Temperature Control Using Artificial Intelligence In Water Bath System

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Abstract: Artificial Intelligence (AI) based controller for temperature control of a water bath system. The generation of membership function is a changeling problem for fuzzy systems and the response of fuzzy systems depends mainly on the membership functions. Artificial Neural Network based input and output used to tune the membership functions in fuzzy system. Two input and single output artificial intelligence is designed to control the temperature system .Further the tuning of controller parameters is difficult in PID because the overshoot and also time constant is large. Fuzzy controller does not require a priori model of process for implementation but the membership values are found by trial and error. A five layer neural network is used to adjust input and output parameters of membership function in a fuzzy controller. In neural network hybrid learning algorithm is used for training this network .When compared with other controllers (PID and fuzzy controller), Neural network shows a better performance achieved with its tuning. Finally, validity of this approach can be illustrated by practical implementation using LabVIEW.

Keywords: PID Controller, Fuzzy controller, temperature control, hybrid learning.

I. INTRODUCTION

Process control systems are often nonlinear and difficult to control accurately for the process. Their dynamic models of the system are more difficult to derive. The conventional PID controllers, in various combinations have been widely used for industrial processes due to their simplicity and effectiveness for linear systems, especially for first and second order systems. It has been well known that Proportional Integral Derivative (PID) controllers can be effectively used for linear systems, but usually cannot be used for higher order and nonlinear systems [1]. Fuzzy control is becoming one of the brightness and most rapidly ascending stars in the galaxy of intelligent control. This is because; due to a simpler, faster and more reliable solution that is clear advantages over conventional technique.

One of its main advantages is that no mathematical modeling is required since the controller rules are especially based on the knowledge of system behavior and experience of the control engineer [2].The inaccuracy of mathematical modeling of the plants usually degrades the performance of the controller, especially for nonlinear system and complex control problems. System mainly includes three parts: normalized fuzzy quantization module, the control algorithm module and intelligent integration module. They shows that in the case of the same response time, the performances of the fuzzy controller with intelligent integration in a stable time, overshoot and several areas are better than conventional PID controller [3]. A five layer neural network is used to adjust input and output parameters of membership function in a fuzzy controller. The hybrid learning algorithm is used for training this network [4]. Back propagation neural network is trained to learn the inverse dynamic model of a temperature control system and then its configured as a direct controller to the process. The back propagation neural network based on the generalized delta learning rule, a gradient descent search technique, has been widely used. The back propagation algorithm has several disadvantages, among which is lack of guaranteed convergence, but it's simple yet powerful mathematical algorithm has made it the mainstay of neurocomputing is used before the neural network can be used as a controller, it first must learn the model of the plant. There are several learning architectures proposed where by the neural network may be trained [5].This paper gives an example where a multilayered back propagation neural network is trained offline to perform as a controller for a temperature control system with no a priori knowledge regarding its dynamics.

The inverse dynamics model is developed (general learning) by applying a variety of inputs vectors to the neural network [5]. Neural networks can thus serve as black-box models of non-linear, multivariable and dynamic system and can be trained by using input–output data observed on the systems. The most common Artificial Neural Networks consist of several layers of simple processing elements called neurons are interconnection among them and weights assigned to these interconnections. More layers can gives a better fit but the training takes time longer. Choose the right numbers of neurons in the hidden layer is essential for a good result. Too few neurons give a poor fitness; while too many neurons result in over-training of the net (poor generalization to the unseen data).A compromise is usually solve by trial and error methods [6].Based on the observation neural network gives better performances when compared to other two controllers.

II. DESCRIBTION OF WATER BATH SYSTEM

The water bath process consist of several things mainly water tank, sensor, data acquisition system and (Artificial Intelligence),labVIEW controller and heater. Here thermocouple is used as the sensor .DAQ is used for inter connection

between sensor and controller as well as controller and driver circuit. The thermocouple output is in terms of mille volt range so we use a amplifier circuit for increasing the voltage range. The working of the system is described as, when the temperature is measured by the thermocouple is converted into the voltage, which is going to the controller through DAQ. The difference between set point and actual value is applied to the controller, nothing but error .The PWM signal is produced corresponding to the 10 output voltage of the sensor. ANFIS is used here to control the temperature of the water bath process, it’s tuned automatically and correcting the error in the process its shown figure 1.

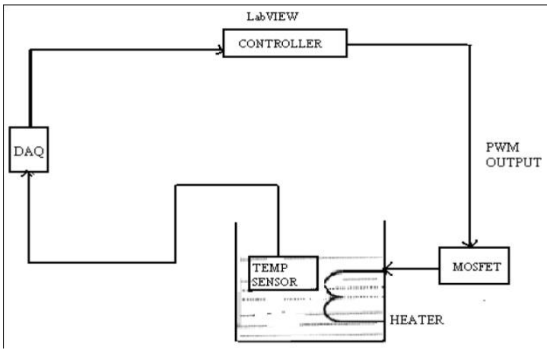

Figure 1 A schematic diagram of the water bath temperature control system

III. SYSTEM IDENTIFICATION

3.1STEPS FOR PERFORMING SYSTEM IDENTIFICATION

1. Give a noticeable change in step input.

2. Observe the change in process variable and note down the steady state.

3. Find out the total change in PV (Process variable) that is going to occurs.

4. Compute the value of 63.2% of PV

5. Note down the time (t1) when it pass through the value

6. Substrate this from the time (t2) When the PV starts to build up, when input change is given

7. Time constant (t) =t2-t1

8. $KP = \frac{change\ \ in\ steady\ \ state}{Change\ \ in\ input}$

9. Time delay time td is the time taken to getting the output from the system, when we applying the input.

10. The general form of the first order transfer function is given by $\frac{Y(S)}{X(S)} = \frac{K_{p}\ e^{-\theta s}}{\tau s+1}$

According to the open loop test, the readings are listed above. The transfer function obtained from this reading is given by

$$\frac{Y(S)}{X(S)} = \frac{0.5662e^{-0.3s}}{7.5s+1}$$

IV. DESIGN & CALCULATIONS

PID Controller: Zeigler Nichols open loop tuning formula

Steady state value=7.5

28.3% of the steady state value t1 = 2.5424 sec.

63.2% of the steady state value t2 = 6.0515sec.

Time constant (T) = (t2 - t1) × 1.5

= (6.0515 -2.5424) × 1.5

= 5.263sec.

Time delay (td) = (t2-T) = (6.0515 – 5.2636)

= 0.7879sec.

Transfer function of the given Process,

$$\frac{Y(S)}{X(S)} = \frac{0.5662e^{-0.3s}}{7.5s+1}$$

Proportional gain, $K_c = \frac{T}{t_d K_p}$

$\frac{5.2636}{0.7879 \times 0.566} = 11.8030$sec

Integral gain, $K_i = \frac{K_c}{T_i}$

Here $T_i = 3.33 t_d$ = (3.33×0.7879)

= 2.6233sec

$K_i = \frac{11.8030}{2.623} = 4.499$ sec^{-1}

Derivative gain, $K_d = K_c\ T_d$

$T_d = 0.5\ t_d = 0.5 \times 0.7879 = 0.39395$ sec

$K_d = 14.1636 \times 0.39395 = 5.5797$ sec.

V. CONTROLLER DESIGN

5.1 PID controller

A proportional integral derivative controller (PID controller) is a generic control loop feedback mechanism (controller) widely used in industrial control systems .PID controller is most commonly used for feedback controller. A PID controller calculates an "error" value as the difference between a measured process variable and a fixed set point. The controller used to minimize the error by adjusting the process control inputs. A PID controller will be called a P, P or I, PD controller in the absence of the respective control actions.

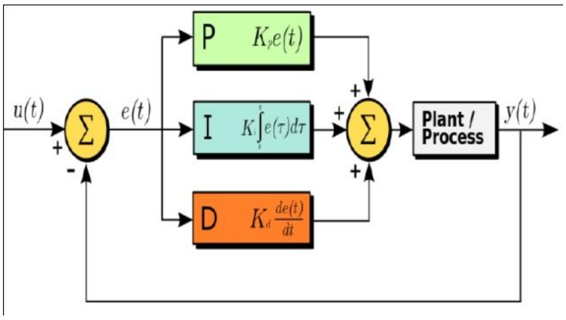

Figure 2 Block diagram of PID Controller

The PID control scheme is named after its three correcting the terms, whose sum values constitutes the manipulated variable (MV). The proportional, integral, and derivative terms are summed to calculate the output of the PID controllers. Defining values in U(t) as the controller output, then final the PID algorithm

is $u(t) = k_p e(t) + k_i \int e(t)dt + k_d \frac{d}{dt} e(t)$

Where

K_p: Proportional gain, a tuning parameter

K_e: Integral gain, a tuning parameter

K_d: Derivative gain, a tuning parameter

e: Error = SP – MV

t: Time or instantaneous time

The Values of KP, KI and KD values of PID Controller is shown in below table 1 are obtained by using the Ziegler Nichols method.

Controller	Kp	KI	KD
PID	14.16	8.98	5.57

Table 1 Values of PID parameter

5.2 Fuzzy controller

The linguistic labels used to describe the Fuzzy sets were, Negative Big (NB), Negative Medium (NM), Negative Small (NS), Zero (Z), Positive Small (PS), Positive Medium (PM), Positive Big (PB).The fuzzy rules are extracted from fundamental knowledge and human experience about the process. These rules contain the input and the output relationships that define the control strategy. Each control input has seven fuzzy sets so that there are at most 49 fuzzy rules. Each rule uses an If – Then logic of the following form:

IF e=Ei and ce=dEj THAN

UPD=UPD(i,j).The fuzzy rule are tabulated below.

		Change of error (de)				
		NL	NS	ZE	PS	PL
Error (e)	NL	NL	NL	NL	NS	ZE
	NS	NL	NL	NS	ZE	PS
	ZE	NL	NS	ZE	PS	PL
	PS	NS	ZE	PS	PL	PL
	PL	ZE	PS	PL	PL	PL

Table 2 Fuzzy rule for fuzzy control

The membership function of output is in the range [-6 6] is shown in figure 5.3.

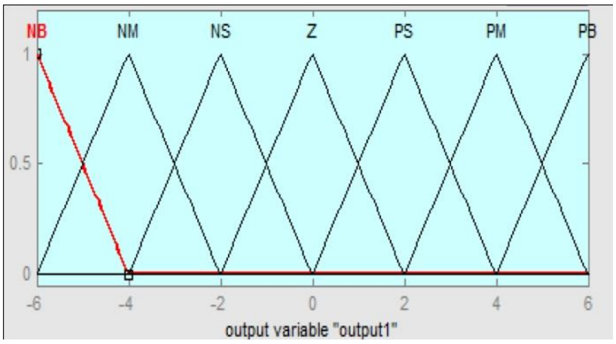

Figure 3 The membership function of output

VI. RESULT AND DISCUSSION

6.1Ziegler Nichols Closed Loop Response for PID Controller

The transfer function obtained through empirical method of modeling is used as the system for studying the performance of P, PI & PID Controllers by Ziegler Nichols closed loop response for PID controller as shown in figure above for the temperature control system for water bath system is shown in figure 4

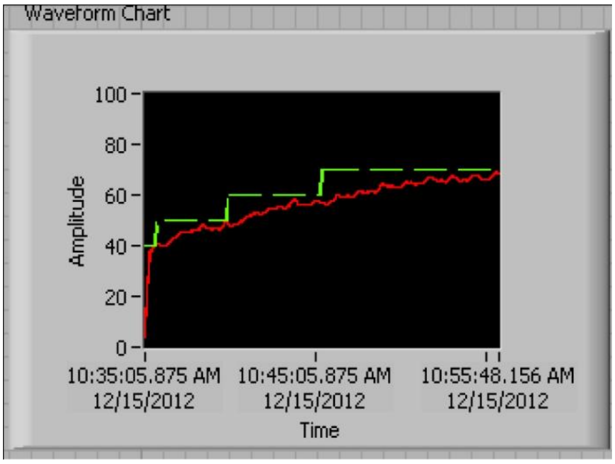

Figure 4 Simulation responses of PID Controller

6.2 Fuzzy Controller

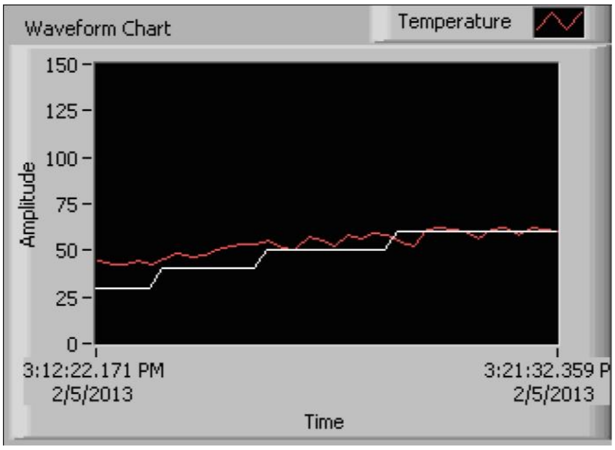

Figure 5 Response of fuzzy logic controller

The control characteristics of a temperature control with fuzzy control and neural network controller compared and tabulated below. When compared with PID controller and fuzzy logic controller, the fuzzy controller gives better performance for the temperature control system.

VII. CONCLUSION

In this study the temperature process and the control strategy adopted is Artificial Intelligence. The temperature controller was identified using the process reaction curve method. By using the transfer function model, simulation of Proportional Integral Derivative controller, fuzzy logic controller was implemented. Artificial neural network based Neuro fuzzy is suitable for adaptive temperature control of a water bath system .Artificial neural network, where the rules should be decided in advance before performance learning is performed, there are no rules initially in the Neural network. Comparison with other controller PID, fuzzy control gives better performance it's verified. Implementation result show that the fuzzy controllers produce the stable control signal than the PID and have a perfect temperature tracking capability.

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