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Fuzzy PID Controller Design for Heating Control System

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ABSTRACT:This paper proposed an artificial intelligent control method for temperature control system and is suitable for low temperature applications such as laboratory equipments (e.g. ovens and incubators).The proposed design uses fuzzy PID as a control method that maintains the temperature of simulated heater to the desired point.The Fuzzy PID controller of heating system adds a conventional PID controller to the common fuzzy control and forms a mix fuzzy PID controller and it can realize the self adaptive of K_p ,$K_i$and$K_d$of PID.So fuzzy PID not only has the advantage of easy to application,strong robust,but also can be more widely used and have higher performance than normal PID.
PID Microcontroller based circuit is built to acquire data from sensor, actuate heat element and communicate with computer workstation.As compared to normal PID the Fuzzy-PID algorithm has better performance of reducing temperature overshoot and improves systems performance.

KEYWORDS: Fuzzy-PID, PID, Heating,Control system

I.INTRODUCTION

The heating ventilation and air conditioning is a technology that provides thermal comfort and acceptable air quality.Heating system is the most important part of this technology and several methods have been proposed for controlling it during last years[2].On/Off control and PID[3],self tuning control, optimal control[4],feedback linearization,fuzzy logic controllers,neural network system and genetic algorithm are only some of the control techniques reported in literature.One of the most popular intelligent control method is Fuzzy logic PID control.Fuzzy control which has been arise as alternative to a conventional control,In it the human mind abilities in problem solving and decisions making is initiated. Fuzzy control which utilizes fuzzy logic to convert the linguistic control strategy based on expert knowledge into an automatic control strategy.Presently Fuzzy control has become more favorable than conventional PID control; because Fuzzy control simply represents the realization of human control strategy,where the PID control relies on the mathematical formulation.Fuzzy controlis a control method based on fuzzy logic. Just as fuzzy logic can be described simply as computing with words rather than numbers; fuzzy control can be described simply as control with sentences rather than equations. A fuzzy controller can include empirical rules, and that is especially useful in operator controlled plants. Fuzzy logic is a derivative from classical Boolean logic. It can often be considered a suspect of conventional set theory. Since fuzzy logic handles approximate information in a systematic manner, it is ideal for controlling non-linear systems and for modeling complex systems where an inexact model exists or systems where ambiguity or vagueness is common. A typical fuzzy system consists of a rule base, membership functions and an inference procedure . Today, fuzzy logic are found in a variety of control applications like chemical process control, manufacturing and in such consumer products as washing machines, video cameras and automobiles. Fuzzy logic is a suspect of conventional Boolean logic that has been extended to handle the concept of partial truth- truth- values between completely true and completely false.Fuzzy theory as a single theory, we should regard the process of fuzzification as a methodology to generalize any specific theory from a crisp (discrete) to a fuzzy (continuous) form. Thus, recently, researchers have also introduced “fuzzy calculus and fuzzy differential equations.Fuzzy logic control algorithm solves problems that are difficult to address with traditional control techniques.There aretwo types of Fuzzy Logic Controller: Mamdani type controller and Takagi-Sugenos type controller .Mamdani type is widely used due to simple structure of min max operation.Temperature control is a process in which change of temperature of a space (and objects collectively there within) is measured or otherwise detected, and the passage of heat energy into or out of the

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space is adjusted to achieve a desired average temperature. Temperature is an essential physical quantity which is found in most application of home appliances, scientific laboratories equipments and industrial processes [9]. Therefore the main issue in every temperature control strategy is to monitor and maintain temperature status of these facilities. In some industrial application the goal is not only precise temperature control, but also a fast heat-up and quick response to disturbances with minimal overshoot and undershoot when the set point changes. Also the chemical laboratories incubator which may contain Living creatures or Parts of organisms, so it's crucial to tightly keep the temperature inside it at required set point. In addition it's too important in rice cooker to make fine adjustments to temperature and heating time to cook perfect rice every time.

The control elements of system include:

1) Sensor measures the actual value of controlled variable such as temperature, humidity or flow and provides information to the controller.

2) Controller receives input from sensors, processes the input and then produces an intelligent output signal for the controlled device.

3) Controlled device acts to modify controlled variable as directed by the controller.

4) Source of energy is needed to power the control system. Control systems use either a pneumatic or electric power supply.

II. System Overview

To present an intelligent controller approach providing best control of temperature process using fuzzy rule-based techniques and to show how Fuzzy PID can overcome the undesirable features of traditional PID controller, a simulated temperature control system consisting of a sensor; actuator and shown in fig. 1 should be realized as follows. The Hardware design is include the temperature sensor to read an actual temperature of the heater to the microcontroller (µC) ADC, in voltage form which is linearly proportional to the Celsius (Centigrade) temperature. Low power Ceramic resister is used to simulate the heater, because it can be simply driven by Microcontroller µC output port using common power transistor. Arduino ATMEGA 328 is used to acquire temperature reading from sensor by its internal ADC and to provide actuating signal to the heater through its programmed PWM by varying on/off duration time and provide interface to computer workstation.

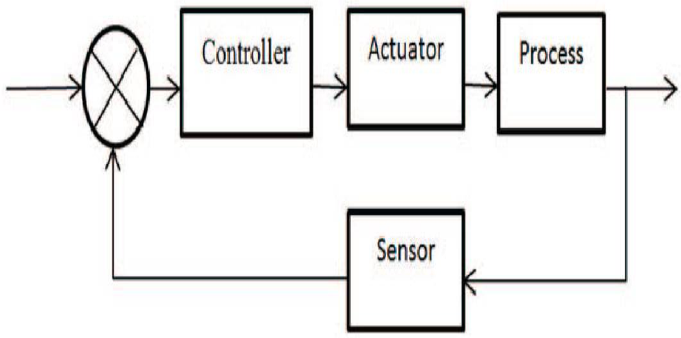

Fig. 1: The control loop diagram of heating system

III. PID CONTROLLER

Proportional (P), integral (I) and derivative (D) are the three main parameters of the PID controller. The values of these three parameters interpreted in terms of time ,where ,'P'depends on the present error, 'I' on the accumulation of past errors and 'D' is a prediction of future errors, based on current rate of change. By tuning the three parameters in the algorithm of PID controller, the controller can provide control action designed for specific process requirements. Theproportional, integral and derivative terms are summed to calculate the output of the PID controller.Fig 2 shows the

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schematic model of a control system with a PID controller. Control signal U (t) is a linear combination of error E (t), its integral and derivative.

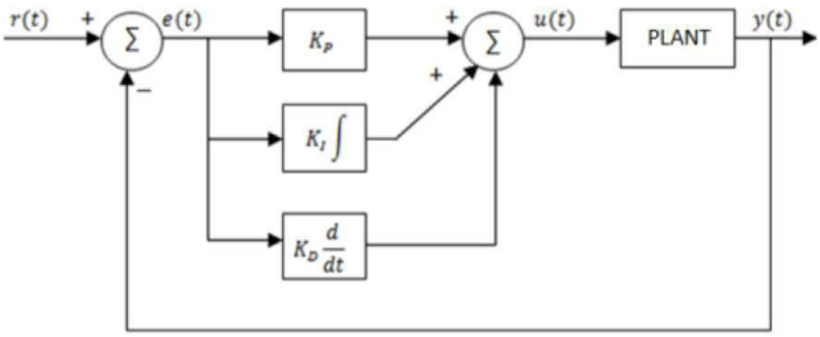

Fig2. PID control system

Where:
Kp = proportional gain
Ki = integral gain
Kd = derivative gain
Ti = integral time
Td = derivative time

$U(t) = Kp.e(t) + Ki\int e(t)dt + Kd\frac{d}{dt}e(t)$ (1)

$U(t) = K_p.e(t)+\frac{1}{Ti}\int e(t)dt + T_d\frac{d}{dt}e(t)$ (2)

$e(t)=r(t)-y(t)$ (3)

If the controller is digital, then the derivative term may be replaced with a backward difference and the integral term may be replaced with a sum. For a small constant sampling time (Ts), Can be approximated as:

$U(n) = K_p[\, e(n) + \frac{1}{Ti}\sum_{j=1}^{n} e(j)T_s + T_d.\frac{e(n)-e(n-1)}{Ts}]$ (4)

Table1: The effect of PID parameter on system response[1]

	Rise time	Overshoot	Settling time	Steady state error
K_p	Decrease	Increase	Small change	Decrease
K_i	Small change	Decrease	Decrease	Small change
K_d	Decrease	Increase	Increase	Eliminate

IV. SELF-TUNING PID BASE ON FUZZY LOGIC

When the system condition changes, the designed controller doesn't have good performance, necessarily[1].Utilizing the self-tuning PID controller is an appropriate solution to dominance these conditions . In Fuzzy logic self tuning-PID, the gain values of PID parameters are tuned based on the fuzzy logic rules. In this controller,known as an auto-adaptive controller, the error and its rate are considered as the inputs and can meet the desire of self-tuning parametersThere are many intelligent methods to achieve a suitable and stable response inwhich the fuzzy logic rules are used for this

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purpose here. A fuzzy logic system consists of four main parts, namely:fuzzifier, rules, inference engine and defuzzifier. These components and the general architecture of a fuzzy logic system are shown in Fig. 3 and Table 2.

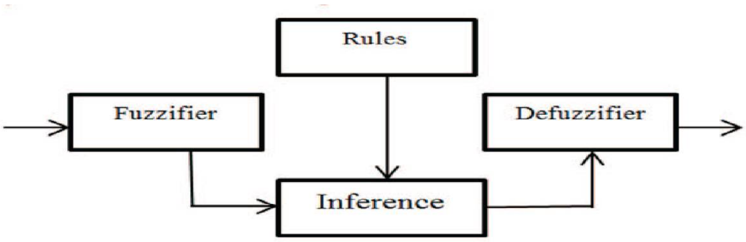

Fig. 3: Structure of fuzzy control design

In this system, the difference between the set point and the output as the error and its changes are considered asthe inputs. Also, three coefficients of PID controller i.e,$K_p K_i$and $K_d$obtained from the fuzzy inference are theoutputs. The membership functions are selected as the triangular form.. Thememembership function for the inputs and outputs are illustrated in Fig. 6.

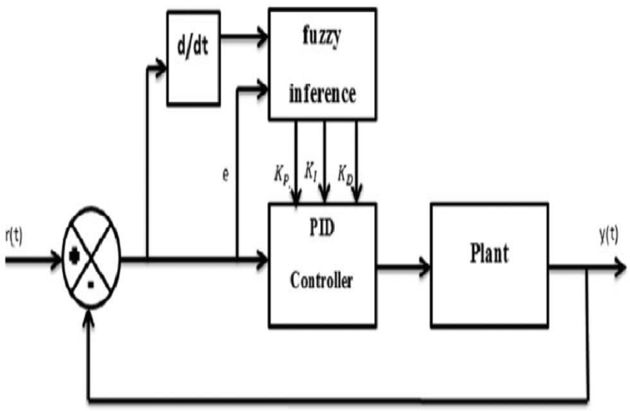

Fig.4 Fuzzy logic-PID

Table 2: Fuzzy Logic Algorithm

Fuzzy Logic Algorithm	
1	Define linguistic variables and terms
2	Construct the membership function
3	Construct rule base
4	Convert crisp data to fuzzy values using the membership function
5	Evaluate rule in the rule base
6	Combine the result of each rule
7	Convert output data to non-fuzzy values

V.RESULTS AND DISCUSSION

The performance of PID and Fuzzy based PID controller on the heating system is studied.
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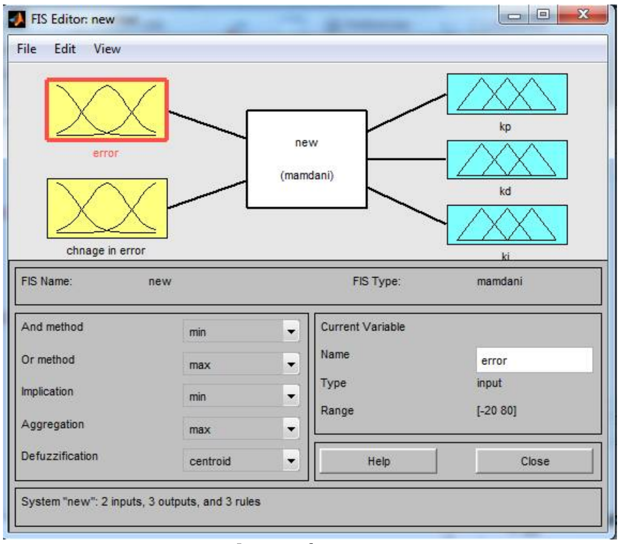

Fig.5. Mamdani Inference System

Fuzzy inference system used is Mamdani system. Here there are two inputs error and change in error and three outputs proportional gain kp integral gain ki and derivative gain kd

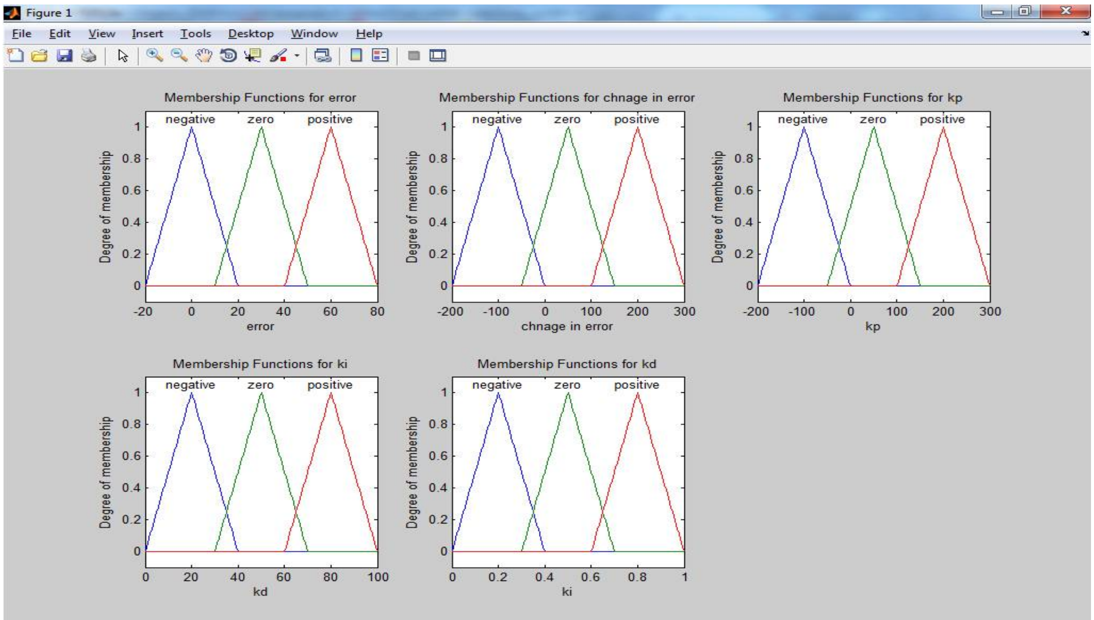

Fig.6. Membership function for e, ec, kp, ki and kd

Figure.6. shows membership function for error e change in error ec proportional gain kp integral gain ki and derivative gain kd

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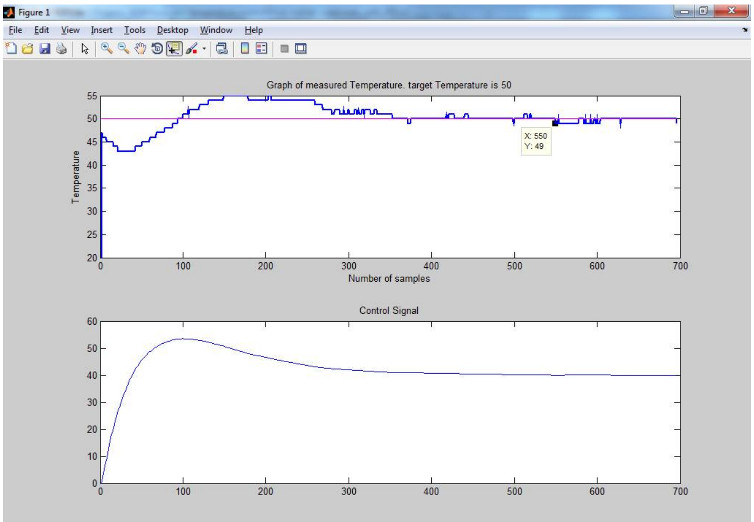

Fig.7.Fuzzy PID at reference temperature 50^0

Figure.7. shows temperature response of Fuzzy based PID for reference temperature of 50^0Celsieus and corresponding control signal.Fuzzy based PID controller achieves desired temperature.

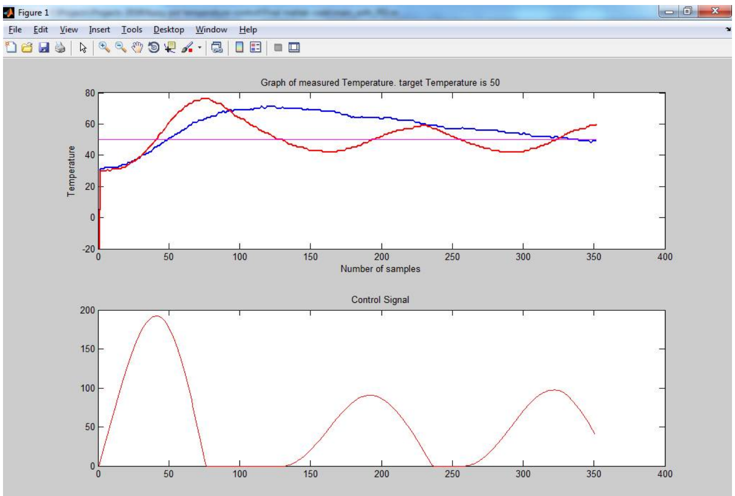

Fig.8.The comparison between pure PID(red) and Fuzzy PID(blue) at reference temperature 50^0

To compare the traditional PID control with fuzzy PID control results, we can see that the overshoot of PID control response curve was larger, the fuzzy PID control strategy of the parameter self-adjusting can be adjusted to achieve very good performance included short settling time, small overshoot, and the system runs into the stable state quickly, non-oscillatory, high control precision, non-steady-state error, and so on.

VI.CONCLUSION

For process control system with class of nonlinear, a big lag ,time varying this paper put a fuzzy PID control which does not rely on deep knowledge of controlled object. Comparisons of experimental results of the conventional

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PIDcontroller and Fuzzy PID shows that the Fuzzy PID is able to perform better than the conventional PID controller. The control system has robustness and high precision control.

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