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A Practical Approach of Self-Tuning Fuzzy Logic Controller for Water Bath System Applications

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Abstract— This project is based on the self-tuning fuzzy logic controller consciously for temperature process , the performance of the system should be trustable. The water bath system system combines the advantages of Self Tuning and Fuzzy Logic Control schemes. In order to assess the performance of the suggested control system methods, upshots from simulation of the process are mounted.

Index Terms—Lab VIEW, Fuzzy logic controller, Self tuning, System identification, Water Bath system

1 INTRODUCTION

Fuzzy control is becoming one of the brightness and most rapidly ascending stars in the galaxy of intelligent control. This is because it offers a simpler, quicker 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 .Although fuzzy logic allows for the creation of simple control algorithms , the tuning of fuzzy controllers is relatively difficult and a sophisticated procedure is required to overcome plant parameter variations or changes in operating condition. This is due to the large number of parameters that can be altered off-line or on-line to improve its performance and robustness. These include membership functions, rule base and scaling factors. Each scaling factor is responsible for mapping an input or output to the UOD (Universe Of Discourse). Selection of these factors and\or tuning them are crucial which in many cases are set based on some training data or through trial and error procedure . They have large effects on the performance, therefore adjustment of these parameters is the most commonly adopted method for tuning fuzzy controllers . However, there is no systematic method to find the proper factors yet. Many researchers used different techniques to tune them. In neural networks are used for tuning the output factor only and genetic algorithms are utilized in to tune I/O factors, but these techniques need a number of iterations to achieve the desired performance and this is not applicable in real time implementation. In the present work a fuzzy technique is used for automatic tuning of the input and output factors. In general, drives do not need a fuzzy chip (like microcontrollers, FPGA) to control them, but, instead a moderate PC , data acquisition card (DAQ) with a well-tuned algorithm are sufficient enough to control many drive systems. Also the major obstacle in using text based programming languages as a tool to implement the intelligent control algorithms, is the difficulty to modify the control algorithm even for a slight change in the drive system. On the other hand, a graphical programming language has the flexibility, reusability and user friendly interfacing.

LabVIEW Virtual Instruments software can be used with a wide range of applications especially in control field. The LabVIEW combined with built in tools being designed specifically for test, measurement, and control, together with a facility for interfacing with real world signals is adopted for implementing the current system. Therefore variations in the control system can be observed in real time and the user commands can also be accepted during the process.

2 SYSTEM DESCRIPTION

The water bath process consist of several things mainly water tank ,sensor, data acquisition system, computer, LabVIEW controller and heater. A stirrer is used for distribution of heat in the water tank. 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 describe 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 output voltage of the sensor. The block schematic of the entire system is described below

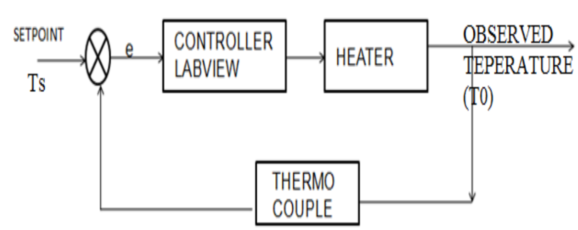

Fig.1 Block diagram of the system

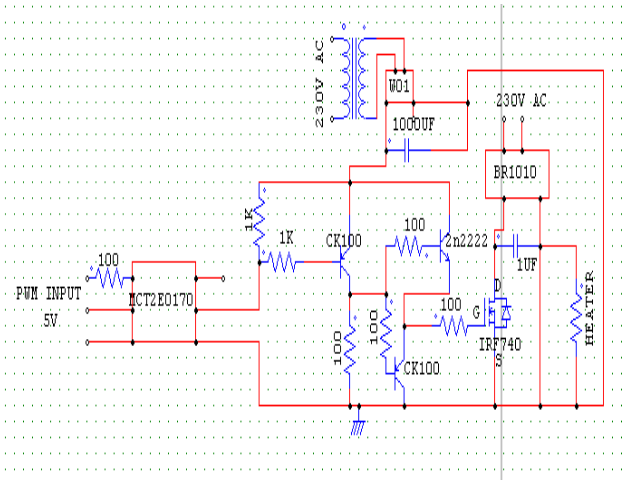

Fig. 2 The Psim diagram of driver circuit

3 SYSTEM IDENTIFICATION

System identification is done by using MATLAB system identification tool box. Here water bath system is a single input single output system So the order of the system is one. When we apply the input to the system it will take some time for heating process. Similarly when we switch off the system, it will take some time to come to the initial state. It clearly indicates the transportation delay present in the system. The system identification toolbox figure is shown below.

The transfer function of the system can be computed as

$$G(s) = \frac{K}{(1+T_{p1}S)e^{-Tds}}$$

K= 3.9165
Tp1=19.328
Td=30

$$G(s) = \frac{3.9165}{1+19.328s} e^{-30s}$$

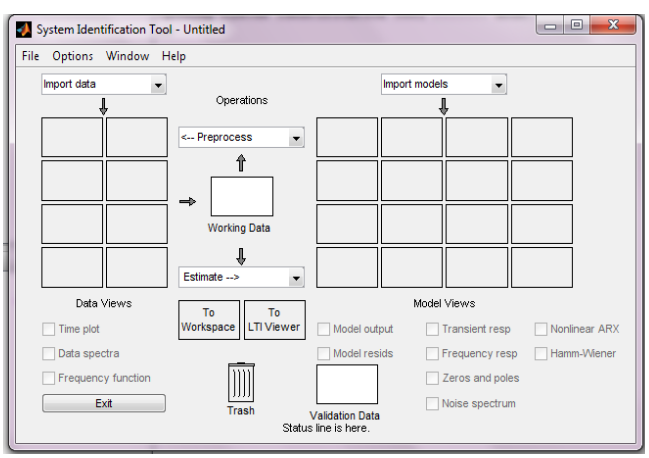

Fig.3 System identification window

Procedure for system identification

1. Open the matlab
2. Select the input and output variable and give the values
3. Type ident to the command window
4. Select the units
5. Remove the means
6. Shifted data views into the working data.
7. Shifted mydata into the validation data.
8. Select the estimate
9. Select the process model
10. Select the PID graph from the model view

4 DESIGN PROCEDURE OF FLC

4.1.Main idea of FLC

Fuzzy logic control is a control algorithm based on a linguistic control strategy, which is derived from expert knowledge into an automatic control strategy. The operation of a FLC is based on qualitative knowledge about the system being controlled .It doesn't need any difficult mathematical calculation like the others control system. While the others control system use difficult mathematical calculation to provide a model of the controlled plant, it only uses simple mathematical calculation to simulate the expert knowledge. The requirement for the application of a FLC arises mainly in situations where The description of the technological process is available only in word form, not in analytical form. It is not possible to identify the parameters of the process with precision. The description of the process is too complex and it is more reasonable to express its description in plain language words. The controlled technological process has a "fuzzy" character. It is not possible to precisely define these conditions. A fuzzy logic controller has four main components as shown in Figure:

a) Fuzzification
b) Inference engine
c) Rule base
d) Defuzzification

4.1.1. Fuzzification

The first step in designing a fuzzy controller is to decide which state variables represent the system dynamic performance must be taken as the input signal to the controller. Fuzzy logic uses linguistic variables instead of numerical variables. The process of converting numerical
variable (real number or crisp variables) into a linguistic variable (fuzzy number) is called fuzzification. This is achieved with the different types of fuzzifiers. There are generally three types of fuzzifiers, which are used for the fuzzification process; they are

1. Singleton fuzzifier
2. Gaussian fuzzifier
3. Trapezoidal or triangular fuzzifier

4.1.2.Rule base

A decision making logic which is, simulating a human decision process, inters fuzzy control action from the knowledge of the control rules and linguistic variable definitions . The rules are in

"If Then" format and formally the If side is called the conditions and the Then side is called the conclusion. The computer is able to execute the rules and compute a control signal depending on the measured inputs error (e) and change in error (de). In a rule base controller

the control strategy is stored in a more or less natural language. A rule base controller is easy to understand and easy to maintain for a non- specialist end user and an equivalent controller could be implemented using conventional techniques.

4.1.3.Inference engine

Inference engine is defined as the Software code which processes the rules, cases, objects or other type of knowledge and expertise based on the facts of a given situation. When there I a problem to be solved that involves logic rather than fencing skills, we take a series of inference steps that may include deduction, association, recognition, and decision making. An inference engine is an information processing system (such as a computer program) that systematically employs inference steps similar to that of a human brain.

4.1.4. Defuzzification

The reverse of Fuzzification is called Defuzzification. The use of Fuzzy Logic Controller produces required output in a linguistic variable (fuzzy number). According to real world requirements, the linguistic variables have to be transformed to crisp output. There are many defuzzification methods but the most common methods are as follows :

1) Center of gravity (COG)
2) Bisector of area (BOA)
3) Mean of maximum (MOM)

4.2. Self-tuning FLC

A different type adaptive scheme in which the estimate of process parameter is updated and controller parameter is obtained from the solution of a design problem using the estimated parameters.The adaptive controller can be thought of as being composed of two loops. The inner loop consists of process and an ordinary feedback controller. The parameter of the controller is adjusted by the outer loop, which is composed of a recursive parameter estimator and a design calculation. It is sometimes not possible to estimate the process parameters without introducing probing control signal .Notice that system may be viewed as an automation of process modeling and design, in which process model and the control design are updated at each sampling period. A controller of this construction is called a self-tuning regulator to emphasize that the controller automatically tunes its parameter to obtained the desired properties of a closed loop system.

5 SIMULATIONS

From the simulation result of the FLC controller ,Found the variation of input scaling factors and output scaling factors variation for various set points. To the design of self-tuning fuzzy logic controller three methods are there. The methods (a)Varying the shape of membership function (b)Change the tuning Rules(c) Change the scalar Gains. Here the third method is used. According to the simulation point of view PI is the best controller except one drawback high integral absolute error.

u(t)		e(t)						
		NB	NM	NS	ZO	PS	PM	PB
Δe(t)	NB	NB	NB	NB	NB	NM	NS	ZO
	NM	NB	NB	NB	NM	NS	ZO	PS
	NS	NB	NB	NM	NS	NS	PS	PS
	ZO	NB	NM	NS	ZO	ZO	PM	PM
	PS	NM	NS	ZO	PS	PS	PB	PB
	PM	NS	ZO	PS	PM	PM	PB	PB
	PB	ZO	PS	PM	PB	PB	PB	PB

Fig.4 Rule base for FLC &Self Tuning FLC

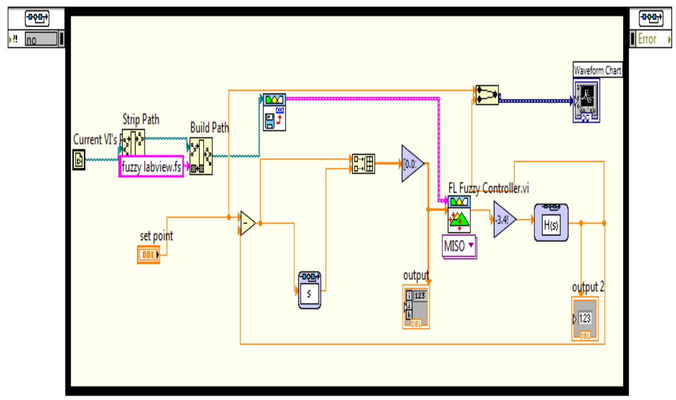

Fig 5.Front Panel diagram of fuzzy logic controller

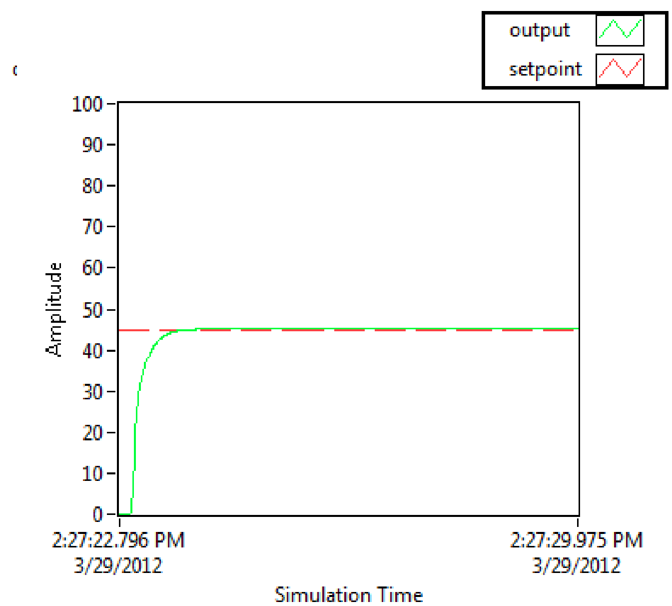

Fig.6 Response of FLC

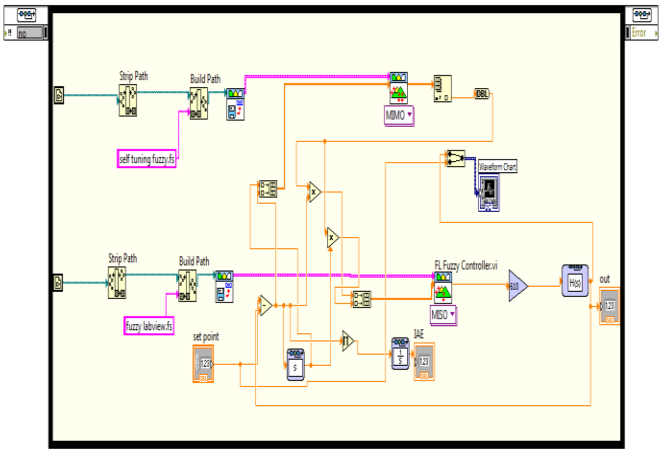

Fig 8. Front Panel diagram of self-tuning FLC

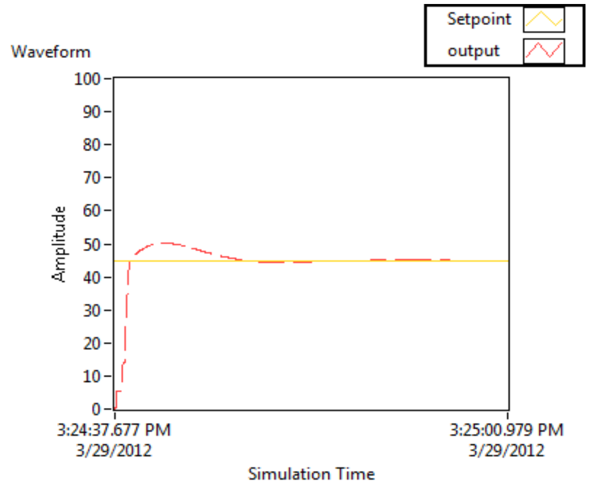

Fig.11. Response of PI controller

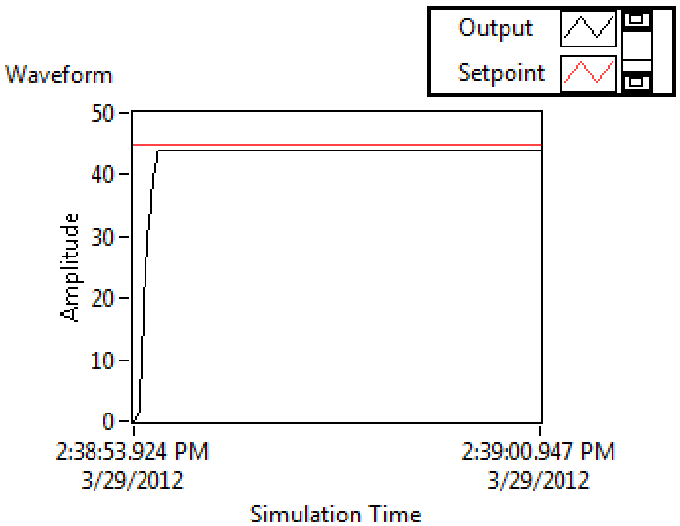

Fig.9 Response of self-tuning FLC

Table 1.

COMPARISON OF CONTROLLERS

Controller	Steady state error	IAE	Settling time(s)	Plant output
FUZZY LOGIC CONTROLLER	0.106	717.23	35	45.106
SELF TUNING FLC	0.50	598	13	44.5
PI	0	892.48	1	45

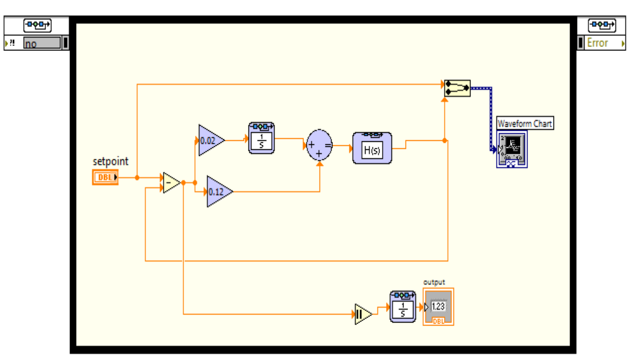

Fig.10 Front panel of PI controller

6 Conclusion

The simulation of Normal fuzzy logic controller Self tuning fuzzy logic controller and pi controller was then done in LabVIEW. By comparison of the response of normal and self-tuning fuzzy logic controller, it was found that the maximum overshoot, settling time ,integral of absolute value of error(IAE) and Integral square error(ISE) are very low compared to the normal fuzzy logic controller and other classical controllers. The result obtained from the comparison is verified in real time implementation. The compact ability of self-tuning in the various field like fish tank control, sterilizing equipment in the hospital and air conditioning system are want to study more deeply.

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REFERENCES

[1]. C. C. Lee,1990 "Fuzzy logic in control systems: Fuzzy logic controller-Part I," IEEE Trans. Syst., Man, Cybern., vol. 20, pp.404-418.

[2]. K. Shimojima, T. Fukuda, and Y. Hasegawa, 1995"Self tuning fuzzy modeling with adaptive membership function, rules, and hierarchical structure based on genetic algorithm," Fuzzy Sets Syst., vol. 71, pp. 295–309.

[3] Karl John Astrom and Bjorn Wittenmark, Adaptive control, second edition

[4] P. Melba Mary1 N.S. Marimuthu, 2007, Design of self-tuning fuzzy logic controller for the control of an unknown industrial process

[5] Julio Tanomaru, Student Member, IEEE,2005 and Sigeru Omatu, Member, IEEE Process Control by On-Line Trained Neural Controllers.

[6] C. Treesatayapun, S. Uatrongjit and K. Kantapanit,2009 Fuzzy Graphic Rule Network and Its Application on Water Bath Temperature Control System.

[7] Y. Zhao, E. G. Collins, and D. A. Cartes, 2003. "Self-tuning adaptive control for an industrial weigh belt feeder," ISA Transactions, pp. 437-450

[8] Huang S. H, Chen Y. H. C. 2006. Adaptive Sliding Control with Self-Tuning Fuzzy Compensation for Vehicle suspension Control. Mechatronics, Vol. 16: 607-622.

[9] Lin CH, Xu YJ , 2006 A self-adaptive neural fuzzy network with group-based symbiotic evolution and its prediction applications. Fuzzy Sets Syst 157(8):1036–1056

[10]. T. H. Lee, J. H. Nie, and W. K. Tan,1998 "A self-organizing fuzzified basis function network control system applicable to nonlinear servo mechanisms," Mechatronics, vol. 5, no. 6, pp. 695–713

[11] R. E. Precup, S. Preitl, J. K. Tar, M. L. Tomescu, M. Takács, P. Korondi, and P. Baranyi,2008 "Fuzzy control system performance enhancement by iterative learning control," IEEE Trans. On Industrial Electronics, vol. 55, no. 9, pp. 3461-3475.

[12] Cheng-Jian Lin, 2006 "Temperature control using neuro-fuzzy controllers with compensatory operations and neural wavelet networks Journal of Intelligent & Fuzzy Systems"