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A Comparative Analysis of GA-PID, Fuzzy and PID for Water Bath System

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Abstract— Temperature is a very important parameter in industrial production. Recently, lots of researches have been investigated for the temperature control system based on various control strategies. This paper presents the comparison of GA-PID, fuzzy and PID for temperature control of water bath system. Different control schemes namely PID, PID tuning using Genetic Algorithms(GA-PID), and Fuzzy Logic Control, have been compared through experimental studies with respect to set-points regulation, influence of impulse noise and sum of absolute error. The new algorithm based on GA-PID improve the performance of the system. Also, it's fit for the complicated variable temperature control system. The simulation results show that the validity of the proposed strategy is more effective to control temperature.

Keywords-Water Bath System, GA-PID controller, Fuzzy, PID

III. INTRODUCTION

Temperature control is an important factor in many process control system [12,13]. If the temperature is too high or too low, the final product is seriously affected. Therefore, it is necessary to reach some desired temperature points quickly and avoid large overshoot. Since the process-control system are often nonlinear and tend to change in an unpredictable way, they are not easy to control accurately. In general, most of the temperature control systems use the conventional PID as it is non-linear, time varying and big lag. However, the conventional PID for this non-linear system is difficult to achieve the desired effect of control. In addition, the parameters of PID need make the corresponding adjustment when the characteristic of controlled object changes.

Fuzzy logic has been mainly applied to control problems with fuzzy if–then rules [4]. In most fuzzy control systems fuzzy if–then rules were derived from human experts. Recently, several approaches have been proposed for generating fuzzy if-then rules from numerical data [4].

A genetic algorithm (GA) is a parallel, global search technique that emulates operators. A GA applies operators inspired by the mechanics of natural selection to a population of binary string encoding the parameter space at each generation; it explores different areas of the parameter space, and then directs the search to regions where there is a high probability of finding improved performance. In this paper, GA is used to tune gain of PID controller

In the following section, basic concepts &, modeling of controllers has been presented. Experimental setup is given in section 3. Simulation results and comparison of various models is shown in section 4. Conclusions follow in section 5.

IV. DESIGN OF CONTROLLER

D. PID Controller

PID stands for Proportional-Integral-Derivative. This is as type of feedback controller whose output, a control variable(CV), is generally based on the error (e) between some user-defined set-point (SP) and some measured process variable (PV). Each element of the PID controller refers to a particular action taken on the error. For the PID control, a velocity-form discrete PID controller [11] is used and is described by

$$\Delta u(k) = K\{e(k) - e(k-1) + \frac{Ts}{2Ti}[e(k) + e(k-1)] + \frac{Td}{Ts}[e(k) - 2e(k-1) + e(k-2)]\}$$

$$=K_P[e(k)-e(k-1)] + K_I e(k)+ K_D[e(k)-2e(k-1)+e(k-2)] \quad (1)$$

Where

$$K_P=-\frac{1}{2}K_I,\quad K_I=K\frac{Ts}{Ti},\quad K_D=K\frac{Td}{Ts} \quad (2)$$

Proportional: Error multiplied by a gain, K_p. This is an adjustable amplifier. In many systems Kp is responsible for process stability: too low and the PV can drift away; too high and the PV can oscillate.

Integral: The integral error is multiplied by a gain K_i. In many systems K_i is responsible for driving error to zero, but set K_i too high is to invite oscillation or instability or integrator windup or actuator saturation.

Derivative: The rate of change of error multiplied by a gain, K_d. In many systems K_d is responsible for system response: too high and the PV will oscillate; too low the PV will respond sluggishly. The designer should also note that derivative action amplifies any noise in the error signal.

"Tuning of a PID involves the adjustment of K_p, K_i and K_d to achieve some user-defined 'optimal' character of a system response."

Although much architecture exists for control systems, the PID controller is mature and well-understood by practitioners. For these reasons, it is often the first choice for new controller design.

E. Fuzzy Logic Controller

The Fuzzy controller developed here is a two-input single output controller. The two inputs are the deviation from set point error, E, and error change rate, EC. This is usually used for temperature control system [8]. The error means the difference between temperature measured and setting temperature. The error change rate means the derivative of error change. The single output is the change of operating value, ΔU. The Fuzzy logic control system and operational structure of Fuzzy controller are showed in Figure 1 which compromise four principal component:

- Fuzzificaion interface
- Knowledge Base
- Decision Making Logic
- Defuzzification Interface

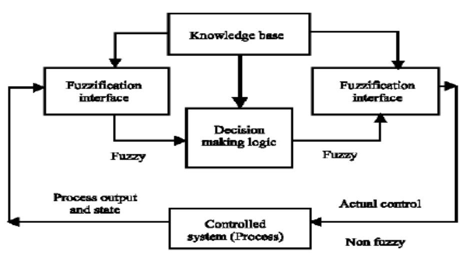

Figure 8: Fuzzy Logic Controller

Fuzzification interface: Fuzzification is related to the vagueness and imprecision in a natural language. The fuzzification module converts the input data into suitable linguistic values. In this paper, the domain of language variable of input, system error e(k) and the rate of error Δe(k), are{ -1, -0.8, -0.6, -0.4, -0.2, 0, 0.2,0.4,0.6,0.8 },the fuzzy sets are {NB, NM, NS, ZO, PS, PM, PB}, the elements of the subset stand for the negative big, the negative medium, the negative small, zero, small, middle, big. Gaussian membership function is used. The output variable u(k) is the PWM signal between 0% and 100%.

Knowledge base: The knowledge base compromise knowledge of application domain and control goals. It consists of "data base" and "linguistic control rule base". The data base provides necessary definitions, which are used to define linguistic control rules and fuzzy data manipulation in an FLC.

Decision making logic: The decision-making logic is the kernel of FLC. It has the capability of simulating human decision-making based on fuzzy concepts and of inferring fuzzy control action employing fuzzy implication and rule of fuzzy inference in fuzzy logic.

Defuzzfication interface: The defuzzification performs the following functions:

- A scale mapping, which converts the range of values of output value into corresponding universe of discourse
- Defuzzfication, which yields a non-fuzzy control action from an inferred fuzzy control action.

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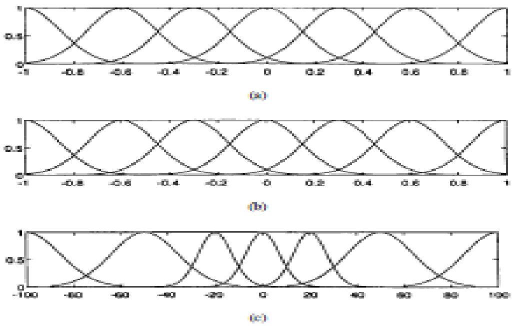


Figure 9: Membership functions of the three fuzzy variables of the water bath system. (a) Input variable e(k), (b) input variable Δe(k), and (c) output variable Δu(k)

F. GA-PID

GAs are powerful search optimization algorithms based on the mechanism of natural selection and genetics. Gain of PID are tuned using GA.GA is implemented using matlab. The GA is coded using MATLAB. Typical values of different parameters of GAs are taken. The programs use static values for maximum number of generations (maxgen=120), probability of crossover (pc=0.08), and probability of mutation(pm=0.05). The initial population is randomly generated. The population size (psize=60), is selected based on the observation. Roulette-wheel method is used to select individuals for reproduction process. In the method, two strings from the population are selected at random with their probability of selection being proportional to their fitness values. The selected strings undergo crossover and mutation and become members of the new population. The GA uses the absolute error i.e. the difference between the actual output and the reference input as a fitness function.

III. EXPERIMENTAL SETUP

Problem Statement

To see whether the proposed GA-PID can achieve good performance and overcome the disadvantages of the FLC and PID, we compare it with the FLC and PID under the same aforementioned circumstances on a simulated water bath temperature-control system. Consider a discrete time SISO temperature-control system

$$y_P(k+1)=a(T_s)y_P(k)+\frac{b(Ts)}{1+e^{0.5yp(k)-\gamma}}u(k)+[1-A(Ts)]yo \quad (3)$$

where a(Ts) and b(Ts) are given by (11). The parameters for simulation are α =1.00151e-4, β = 8.67973e-3, γ = 40.0 and Y0=25C, which were obtained from a real water bath plant [8, 9].

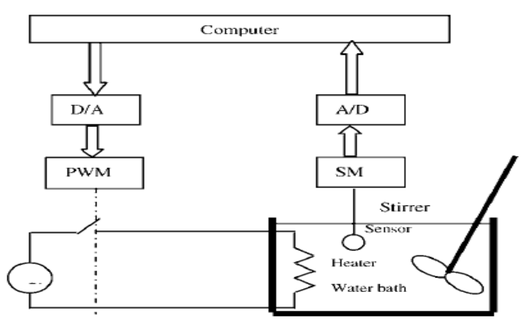


Figure 3: Schematic diagram of Water bath temperature control system.

The plant input u(k) is limited between 0 and 5 V, and it is also assumed that the sampling period is T_s=30s . The schematic diagram of the real water bath process is depicted in figure3. A personal computer reads the temperature of the water bath through a link consisting of a diode-based temperature sensor module and an 8-bit analogue to digital converter. The plant input produced by the computer is limited between 0 and 5 V and controls the duty cycle for a heater through a pulse-width-modulation scheme. The task is to control the simulated system to follow three set points.

$$yref(k) = \begin{cases} 35℃, & k \leq 40 \\ 55℃, & 40 < k \leq 80 \\ 75℃\,, & k \leq 120 \end{cases}$$

IV.SIMULATION STUDIES

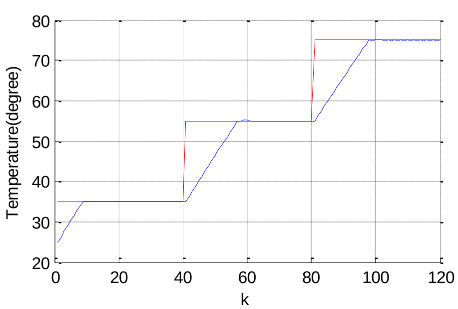
For the aforementioned controllers (GA-PID controller, PID controller and manually designed fuzzy controller), two groups of computer simulations are conducted on the water bath temperature control system. In the first set of simulations, the regulation capability of the three controllers with respect to set-point changes is studied. Three set-points to be followed are

$$yref(k) = \begin{cases} 35℃, & k \leq 40 \\ 55℃, & 40 < k \leq 80 \\ 75℃\,, & k \leq 120 \end{cases}$$

To test their regulation performance performance index, sum of absolute error (SAE), is defined by

$$\text{SAE}= \sum |yref - y|$$

where yref (k) and y(k) are the reference output and the actual output of the simulated system ,respectively.



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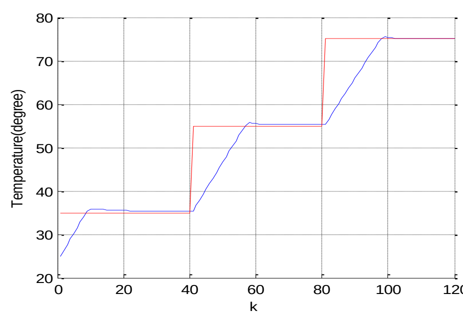
(a)



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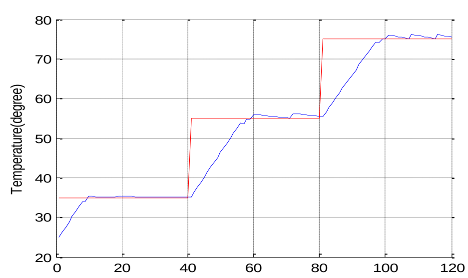
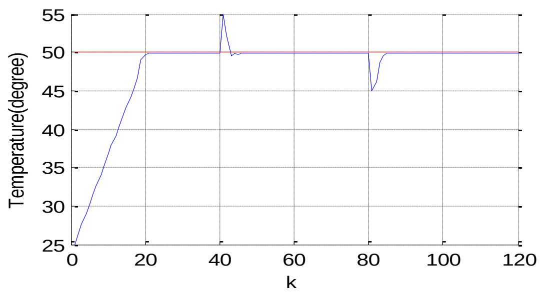


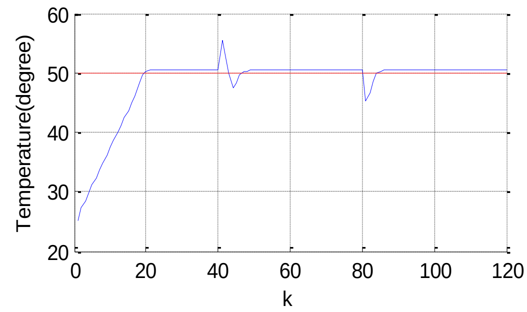
(c)

Figure4: Regulation performance of three controller for water bath system. (a).GA-PID (b).FLC (c). PID

Results shows that GA-PID controller exhibits good regulation capability.FLC shows small overshoot at $55^{c.}$.,but PID controller shows poor regulation performance.

In second set of experiment, two impulse noise values 5.0^{C} and -5.0^{C} is added at output at the fortieth and eightieth sampling instants, respectively. A set-point of 50.0^{C} is performed in this set of experiments. Figure5 shows behavior of controller to impulse noise





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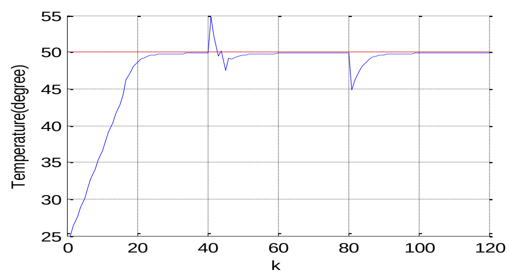

(c)

Figure 5: Behavior of the three controllers under the impulse noise for the water bath system. (a).GA-PID (b).FLC (c). PID

A summary of comparisons among the three controllers on the water bath temperature-control system is shown in Table 1. Experimental study shows that GA-PID shows better result as comparison to conventional control like PID controller

TABLE 1: SUMMARY OF COMPARISONS AMONG THE THREE CONTROLLERS ON THE EXPERIMENTAL WATERBATH SYSTEM

Design Criteria	**Regulation performance**	**Influence of impulse noise**
GA-PID	**SAE=394.2**	**SAE=283.2**
FUZZY	**SAE=409.3**	**SAE=295.3**
PID	**SAE=419.4**	**SAE=305.7**

V. CONCLUSION

In this paper, GA-PID, has resulted in better regulation performance & thus minimizing overall absolute error The results show that the GA-PID can be easily applied to the in presence of unknown noise .Performance of GA-PID is also better than the FLC and PID controller. SAE value of GA-PID is also less than the FLC and PID. In addition, the proposed method would be applied in much industrial process with better performance.

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