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Hardware Implementation of Fuzzy Logic Controller for Realtime Application

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ABSTRACT: Fuzzy logic is a superset of Boolean logic which has been extended to handle the concept of partial truth values between "completely true" and "completely false". It is the logic basic modes of reasoning which are approximate rather than exact. Fuzzy logic replicates human knowledge into control logic. The actuators having wast application in industries and also in automation anywhere. The actuators are controlled depending upon the process parameters known as inputs, output, and variables. To control any actuator based system there are various controllers are designed like Proportional controller, integral controllers, derivative controllers and also integrated controllers. Most of time the computers are used to control the whole system or PID control unit, but the artificial intelligence which means the fuzzy can also be implemented on computer using various software. Here we proposed a hardware implementation for fuzzy logic controller to control actuators which we here used the DC motor to control its speed.

KEYWORDS: Actuators, automation, controllers, derivative controllers, Fuzzy logic, human knowledge, integral controllers, Proportional controller, reasoning.

I. INTRODUCTION

The actuators are main parts of any automatic system might be open loop or close loop and used to apply actuation in system. The essential characteristics of fuzzy logic as founded by Zader Lotfi are as follows:

- Any logical system can be fuzzified.
- In fuzzy logic, knowledge is interpreted as a collection of elastic or equivalently fuzzy constraint on a collection of variables.
- No need of any exact mathematical model.

A block diagram of a fuzzy control system is shown in Fig. 1. The fuzzy controller is composed of the following four elements:

(i) **Rule-base** (a set of If-Then rules), which contains a fuzzy logic quantification of the expert's linguistic description of how to achieve good control.
(ii) **Inference mechanism** (also called an "inference engine" or "fuzzy inference" module), which emulates the expert's decision making in interpreting and applying knowledge about how best to control the plant.
(iii) **Fuzzification interface**, which converts controller inputs into information that the inference mechanism can easily use to activate and apply rules.
(iv) **Defuzzification interface**, which converts the conclusions of the inference mechanism into actual inputs for the process [5] [6].

By application of artificial intelligent techniques suitable controllers can be created for most complex non-linear systems where the mathematical modelling is uncertain. Intelligent controllers are preferable since the controller for any system can be developed without a mathematical model and in this manner, efficiency and reliability of the controller are increased

This work addresses an application that involves the system control system. It presents a fuzzy controller that uses an adaptive neuro-fuzzy inference system. Fuzzy Inference system (FIS) is a popular computing framework and is based on the concept of fuzzy set theories, fuzzy if and then rules, and fuzzy reasoning.

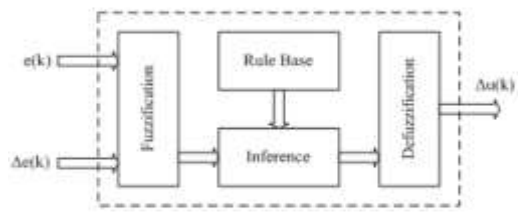

Fig. 1. Block diagram of the fuzzy control system

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II. FUZZY LOGIC AND D.C MOTOR

Basics of Fuzzy logic

Fuzzy logic is a powerful way to put engineering expertise into products in a short amount of time. It's highly beneficial in automotive engineering, where many system designs involve the experience of design engineers as well as test drivers. Due to their simple formulas and computational efficiency, both triangular and trapezoidal MFs have been extensively used especially in real time implementation. How-ever, since the MFs are composed of straight line segments, they are not very smooth at the corner points specified by the parameters. Since trapezoidal MF has two corner points while triangular MF has just one, we use triangular MF most frequently among all MFs. The implementation of fuzzy logic for control applications requires a microprocessor or Microcontroller based system. The microcontroller offers low cost and compact digital systems due to integration of CPU, memory devices and peripheral devices in a single chip.

Structure of fuzzy interference system is shown in figure below for better understanding the fuzzy logic controller or system.

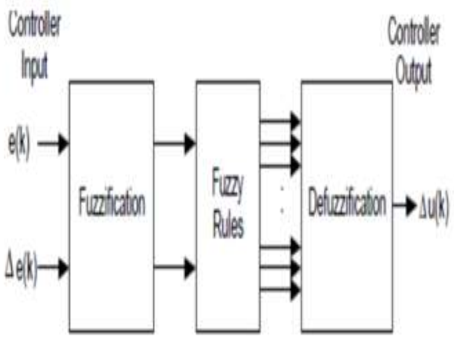

Fig. 2. Block diagram of the fuzzy control system

Basics of DC motor

A DC motor is any of a class of electrical machines that converts direct current electrical power into mechanical power. The most common types rely on the forces produced by magnetic fields. Nearly all types of DC motors have some internal mechanism, either electromechanical or electronic, to periodically change the direction of current flow in part of the motor. Most types produce rotary motion; a linear motor directly produces force and motion in a straight line. Fig. 3 represented a DC motor.

Fig. 3. DC Gear motor from Johnson

III. BLOCK DIAGRAM AND HARDWARE IMPLEMENTATION

The Fuzzy Logic Controller used has two inputs (error and change in error) and has a single output that is given as Control Input to the desired plant. First, the membership function of the FLC is optimized by using hit and trial meth-od using MATLAB. After optimization, it was found out that after fuzzification and de-fuzzification, the crisp output that we were getting had its range between -7 to 7. But the Digital Microcontroller operates in the TTL of 0V to 5V. So, inside the code, the crisp value was converted to the required range.

The data from the optimized membership functions were used in writing the C++ code. The C++ code was converted to Arduino language and was burned in the microcontroller present in the Arduino hardware. The required debugging was done and the final PWM output was seen through a DSO. The PWM output from the hardware was then com-pared with the PWM output that was found out by simulating in MATLAB.

The figure consists of microcontroller that is ARDUINO UNO for implementation purpose and the inputs are motor speed set which comes from 100K pot which is converted in to 0 to 500RPM equivalency. Second input is current speed which is measured using opto-encoder which will encode the rotation of shaft hence the duration of one minute will gives number of count from encoder which can easily con-verted in to RPM that is feedback element for current speed. The third input is the torque, here the DC motor is used which is having specification as RPM=500, torque=4.4kg, operating voltage=12V which we used.

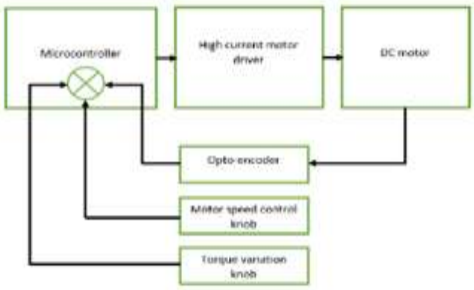

Fig. 4. Block diagram of proposed model

The third input is selected as calibrated torque which can increase or decrease according to load or we can say according to break applied. According to three input parameters the ARDUINO UNO having fuzzy log algorithm or program in it designed by considering input and output and factors will have responded to input parameters and to control the speed it will increase or decrease PWM output. The motor driver which is high current motor driver consist of L298 motor driver IC with 2amps capacity will convert the 5v PWM signals to 12v signals to drive 12v rated motor. By setting speed at particular value the factors affecting speed can be observed in this project.

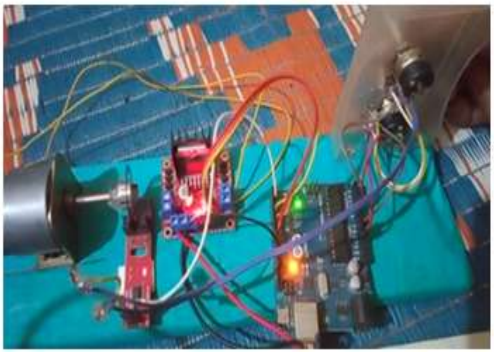

Fig. 5. Proposed model hardware setup

The working condition model is shown in above figure whereas the desired output we are getting by varying the load knob and set speed knob.

IV. RESULTS AND DISCUSSION

The following diagrams and pics shows the results of pro-posed system using Matlab and hardware. The results fully satisfy the use of Matlab fuzzy app.

Fig. 6. Fuzzy rules for hardware algorithm

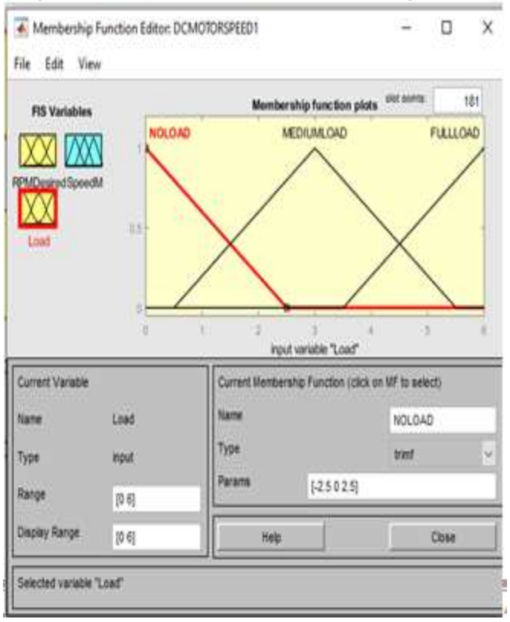

Fig.7. Membership function plot for RPM Desired

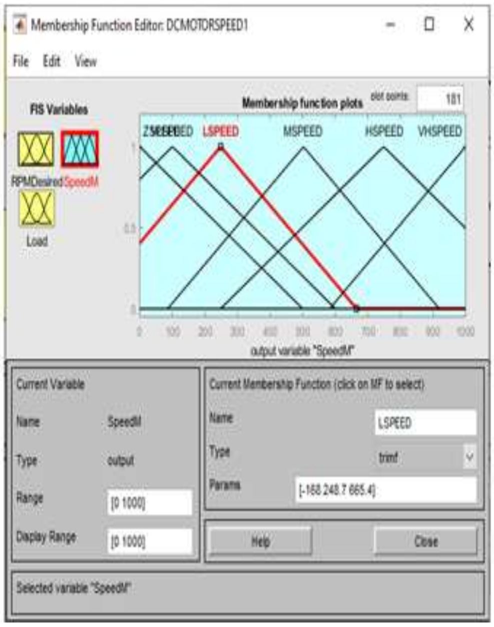

Fig.8. Membership function plot for Load

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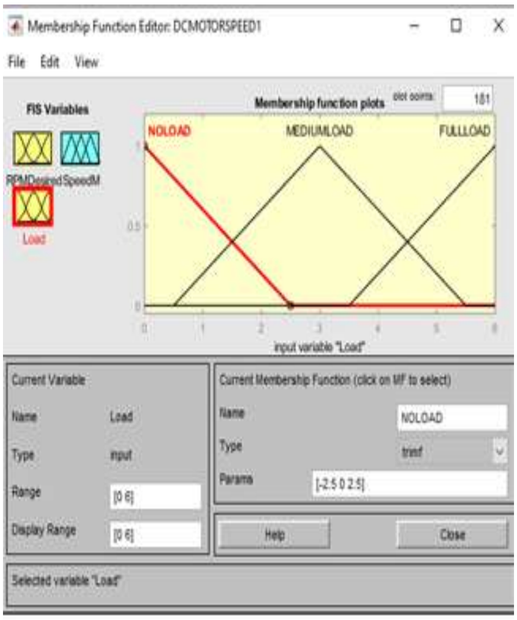

Fig.9. Membership function plot for output speed

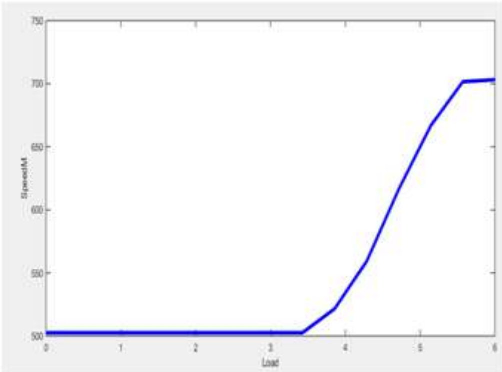

Fig.10. output speed and load plot of proposed system

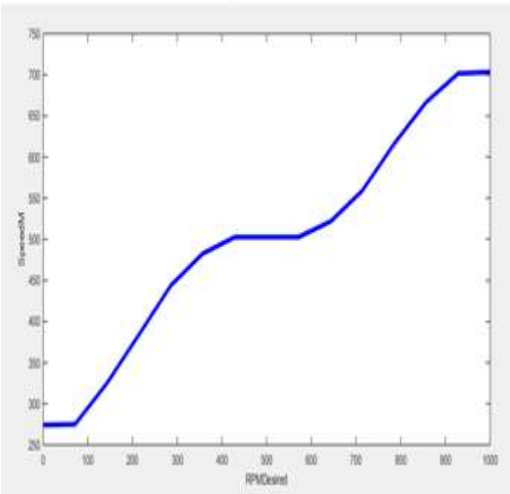

Fig.11. output speed and input speed plot of proposed system

CONCLUSION

The real-time application of fuzzy logic based controller has implemented successfully and control of DC motor using fuzzy logic showed that the output of the DC motor does not suffer from the overshoot, although, the settling time of fuzzy logic controller. However, there is a steady state error in case of fuzzy control due to the inefficient design of the fuzzy controller, but this is to be believed that by increasing perfection in fuzzy logic controller the steady state error can be reduced. The fuzzy-integral controller has also introduced for the removal of steady state error and the results are inspiring.

The hardware model used in this project is efficient and can be modified using few steps for different application The overall performance of position control of DC motor control using fuzzy logic is appreciable.

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