Study on Design of Control Module and Fuzzy Control System

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1. Introduction

Performance of control unit is improved by introduction of fuzzy control theory and compensation for input of control unit as FLC(Fuzzy Logic Controller). Here, FLC drives thermal control system by linguistic rule-base. Hence, In case of using compensative PID control unit, it doesn't need to revise or compensate for PID control unit. Consequently, this study shows proof that control system which implements H/W module and then uses fuzzy algorism in this system is stable and has reliable performance.

2. Design of control module and fuzzy control system

2.1 Design of control module

It's designed for control module to play a role of the main MPU and AD conversion. Basically, input and output of data are working through VME Bus. But Platinum temperature sensor(pt-100Ω) and RTD circuit, RTD circuit and ADC module are directly connected with the copper cable. 0 to 10 Voltage from RTD is converted into digital data through ADC module. After process of this value in the MPU module, it's transported data to virtual emulator in PC through RS232C communication. And then the experiment which produced the result of control had been done.

2.2 Design of fuzzy control system

Fuzzy control system like figure 1 is designed as compensative structure which controls input of PID control unit. That is, performance of control unit was advanced as compensating for input of PID control unit. Here, applied FLC through linguistic rule-base can drive plant. Therefore, when using compensative PID control unit, there is nothing to revise and compensate.

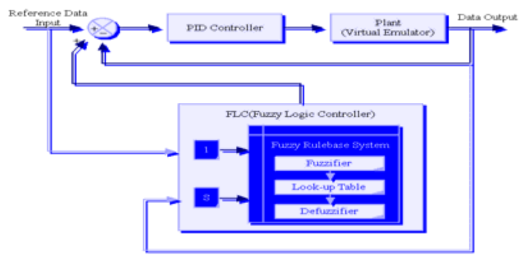

Figure 1. Modeling of fuzzy control system

2.2.1 Fuzzification

In order to construct FLC, two ambiguous linguistic input and one output variable which use in the control rule are required to define the membership function. As input variable, error(e) and error changing quantity(Δe) is used and as output variable, control input changing quantity of FLC(Δu) is used. The related equations are following below.

$$e(k) = SP(k) - Y(k) \quad (1)$$

$$\Delta e(k) = e(k) - e(k-1) \quad (2)$$

$$u(k) = u(k-1) + \Delta u(k) \quad (3)$$

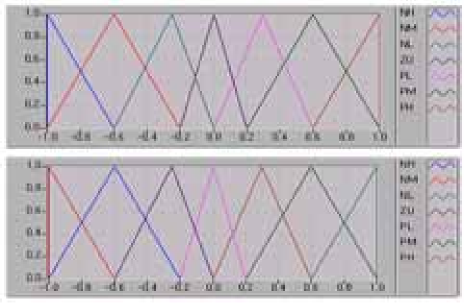

Figure 2. Membership function about input and output variables

At equation (1), SP(k) shows thermal set value in the fuzzy control system and Y(k) shows current temperature. Equation (2) is Δe(k) (error changing quantity), and e(k-1) (error) shows former error. Equation (3) shows Δu(k) (control input changing quantity), former control input, and u(k) (control input) respectively. Membership function that is the control variable of fuzzy control system can be shown like figure 2. U(Universe of discourse) for input & output variable of Membership function quantized 11 levels like below.

U = {-1.0, -0.8, -0.6, -0.4, -0.2, 0, 0.2, 0.4, 0.6, 0.8, 1.0}

2.2.2 Fuzzy Inference

The used control rule of fuzzy control system is the same with table 1. And linguistic control variables presents NTH(Negative Temp. High), NTM(Negative Temp. Middle), NTL(Negative Temp. Low), ZTU(Zero Temp. Uniform-motion), PTL(Positive Temp. Low), PTM(Positive Temp. Middle), and PTH(Positive Temp. High).

Table 1. Rule base for fuzzy compensator

Y \ R	NTH	NTM	NTL	ZTU	PTL	PTM	PTH
NTH	NTH	NTH	NTH	NTM	NTL	NTL	PTL
NTM	NTH	NTH	NTM	NTL	NTL	PTL	PTL
NTL	NTH	NTM	NTL	NTL	PTL	PTL	PTM
ZTU	NTM	NTM	NTL	ZTU	PTL	PTM	PTM
PTL	NTM	NTL	NTL	PTL	PTL	PTM	PTH
PTM	NTL	NTL	PTL	PTL	PTM	PTH	PTH
PTH	NTL	PTL	PTL	PTM	PTH	PTH	PTH

2.2.3 Programming for thermal control system

Look-up Table, which constructed by using fuzzy inference, is used of concluding input value during programming. First of all, response rate of set point can be measured by inputting array value which is consisted of Look-up Table using Fuzzy-PID Simulator that was made on a basis of PC. And then it is possible for program of fuzzy control system to construct. With this, the whole of the control system can be programmed. Below figure 3 shows Fuzzy-PID Simulator.

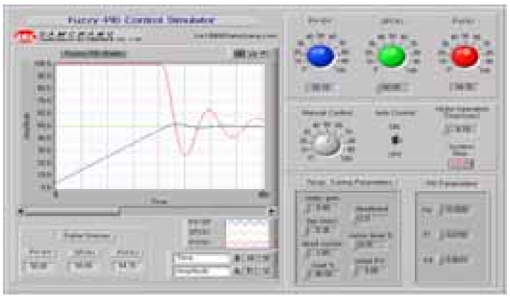

Figure 3. Fuzzy-PID Control Simulator

3. Experiment and Result

Thermal control system is connected to Platinum temperature sensor(pt-100 Ω) in the temperature chamber. And voltage value changing in the RTD is accepted from AD Conversion module. Here, accepted data through VME Bus is transferred to TMS320C40 module. Figure 4 below shows thermal control system for the experiment. This data which fuzzy control algorism is applied is processed in the Firmware and control signal is generated.

Figure 4. Constitution of thermal control system

For Virtual Emulator as the objective of control on a basis of PC, it's checked by changing temperature whether to be convergent or not from 0° C to 120° C in the temperature chamber. And the simulation for this was done. The result of the stable system compared output characters from general PID control with output characters from fuzzy control system was extracted. It's possible to pre-design of the system. And the simulation of the response character is possible by using PID simulator and Fuzzy-PID simulator.

Finally, when compared thermal control system of PID control algorism with fuzzy compensative thermal control system of fuzzy algorism, stability and reliability of the system can be proved. In figure 5, disturbance of hot water and cold water added in the three-point, was given and then data for response was obtained. For set point, response of control system was outputted as the same formation, and was considered to have reliability. Therefore, in the below figure 5, fuzzy control system probed into stable system.

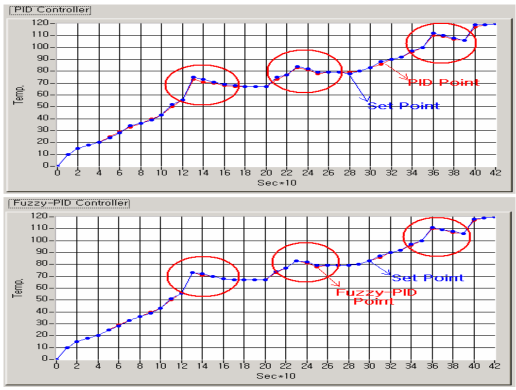

Figure 5. Temperature transition of control system

4. Conclusion

In the general thermal control system, re-setting up the coefficient for PID depends on experts, and it's limited to solve for error data generated on site in real-time. On the other hand, fuzzy control system has stability and reliability by automatically tuning the coefficient of PID with the introduction of fuzzy compensator. Therefore, using control system with the method of artificial intelligence is much better efficient.

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