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Dialogical Tuning of the Sampling Period in Fuzzy Control Systems

Kunihiko OURA*, Tsutomu ISHIMOTO*, Kageo AKIZUKI* and Naoyuki ISHIMARU**
*Department of Electrical Engineering, Waseda University, Shinjuku-ku, Tokyo 169, JAPAN
**Engineering R & D Center, Japan Tobacco Inc., Hiratsuka, Kanagawa 254, JAPAN

Abstract: It is the purpose of this paper to present a dialogical tuning method of the sampling period in fuzzy control systems. Last year, the authors gave a dialogical tuning technique of fuzzy control system under the fixed sampling period in this symposium.

In the case where sampling period is chosen larger, the response of the control system is unsatisfactory, and in the case where the sampling period is smaller, ineffective control actions are repeated.

The appropriate sampling period is chosen through the step response of the closed loop fuzzy control process. As the tuning technique depends on the controlled plant, it is necessary to estimate the rough characteristics of it. The authors propose a method to decide the appropriate sampling period, by inspecting the characteristics of the plant.

1 INTRODUCTION

The authors gave a dialogical tuning technique of fuzzy control system using rough grasp of the unknown process properties [1][2]. In this technique, they deal with a single-input single-output feedback control system containing a fuzzy controller as shown in Fig.1. The process property is roughly estimated by the step response, and the fuzzy controller is interactively modified according to the operator's requests.

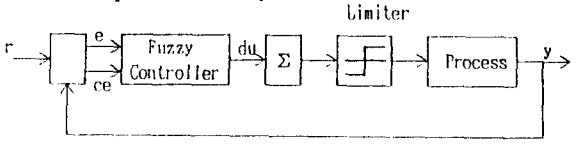

Fig.1: Fuzzy Control System

In addition to the work mentioned before, the authors deal with a dialogical tuning method of the sampling period in fuzzy control system in this paper. In the same way as the previous work, the following conditions are supposed.

1. Reference input r is step.
2. Process is unknown.
3. Input u and output y is observed.

At first, sampling period is fixed to 0.1(s) and according to the step response, fuzzy controller for an unknown process is tuned. Initial conditions for the fuzzy controller are: (1) the hight of step is 0.5, (2) the membership functions of e and ce have a triangle shapes, (3) the membership functions of u and du are singletons.

Fundamental control rules are shown in table.1 and GDU tuning method is as follows:

$$GDU = [SetPoint] \times \frac{T_s}{T_f} \times \frac{[u_{max}]}{[y_{max}]}$$

Here, T_s is the sampling time and T_f is the time to the first maximum value.

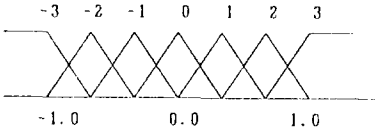

Fig.2: The Membership Function of e and ce (fundamental type)

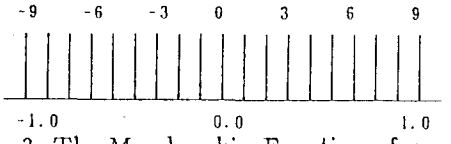

Fig.3: The Membership Function of u and du (fundamental type)

ce \ e	-3	-2	-1	0	1	2	3
3	0	3	6	9	9	9	9
2	-3	0	3	6	9	9	9
1	-6	-3	0	3	6	9	9
0	-9	-6	-3	0	3	6	9
-1	-9	-9	-6	-3	0	3	6
-2	-9	-9	-9	-6	-3	0	3
-3	-9	-9	-9	-9	-6	-3	0

Table.1: Fundamental Control Rules

2 PROCESS DISCRIMINATION

The method of tuning a fuzzy controller differs, depending on the characteristics of the process whether it is stable or unstable, or it has an integral element. We can estimate its characteristics from the step response by the following discriminating methods.

(1) Discriminating stability of process

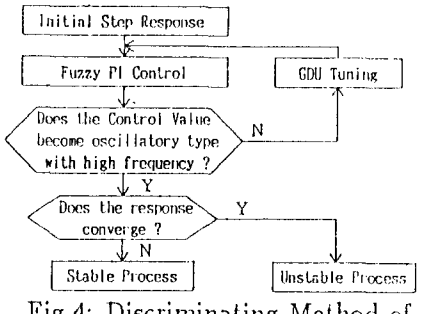

Fig.4: Discriminating Method of Stability

(2) Discriminating integral element of process

(a) Stable process

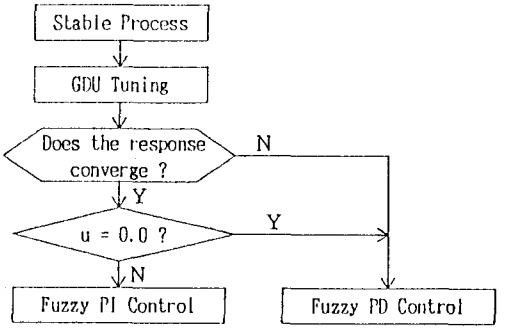

Fig.5: Discriminating Method of Integral Element (stable process)

(b) Unstable process

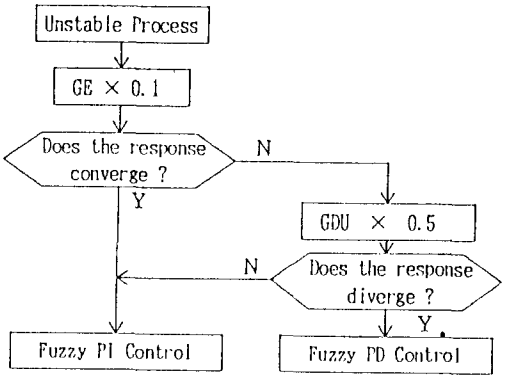

Fig.6: Discriminating Method of Integral Element (unstable process)

A dialogical tuning technique of fuzzy control system with a rough grasp of its characteristics under fixed sampling period is based on our previous work [1][2].

3 TUNING OF SAMPLING PERIOD

In the preceding discussions, fuzzy controller is designed under the fixed sampling period which is small enough to simulate most of processes. But, for some processes, fuzzy controllers designed with fixed sampling period do not work properly. Only if we get undesirable result after tuning, we should change sampling period in the above fuzzy control systems.

3.1 Undesirable Plobrems Caused by the Fixed Sampling Period

Undesirable problems caused by a fuzzy controller designed with a fixed sampling period are the followings: (1) Control performance becomes worse, (2) Tuning method becomes complicated, (3) Some processes become uncontrollable, (4) Control efficiency becomes worse. In order to overcome each of these problems, some techniques are considered:

(1) To avoid bad performance, smaller sampling period is desired. Because bad control performance is due to its larger sampling period compared with the process' time constant.

(2) Complicated tuning method is due to the inadequate sampling period. So the sampling period should be changed in this case.

(3) If the sampling period is fixed as 0.1(s), the processes which diverges rapidly are unable to be controlled. By using the smaller sampling period, stable control is achieved.

(4) If control input is saturated, or delay time is larger than the sampling period, fuzzy inference in that part is of no use. Then, the larger sampling period is desired.

To overcome the above undesirable problems, the sampling period should be changed according to the characteristics of the process. However, if sampling period becomes smaller, control performance will be better, but control efficiency will be worse than before. It is a trade-off relation. So that, which tuning method should be taken depends on the operator's requests.

3.2 Basic Idea of Changing a Sampling Period

There are two methods of changing sampling period:

(1) Sampling period is changed before designing a fuzzy controller.

(2) Design a fuzzy controller under fixed sampling period, and after that, sampling period is changed according to operator's requests.

The latter method is adopted in this paper because the former is difficult to be implemented in dialogical method.

Basic idea of tuning the sampling period is as follows:

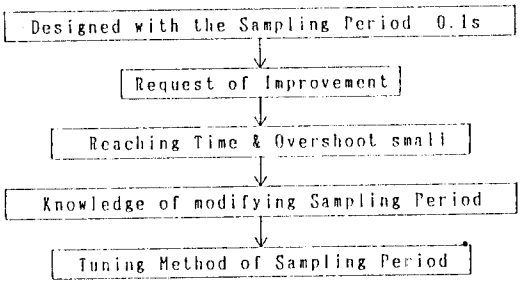

Fig.7: Basic Idea of tuning Sampling Period

At first, fuzzy controller is designed under the fixed sampling period. After that, the judgement whether the sampling period should be changed or not is made, and if it should, the choise whether the sampling period should be smaller or larger is made. The fuzzy controller is tuned by the operator's request which is given based on the rising time and overshoot of the step response.

3.3 Method of Tuning the Sampling Period

The method of tuning the sampling period differs depending on the process whether the process is stable or unstable, or it has an integral element. Then we can suppose 4 types of tuning methods. They are shown in Fig.8 to 10.

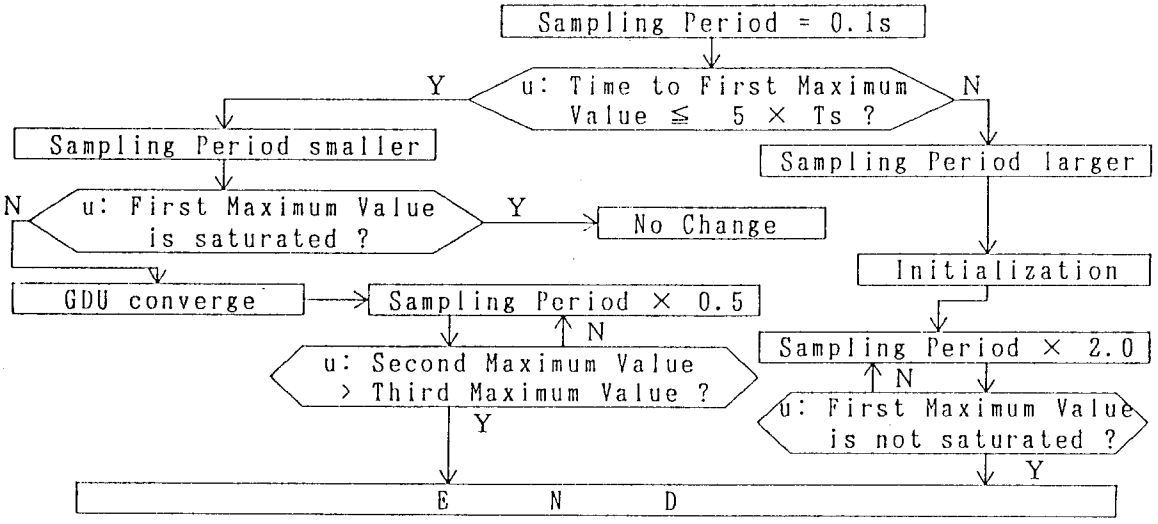

Fig.8: Tuning Method of Sampling Period (Stable process, Fuzzy PI controller)

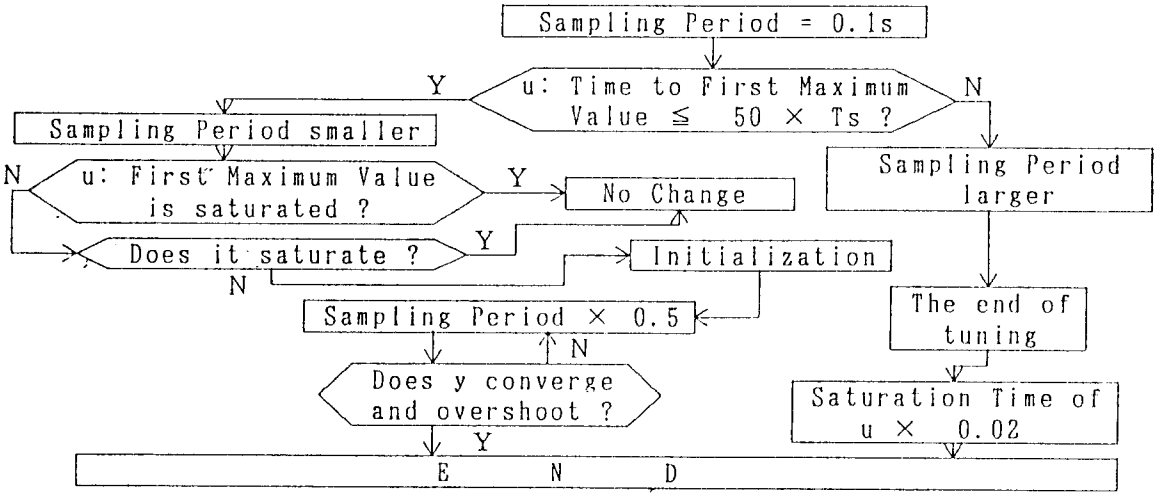

Fig.9: Tuning Method of Sampling Period (Stable process, Fuzzy PD controller)

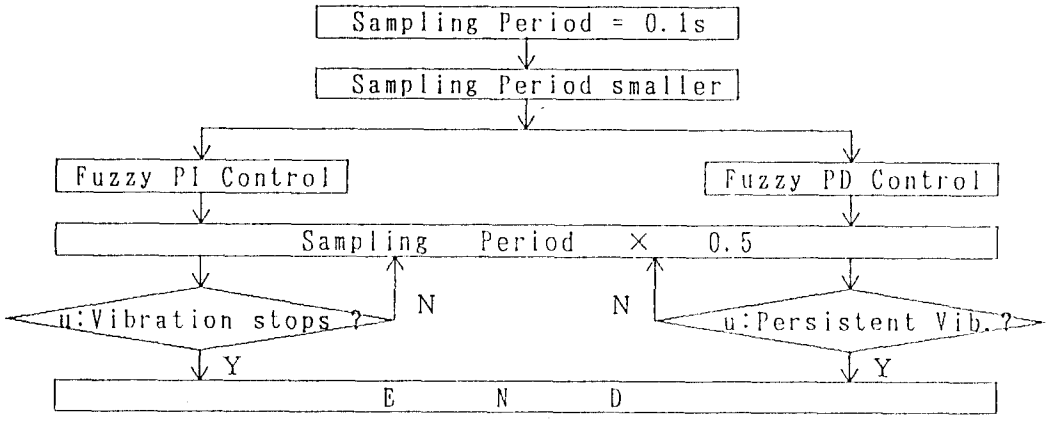

Fig.10: Tuning Method of Sampling Period (Unstable process)

4 SIMULATION EXAMPLES

A few simulation results are shown here.

(1) Improvement of control performance

Process: $\frac{10}{s+20}$

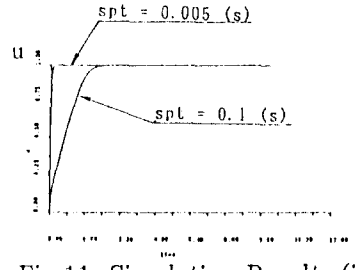

Fig.11: Simulation Results (input)

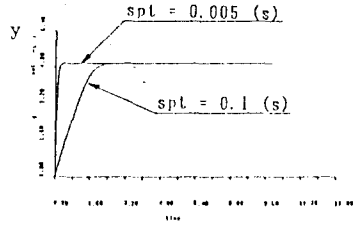

Fig.12: Simulation Results (output)

In the case where sampling period is 0.1(s), the process is controlled with the smaller open loop gain and the time constant of the closed loop system becomes larger than the process. By changing the sampling period to 0.005(s), the closed loop system can be controlled with smaller time constant.

(2) Simplified tuning method

In the above example, tuning method is simpler for the sampling period 0.005(s) than that of 0.1(s).

(3) Stabilization

Process: $\frac{10}{s-20}$

The unstable process can be stabilized by changing the sampling period from 0.1(s) to 0.01(s).

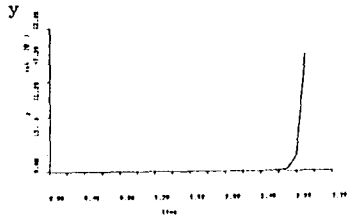

Fig.12: Simulation Results (output)

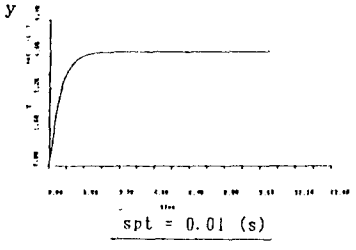

Fig.13: Simulation Results (output)

(4) Taking larger sampling period without loss of control performance.

Process: $\frac{1}{50s+1}$

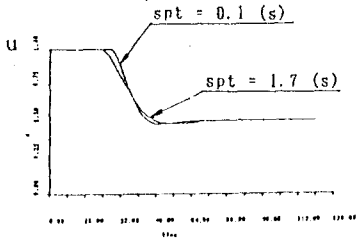

Fig.14: Simulation Results (input)

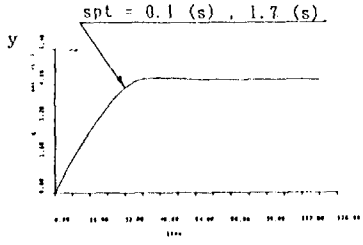

Fig.15: Simulation Results (output)

Sampling period is changed from 0.1(s) to 1.7(s), but control performance does not become worse.

5 CONCLUSION

The authors propose a dialogical tuning method of sampling period in fuzzy control systems in this paper. Making it simple, the method consists of the following three steps
(1) Design a fuzzy controller under fixed sampling period.
(2) Decide whether sampling period should be changed or not. If it is better to change, based on our work, we are able to know that it should be larger or smaller.
(3) If the operator requests to change the sampling period, appropriate sampling period is chosen.

The effects of changing the sampling period are, 1)improvement in control performance, 2)simplifying tuning method, 3)improvement in control efficiency. And it is confirmed that uncontrollable process becomes controllable by changing the sampling period.

This method is of use to select a sampling period when fuzzy controller is designed.

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1) N.Ishimaru, T.Ishimoto, K.Akizuki : Dialogical Design of Fuzzy Controller Using Rough Grasp of Process Property. '92 KACC , pp265-271(1992)

2) T.Yonezawa , K.Uchida , T.Ishimoto , N.Ishimaru, K.Akizuki: Fuzzy Control Based on Rough Grasp of Process Property. Prep. of 23rd ISCIE Symp., pp75-78(1991)