Tuning of the PID Control Gains by GA

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Abstract -PID controller has been extensively used in the industrial world. But in this controller it is difficult to tune the PID gains. We apply the genetic algorithm(GA) to tune the PID gains. The GA is an optimization algorithm using the biotic genetics. At first, the GA encodes a solution's candidate of the problem to a string. There are some ways of encoding. One of the most popular ways is a binary encoding(bit string). Because it is simpler to operate and prove the GA than the other encordings. As a matter of fact, there is a little binary to be adopted to the real problem. In this study, we propose another way that is real number string to use the PID controller, and compare with a usual bit string method by simulations.

I .INTRODUCTION

In this study. we propose a method to adopt each bit and real number strings for the PID controller, and compare each capacity. Here we take a simple GA(SGA) as the GA of bit string [1].[2].

II. THE CONTROLLED PLANT

The plant that is controlled by the PID controller is a water bath whose block diagram is shown in Fig.1. The transfer function of the water bath is given by the following difference equation .

$$y(k+2) = 0.9 \cdot y(k+1) - 0.001 \cdot y^2(k) + u(k+1) + \sin(u(k)) \quad (2\text{-}1)$$

As a GA's population, we takes the PID control gain's $k_p(k)$, $k_i(k)$, and $k_d(k)$. At each sampling k, the GA decides the PID gains. Here, the plant input u(k) ranges over 0 to 5. The system input r(k) use the function following equation .

$$r(k) = \begin{cases} 30 & (0 \le k < 20) \\ 60 & (20 \le k < 50) \end{cases} \quad (2\text{-}2)$$

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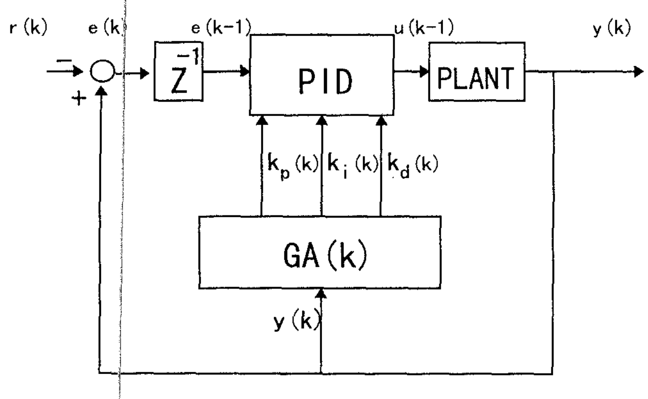

Fig.1 Tuning of the PID Control Gains by GA

III.ENCODING

On the binary encoding, each of PID gains shown by $k_p(k)$, $k_i(k)$, and $k_d(k)$ encode to a 8 bits string. And make one 24 bits string. On the real number string, a set of the three gains is taken as a string in direct. Here, we obtain the gain's range over 0 to 100. Two type of strings are shown in Fig.2.

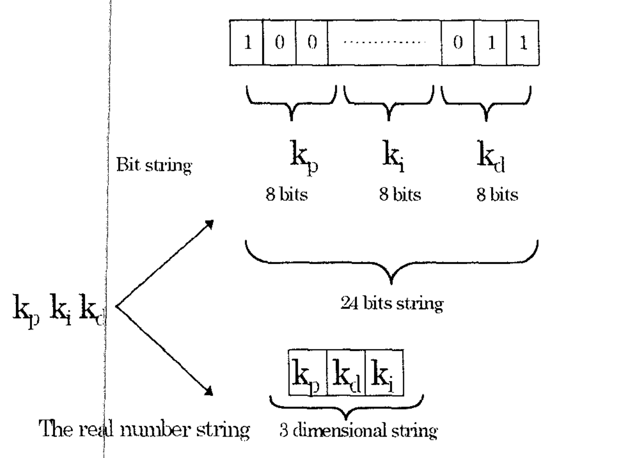

Fig.2 Two types of string.

IV.SIMPLE GA

SGA consists of three operations shown in the following list:

1. Roulette wheel selection.
2. Simple crossover.
3. Simple mutation.

Three operations are applied to binary encode strings.

V.THE GA APPLIED TO THE REAL NUMBER STRING

The GA consists of three operations. The selection is the same as SGA's one, the mutation(The real number mutation) is to mutate a certain real number of some string that is selected with random, and the crossover is very different from SGA's one since this string is no encoding. When we obtains this crossover, we consider two parents' strings as two three-dimensional vectors, Children string's vector is made as the ratio of norms between children's vector and two parent's ones becomes the ration of two parent's fitness values. This crossover's image is shown in Fig.3

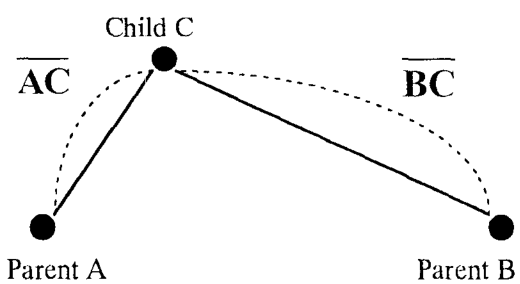

Fig.3 The real number crossover's image. There is the following equation between points A, B, and C :

$$\overline{AC} : \overline{BC} = \frac{1}{A's\ fitness} : \frac{1}{B's\ fitness}$$

VI. FITNESS FUNCTION

We consider a fitness function given by

$$\mathbf{fitness(p)} = \frac{1}{1 + \mathbf{e_p}^2(\mathbf{k}) + \mathbf{w} \cdot \mathbf{o_p}^2(\mathbf{k})}$$

$$e_p(k) = r_p(k) - y_p(k) \qquad (6\text{-}1)$$

$$o_p(k) = \begin{cases} 0 & (0 \le u_p(k) \le 5) \\ u_p(k) & (0 > u_p(k), u_p(k) > 5) \end{cases}$$

p : individual's number of GA, w : weight,

Ⅶ. RESULTS

The plant's sampling numbers are 40 times. The GA works 100 generations in every 40 samplings. 100 times of the plant simulations are performed and makes the averaged simulation's results. The plant's and the GA's result are shown in Figs.4, 5 and 6.

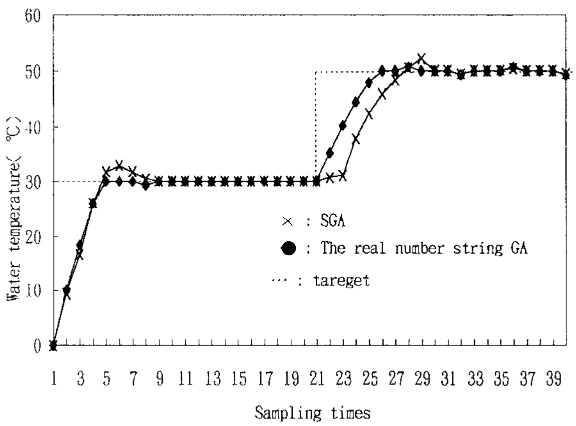

Fig.4 The plant output.

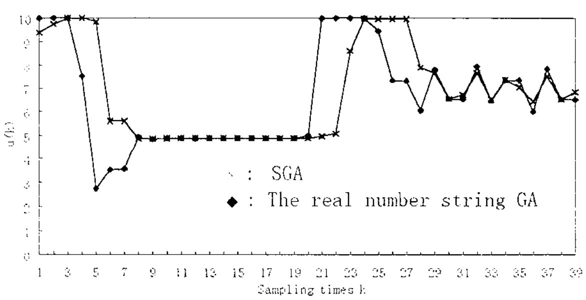

Fig.5 The output u(k) of PID controller

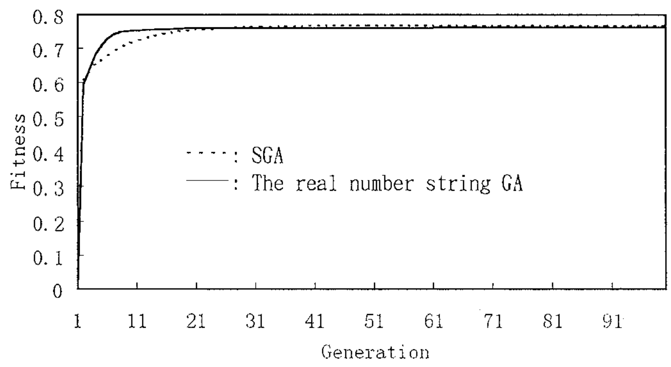

Fig.6 The compare of two GA's performance.

IIX. SUMMARY

From the result of this study, SGA has a little overshoot, and both SGA and real number string GA are good at controlling the plant. When water temperature is high(50℃), the plant keeps flat. The real number string GA is better than the bit string GA(SGA) to control the plant. But The real number string GA is hard to plan the crossover. We make sure that the performance of the GA will be become bad for the design of crossover. For improvementing SGA, SGA will obtain the same performance.

REFERENCES

[1] Hiroaki Kitano "Genetic Algorithms", Sangyou-Tosho Pub, (in Japanese), 1993.

[2] L.Devis, "Genetic Algorithms Handbook", Van Nostrand, New York, 1995.