'95 KACC (1995. 10. 23 ~ 25)

Look-up table based Self Organizing Fuzzy Control

Han-Soo Choi , Heon Jeong , Young-Dong Kim

Dept. of Control & Instrumentation Eng., Chosun University, Seoul Korea

Abstract

Fuzzy controllers have proven to be powerful in controlling dynamic processes where mathematical models are unknown or intractable and ill-defined.

The way of improving the performance of a fuzzy controller is based on making up rules, constructing membership functions, selecting a defuzzification method and adjusting input-output scaling factors. But there are many difficulties in tuning those to optimize a fuzzy controller.

So, in this paper, we propose the look-up table based self-organizing fuzzy controller(LSOFC) which optimizes look-up values resulting from the above fuzzy processes. We use the plus-minus tuning method(PMTM), scanning the value through the processes of addition and subtraction.

Simulation results demonstrate that the performance of LSOFC is far better than that of a non-tuning fuzzy controller.

1. Introduction

Currently, fuzzy logic control is widely studied in unknown, ill-defined plants. It relies primarily on a collection of linguistic operator-specified or common sense rules. So we can control such a system with minimum effort, if we adapt a fuzzy controller to the plant.

A fuzzy controller consists of : rule base, membership function, fuzzy inference, in/output scaling factors and defuzzification. Each element is very important for the optimum performance of a fuzzy controller, So we have to adjust them to the system. But there are many difficulties to surmount.

We can also construct the fuzzy controller by using the look-up table which is prepared through the processes of membership function, rule, fuzzy inference and defuzzification. Construction of a look-up table means selecting and organizing the above. Therefore, if we make the controller itself organize the look-up table, we then have a powerful way to optimize the system.

Hence, in this paper, we propose the look-up table based self organizing fuzzy controller(LSOFC). And we use the plus-minus tuning method, tuning the initial look-up table to the properly optimized table by adding and subtracting the values. To shorten the tuning time, we affix the block of the look-up table inspection.

We show the efficiency of this LSOFC by the results of simulation for nonlinear time-varying plants with unmodelled dynamics.

2. Fuzzy controller

The fuzzy control system is illustrated in Figure 1. The main fuzzy controller adopts the PD(proportion and differential) output structures. As we show, to tune the look-up table we lay the plus-minus tuning block and performance index block on top of the general fuzzy controller.

We use error and change-error for input. Inputed error and

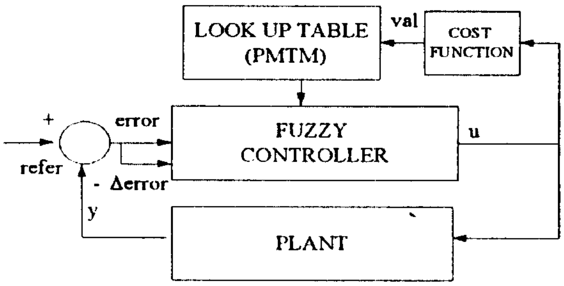

Figure 1. Look-up table base self organizing fuzzy controller

refer	:	reference
y	:	plant output
error	:	error
△error	:	change error
u	:	plant input
val	:	the result of cost function

change-error are altered into the process control value and the control value will be inputed at plant at each sampling time.

We also use the look-up table values of the control value, previously made up through membership function, rule base, fuzzy inference, and defuzzification in off-line

For the general look-up table, We use triangular membership function, general rule base suggested by MacVicar-Whelan, Min-Max fuzzy inference and central gravity method for the defuzzification.

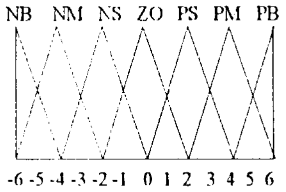

Fig2. Triangular membership function

Table 1 Rule base

Δe / e	NB	NM	NS	ZO	PS	PM	PB
NB	NB	NB	NB	NM	NM	NS	ZO
NM	NB	NB	NM	NM	NS	ZO	PS
NS	NB	NM	NM	NS	ZO	PS	PM
ZO	NM	NM	NS	ZO	PS	PM	PB
PS	NM	NS	ZO	PS	PM	PB	PB
PM	NS	ZO	PS	PM	PB	PB	PB
PB	ZO	PS	PM	PB	PB	PB	PB

Table 2 Look-up Table

		△ERROR												
		-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6
ERROR	-6	-6	-6	-5	-5	-4	-4	-3	-3	-2	-2	-1	-1	0
	-5	-6	-5	-5	-4	-4	-3	-3	-2	-2	-1	-1	0	1
	-4	-5	-5	-4	-4	-3	-3	-2	-2	-1	-1	0	1	1
	-3	-5	-4	-4	-3	-3	-2	-2	-1	-1	0	1	1	2
	-2	-4	-4	-3	-3	-2	-2	-1	-1	0	1	1	2	2
	-1	-4	-3	-3	-2	-2	-1	-1	0	1	1	2	2	3
	0	-3	-3	-2	-2	-1	-1	0	1	1	2	2	3	3
	1	-3	-2	-2	-1	-1	0	1	1	2	2	3	3	4
	2	-2	-2	-1	-1	0	1	1	2	2	3	3	4	4
	3	-2	-1	-1	0	1	1	2	2	3	3	4	4	5
	4	-1	-1	0	1	1	2	2	3	3	4	4	5	5
	5	-1	0	1	1	2	2	3	3	4	4	5	5	6
	6	0	1	1	2	2	3	3	4	4	5	5	6	6

3. LSOFC strategy

The principal influential things of performance are the input/output scaling factors and look-up table values. So we will tune those initial values to be optimal for unknown plant.

The strategy is as follows.

1) *Make the initial look-up table* (table 2)

2) *Find the approximal in/out gain factors*

k1 : The gain of error (= refer / 6 ,initial plant value is 0)
We assume that the maximum error is almost the reference value.

k2 : The gain of change error (= k1)
We assume that the bands of error and change error are almost same

k3 : Output gain.
Varies with the result of the cost function.
Until the state-errror is within tolerance, adjusting routine is continued. When we use a proper value of k3, we then can get a optimized look-up table.

3) *Checking the performance of the fuzzy controller* in used initial look-up table and in/out scaling gain factors.

4) *Using the plus-minus tuning method*
Change and find the optimized look-up table-value

5) *Save and use* the optimized look-up table values and k3 output scaling factors for the plant.

3.1 Cost function.

If we want to check whether the plant response to the newly changed fuzzy controller is promoted or not, we should use the cost function. So, in this paper we use the Error-time-square-integral method(1). Less-cost look-up table is the better look-up table.

$$J = \sum_{t=0}^{k} (t * error(t))^2 \qquad (1)$$

3.2 Plus-minus tuning method.

Look-up table tuning means totally checking the error, missing or non-optimized point in fuzzy process. So look-up table tuning is better than each element tuning.

In this paper, we propose the plus-minus tuning method to tune the look-up table. The method is basically divided into three parts: checking the used look-up value parts, increasing and decreasing the part.

1) Checking the used look-up table parts :

The look-up table consists of 13×13 values(table 2). Only a few parts of the look-up table values are used to control a plant, so we don't have to check the invalid values. To reduce checking time, we must know the used values and these are only considered in our mind.

After checking the used part, we store the data in que buffer, and we only check the data during tuning.

2) Increasing part

In this part, we check the look-up values which were obtained in used look-up table part. We add a value and input the changed look-up table to plant. If the response of the plant is improved, that is, the cost function is lower, the increasing part will be continued. But if not, the look-up table will be changed before increasing the value and if the value has never changed in this part, we then go to next minus part. or not, shift to next look-up value. In this part, we can reduce the rising time. The maximum value is 6.

3) Decreasing part

In this part we check the look-up values which do not any improve in increasing time. We subtract a value and input the changed look-up table to the plant. If the response of the plant is improves, the decreasing part is continued. But if not, we then change the value to prior increasing value and shift to next value. The values must be greater than -6.

4. Simulation experiments

To analyze the performance of LSOFC, we use two different kinds of models of the controlled plant. We concentrate our efforts on the comparison of the step response of the fuzzy controller with and without LSOFC.

$$G(s) = \frac{3.3}{(s+0.9)} \quad (2)$$

$$G(s) = \frac{1}{(s-0.3)(s-3.3)} \quad (3)$$

The first simulation model of a plant is a first-order system. Figure 3(a) shows the step responses of the fuzzy control system when the LSOFC does not come into action, and Figure 3(b) shows the step responses of the fuzzy control system when the LSOFC does come into action.

Before regulating the fuzzy control system does not act satisfactorily. But after regulating, the step response is achieved to optiminum.

In figure 3(a)(b), we can also find the role of k3. When we use k3 in proper, the performance of LSOFC is quitely good. But when we do not, the performance is much less. when we set the k3=1.022, the fuzzy controller active ultimately good.

After tuning the look-up table, we can get the new optimized look-up table(table 3). We can then find some varying values(in table 3, circle characters are varied)

There is a static error for the output of non-look-up table tuning fuzzy controller which it use the general look-up table(table 2). But the simulation shows that, as expected, the LSOFC can make the fuzzy control system achieve a faster rising , a smaller overshoot and a shorter setting time.

Table 3. The look-up table resulted from the 1st-order system.(k3=1.022)

		ΔERROR												
		-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6
ERROR	-6	-6	-6	-5	-5	-4	-4	-3	-3	-2	-2	-1	-1	0
	-5	-6	-5	-5	-4	-4	-3	-3	-2	-2	-1	-1	0	1
	-4	-5	-5	-4	-4	-3	-3	-2	-2	-1	-1	0	1	1
	-3	-5	-4	-4	-3	-3	-2	-2	-1	-1	0	1	1	2
	-2	-4	-4	-3	-3	-2	-2	-1	-1	0	1	1	2	2
	-1	-4	-3	-3	-2	-2	-1	-1	0	1	1	2	2	3
	0	-3	-3	-2	-2	-1	-1	0	1	1	2	2	3	3
	1	-3	-2	-2	-1	-1	②	1	1	2	2	3	3	4
	2	-2	-2	-1	-1	0	1	1	2	2	3	3	4	4
	3	-2	-1	-1	0	1	1	2	2	3	3	4	4	5
	4	-1	-1	0	1	1	2	⑥	3	3	4	4	5	5
	5	-1	0	1	1	2	2	⑥	3	4	4	5	5	6
	6	0	1	1	2	2	3	3	4	4	5	5	6	6

Table 4. The look-up table resulted from the 2nd-order system.(k3=0.368)

		ΔERROR												
		-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6
ERROR	-6	-6	-6	-5	-5	-4	-4	-3	-3	-2	-2	-1	-1	0
	-5	-6	-5	-5	-4	-4	-3	-3	-2	-2	-1	-1	0	1
	-4	-5	-5	-4	-4	-3	-3	-2	-2	-1	-1	0	1	1
	-3	-5	-4	-4	-3	-3	-2	-2	-1	-1	0	1	1	2
	-2	-4	-4	-3	-3	-2	-2	-1	-1	0	1	1	2	2
	-1	-4	-3	-3	-2	-2	-1	-1	0	1	1	2	2	3
	0	-3	-3	-2	-2	-1	-1	0	1	1	2	2	3	3
	1	-3	-2	-2	-1	-1	0	1	1	2	2	3	3	4
	2	-2	-2	-1	-1	0	1	1	2	2	3	3	4	4
	3	-2	-1	-1	0	1	1	2	2	3	3	4	4	5
	4	-1	-1	0	1	1	2	⑥	3	3	4	4	5	5
	5	-1	0	1	1	2	2	⑥	3	4	4	5	5	6
	6	0	1	1	2	2	3	⑥	4	4	5	5	6	6

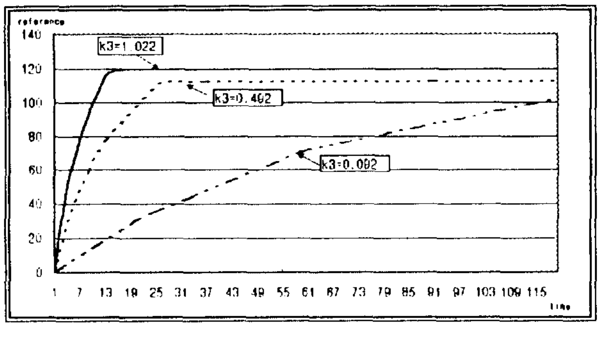

Figure 3(a) The response of first-order system (without LSOFC)

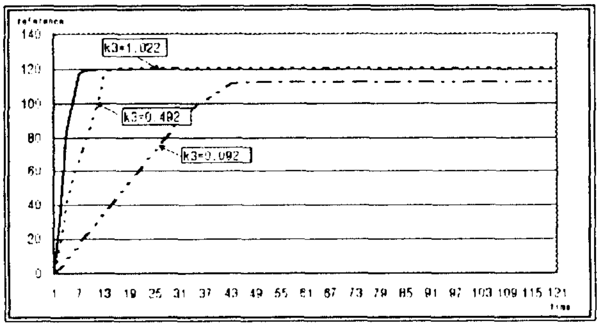

Figure 3(b) The response of first-order system (with LSOFC)

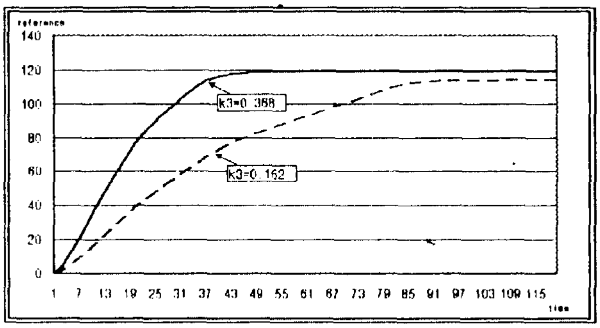

Figure 4(a) The step response of the second-order plant(wihout LSOFC)

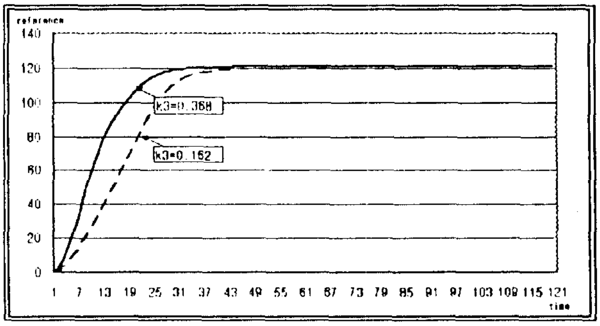

Figure 4(b) The step response of the second-order plant(wih LSOFC)

Obviously, the system obtains an optimized performance as what the designers hoped it would.

We can see the result of second-order plant. in fig 4. Table 4 is an optimized look-up table. Fig 4(a) is the curve of a non-tuning fuzzy controller and fig 4(b) is that of LSOFC.

We can also find that there was a static error in non-tuning fuzzy controller. However, we can find that the static error not only disappears but also the rising time is shortened in LSOFC.

Through results of simulation in two models of plants, we found that it was unreasonable to use the general look-up table(Table 2), and after tuning look-up table with using the plus-minus tuning method, We could get new look-up table(Table 3,4) and those made fuzzy controller good performed(Fig 3(b),4(b))

5. Conclusion

In this paper, to get the optimum performance of a fuzzy controller, we propose self-organizing a fuzzy controller based on look-up table modification. We've organized a unique look-up table with a plus-minus tuning method.

As we show, we have simulated in both first-order and second-order plants, and the response of the plant with LSOFC is much improved, the rising time was shortened and the static error disappeared. The newly gutted look-up table have us work and cover the defects in rule, membership function, defuzzification, fuzzy inference.

So, for best control results, we recommend using the unique look-up table and we can get that look-up table with LSOFC.

References

1. Dasaradh millampati and Sujeet shenoi, "Self-Organizing Fuzzy Controller," Elsevier Science Publishing Co. , 1991

2. Wu zhi Qiao, Wang Pie Zhunag and the Hoon Heng, "A Rule Self-Regulating Fuzzy Controller," Fuzzy Sets and System, Vol. 47, pp. 13-21, 1992

3. Mohanmmad Jamshidi, Nader Vadiee, Timothyj. ross, "Fuzzy Logic And Control" software and hardware applications volume 2, 1993

4. Stjepan Bogdan, Zdenko Kovacic " Fuzzy Rule-based Adaptive Force Control Of A Single DOF Mechanisms", Proceedings of the 1993 International Symposium on intelligent control, Chicago, illinois, USA - August, 1993.

5. T.J. Procyk "A Self-Organizing Controller For Dynamic Procrsses", Ph. D. Thesis, September, 1977.

6. Chuen-Tsai Sun, "Rule-Base Structure Identification in an Adaptive-Network-Based Fuzzy Inference System", IEEE Transaction on Fuzzy Systems, VOL. 2, NO. 1, February 1994.