinearity is a current topic as it is involved in aerospace, vibration control, motor control, signal processing, robotic manipulators, etc. In control engineering, objects are often fuzzy and uncertain. These objects and processes are difficult to describe with the precise mathematical model. The Robotic Arm is a benchmark problem of nonlinear multivariable system with inherent instability. It is a highly nonlinear and open-loop unstable system. So, consider robotic arm as nonlinear control system and control it with fuzzy approach by designing fuzzy inference system. Also make it adaptive by connecting encoders to motor of robotic arm to give feedback and form closed loop system.

Keywords: Fuzzy control, Fuzzy Logic Controller (FLC), Nonlinear Control System, Robotic Arm

1. Introduction

Two methods for control strategies of robotic arm are classical methods and non-classical methods. The classical methods make use of the conventional control theory whereas non-classical methods apply the artificial intelligence (AI) theory such as fuzzy logic, neural networks and/or neuro fuzzy.

Integration, proportional, derivative (also known as PID), the computed torque scheme and the adaptive control scheme are Conventional control methods. An easy structure of traditional PID control and implementation has proved itself to utilize it as for industrial manipulator thoroughly and popularly as well. Fuzzy control handles ambiguity by maintaining its control related to human behavior or logic. Deep research has been done and is going on in design of fuzzy control systems [1- 3]. Stability of such systems is studied and developed on the parallel track. By using adaptive fuzzy approach fuzzy controller performance is improved day by day.

Basically, FL is a multi-valued logic. This logic gives permission for partial truth and partial false values to appear and process in terms of linguistic variables. Linguistic variables are formulated mathematically and processed by computers very fast. This is done to pour human thinking in the computer programming. Fuzzy control works out a technique for showing of and building human logic to control a system. It might provide a creative concrete basis for non-linear systems. Fuzzy controller stands out to be one and only approach to harness and utilize qualitative and quantitative information as well. The target of this paper is to control angular movement of robotic arm using fuzzy logic concepts also take feedback of it using encoders.

2. Scheme of Implementation

Roadmap of the paper is as follows:

- To design 3 axes Robotic Arm.
- To design Fuzzy Logic Controller using Rule Base.
- To design and implement a Fuzzy Logic controller using microcontroller.
- To connect encoders to the motor as sensors to get feedback of system and get adapative control of system by creating closed loop sysetm.
- To evaluate performance parameters such as delay, and accuracy.

The system hardware consists of an experimental setup of robotic arm, fuzzy controller, servo motor etc. Block diagram of proposed system is as shown in fig.1.

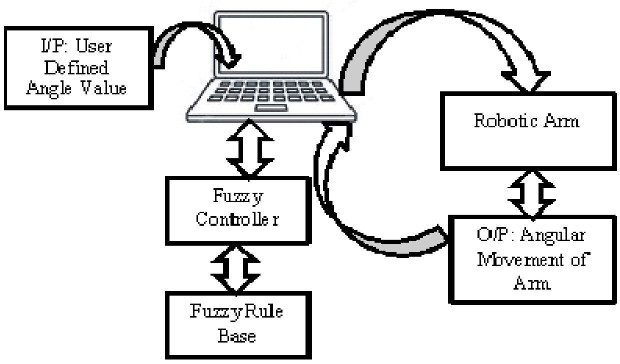

Fig. 1 Block diagram of System

Robotic arm is complicated nonlinear vigorous system with unmixed kinetics and vague uncertainties. These uncertainties make the controller design for arm a difficult task in the framework of control action. The proposed method gives stable control over robotic arm. Robotic arm used in experimental setup is as shown in figure 2.

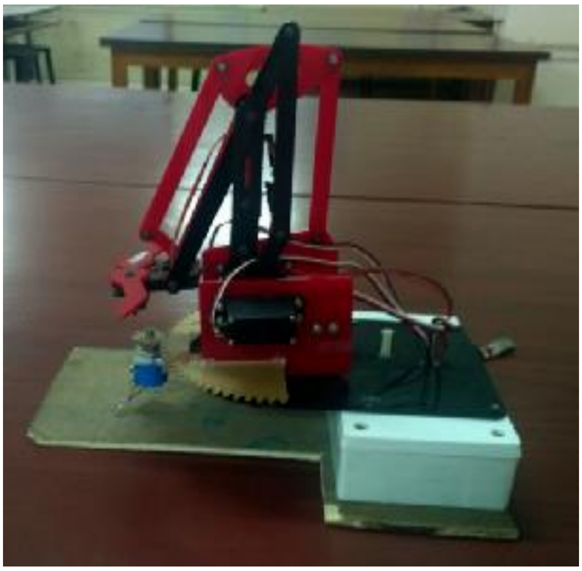

Fig. 2. Robotic arm setup

Here in the system 8 bit controller ATMEGA328 used as fuzzy controller. There are 4 DC servo motors attached to robotic arm equipment; two for Arm 1 and Arm 2 and other two are base and gripper motor. For gripper we use SG90 and rest are of MG995 DC servo motors. For programming purpose we have used MATLAB and Arduino software.

The parameters and its specification have been given below in Table 1 & Table 2 as mechanical and electrical specifications.

Table 1. Mechanical Specification

Parameter	Specification
Payload Capacity	200 gms
Maximum reach	300mm
Material	Coloured acrylic 4mm
Gripper motor angle	0° to 180°
Base motor angle	0° to 180°
Arm1 motor angle	50° to 150°
Arm 2 motor angle	50° to 150°

Table 2. Electrical Specification

Parameter	Specification
Operating voltage	5 volt DC
Opertimg Current	200mA per motor
Motor type	MG995 DC servo, SG90(gripper)
Microcontroller	ATmega328(8bit)
Interface with PC	USB to TTL module (cp2102)

2.1 Fuzzy Rule Base

Fuzzy rules are used within fuzzy logic systems to infer an output based on input variables. Fuzzy logic systems address the imprecision of the input and output variables by defining fuzzy numbers and fuzzy sets that can be expressed in linguistic variables (e.g. small, medium and large). Many of existing systems need the rules to be formulated by an expert. However rules can be also generated automatically on the basis of numerical data describing a certain phenomenon.

Following fuzzy rule base is used to design fuzzy inference system in MATLAB:

a) If Motor angle is less than set point, increase PWM duty cycle.

b) If Motor angle is equal to set point, No change in PWM duty cycle.

c) If Motor angle is greater than set point, decrease PWM duty cycle.

Rules mentioned above use for fuzzy rule base while designing for input and output 3 membership functions while input and output possibilities are mentioned below:

- **Input possibilities :**

a) Motor Angle is less than set point

b) Motor Angle is equal to set point

c) Motor Angle is greater than set point

- **Outputs :**

a) Increase PWM duty cycle.

b) No change PWM duty cycle

c) Decrease PWM duty cycle

2.2 Fuzzy Inference System

Fuzzy inference is the process of formulating the mapping from a given input to an output using fuzzy logic. The mapping then provides a basis from which decisions can be made, or patterns discerned. The process of fuzzy inference involves membership functions, fuzzy logic operators, and if-then rules. There are two types of fuzzy inference systems that can be implemented in the Fuzzy Logic Toolbox: Mamdani-type and Sugeno-type.

These two types of inference systems vary somewhat in the way outputs are determined.

Mamdani-type inference, as we have defined it for the Fuzzy Logic Toolbox, expects the output membership functions to be fuzzy sets. After the aggregation process, there is a fuzzy set for each output variable that needs defuzzification. It's possible, and in many cases much more efficient, to use a single spike as the output membership functions rather than a distributed fuzzy set. In general, Sugeno-type systems can be used to model any inference system in which the output membership functions are either linear or constant.

So, here Mamdani fuzzy inference system is used while programming in MATLAB.

3. System Design

Fuzzy controller designs generally have following steps:

- Choose inputs, outputs and their membership functions.
- Choose methods of fuzzification and defuzzification of inputs and outputs.
- Designing each of the four components of fuzzy controller.

"Crisp" values taken as inputs values and after that its converted into a fuzzy value which is suitable for fuzzy controller known as Fuzzification of input.. Then in the fuzzy control process important task is to prepare the rule base. Then according to a rule base fuzzy inputs are gets compared along with membership function of each and output gets decided which is fuzzy output. In defuzzification process fuzzy output again converted into its original form.

3.1 Design of Fuzzy Controller

Fuzzy controller design procedure in MATLAB as given below:

1. Type Fuzzy in MATLAB command Window, FIS editor will open as shown figure 3.
2. Double click on input1 and change its name to motor angle.
3. Change Range and membership function name to desired value
4. Repeat step3 for all membership function.
5. Now double click on output1 and change its name to PWM.
6. Similar to Input membership functions we can also change name and range of output membership function.
7. Final Step is to assign rules as per our requirements.
8. After Assigning Rules Save fis file to current folder.

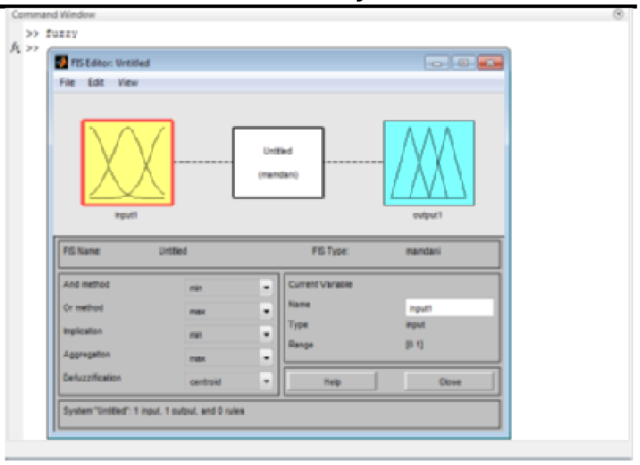

Fig. 3. FIS editor window

3.2 Servo Motor Control Mechanism:

Servo motor can be controlled by sending PWM pulses to it from microcontroller. DC servo motor has minimum angle of 0 degree and maximum angle of 180 degree. When 544 microsecond pulses are sent through microcontroller servo motor angle is zero degree and when 2400 microsecond pulses are sent servo motor angle is 180. Frequency of PWM is 50Hz.

3.3 Algorithms

Algorithm (Host Computer)

1. Start
2. Read Program (Fixed Sequence of Motor Angles)
3. Send serially though USB port to microcontroller
4. Read expected angle from microcontroller
5. If there is difference between expected angle and actual angle, correct angle using fuzzy logic controller.
6. End.

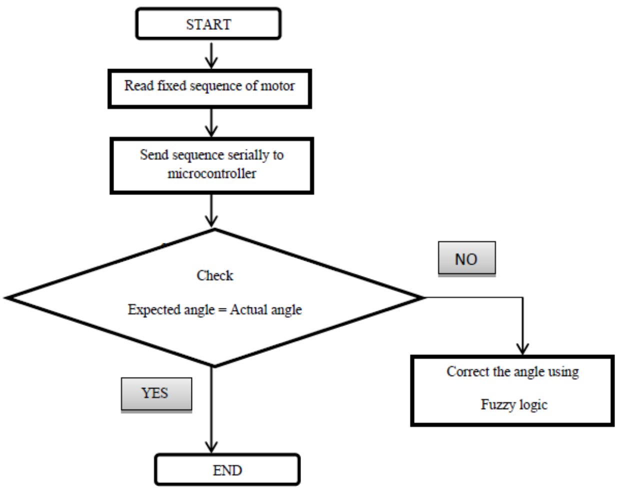

Fig. 4. Flowchart at Host Computer

Algorithm (Microcontroller PART)

1. Start
2. Initialize Serial communication
3. Read Motor Angle from matlab
4. Move motor to that desired angle.
5. If there is difference between actual angle and expected angle send error to matlab for fuzzy correction.
6. End.

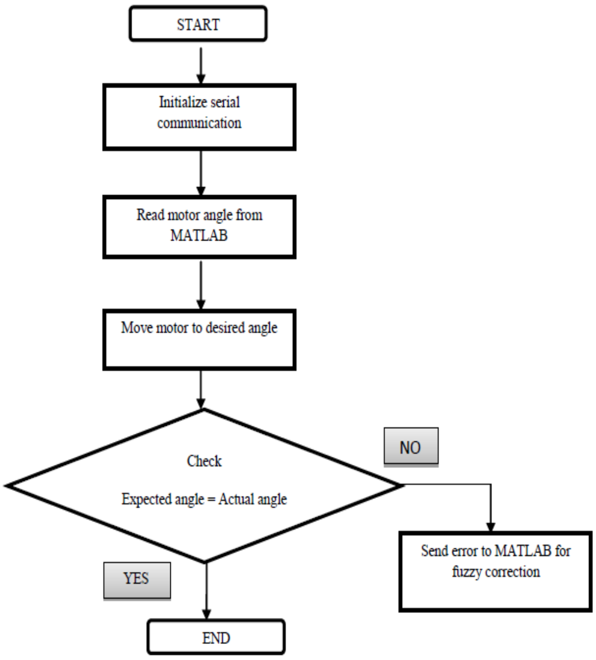

Fig. 5 Flowchart of Microcontroller code

4. Results

The proposed system is "Adaptive Fuzzy Control for Nonlinear Control System", by using this system we are able to get the quick and accurate results. For this system results are angular movement of robotic arm according to expected value feed by user and observation part is that to compare if actual angle and expected angle are same or not even it shows fuzzy corrected angle. It implies accuracy of system.

Fig.6. Experimental Setup

In above fig. 6 Experimental setup of system is shown in which robotic arm is connected to laptop via CP2102 module which act as USB to UART bridge. GUI created in MATLAB also shown in setup which is used by user to feed expected angle of robotic Arm.

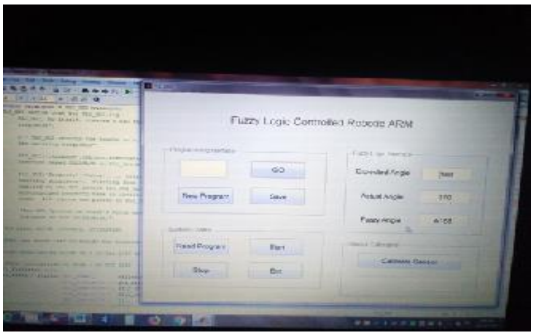

Fig.7 Result of system

In fig. 7 Results for this system shown on laptop which gives Expected angle value, Actual angle value and Fuzzy corrected angle value. So, we can easily check accuracy of system by using this data shown in output by making in tabular form.

Results for this system shown in tabular form as below in table 3.

Table 3. Results

Expected Angle	Actual Angle	Fuzzy Corrected Angle
30	39	32
60	68	62
90	98	89
120	124	118
135	139	135
160	170	158
180	172	179

5. Conclusion

Accuracy of Fuzzy control is more i.e. about 90-95%. If the system is made with more number of Rules, system will be more accurate only it will be more complicated to design. The system is presently implemented with microcontroller, but if implemented through FPGA, it will be more optimized. The accuracy can be added if combination of neural network and Fuzzy systems is applied.

Acknowledgement

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