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MEMBERSHIP FUNCTIONS OPTIMIZATION OF FUZZY CONTROL BASED ON GENETIC ALGORITHMS

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ABSTRACT

The principle and implementation procedure of genetic algorithms were introduced and were applied to optimize the parameters of fuzzy controller which control the superheat of evaporator in refrigeration system. Simulation results of performance of optimized fuzzy control rules, comparing with the primary rules, were obtained.

Key words: genetic algorithm, fuzzy control, superheat, evaporator

INTRODUCTION

Although fuzzy logic controllers have been applied in many complex industrial processes, they experience a deficiency in knowledge acquisition and rely to a great extent on empirical and heuristic knowledge which, in many cases, can't be objectively elicited. There is no generalized method for the formulation of fuzzy control strategies, and design relies on repeatedly modification of control rules to obtain satisfaction performance.

This paper presents a new approach to design of fuzzy controllers, used to control superheat of evaporator. The approach adopts genetic algorithms, a recent search and optimization technique, to optimize the parameters of membership functions of fuzzy control. Simulation results of GA based fuzzy controller are compared with those of not optimized.

FUZZY CONTROL OF SUPERHEAT OF EVAPORATOR

Evaporator superheat control is very important for safety and efficiency of refrigeration system. Most of refrigeration system control refrigerant flow rate by superheat feedback. Mathematical model of superheat of evaporator derived from fundamental mass, energy, momentum conservation is very complex, not suitable for control purpose. So, many studies applied fuzzy control to the superheat of evaporator system. A typical design methodology for fuzzy controllers usually follows the iterative steps shown in fig. 1. It is noted that the first step in the fuzzy design procedure is to obtain an understanding of the process dynamics. This is necessary because, as is the case with other types of controllers, it is not possible to design a controller without assuming certain characteristics about its environment. However, in the case of fuzzy controllers this requires a less rigorous model of the process that may be expressed merely as estimates of the gain sensitivity, the system delays and an estimate of the order of the system.

In this paper, in order to simplify the problems, only the parameters of membership function of fuzzy control, are optimized by Genetic algorithms method. That is to say, to achieve the iteration steps automatically.

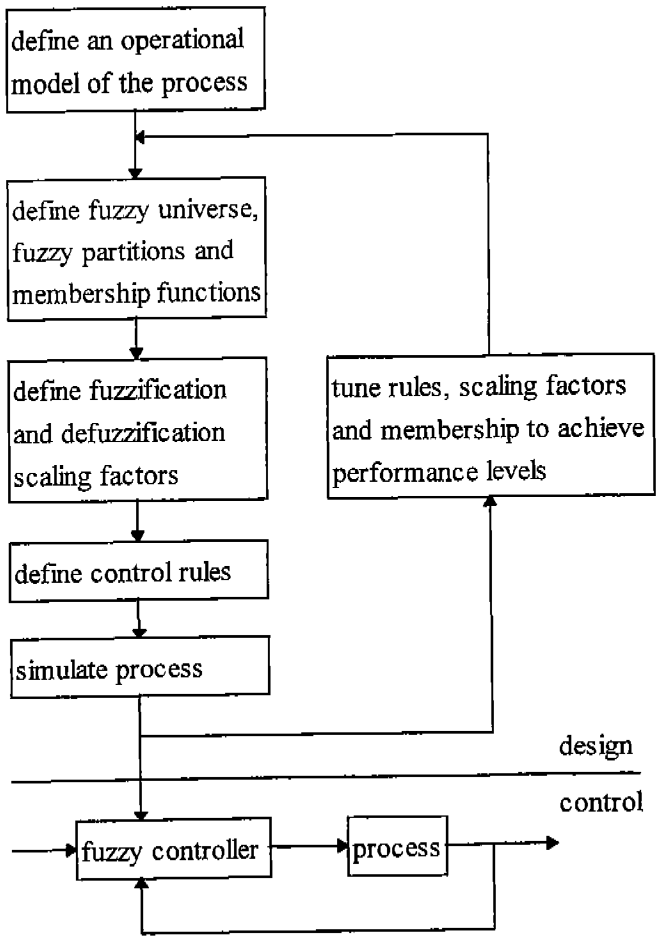

Fig. 1 Fuzzy design methodology

A block diagram of a fuzzy control system of evaporator superheat system is shown in figure 2, where e, d and u are superheat tracking error, superheat derivative error, and output control action (valve open) respectively; $\bar{e}$, $\bar{d}$, and $\bar{u}$ are their fuzzy counterparts; y is the controlled parameter (superheat); and r is the certainty for y, Kp is the scale factor for e; Kd is the scale factor for d, and Ko is the output gain.

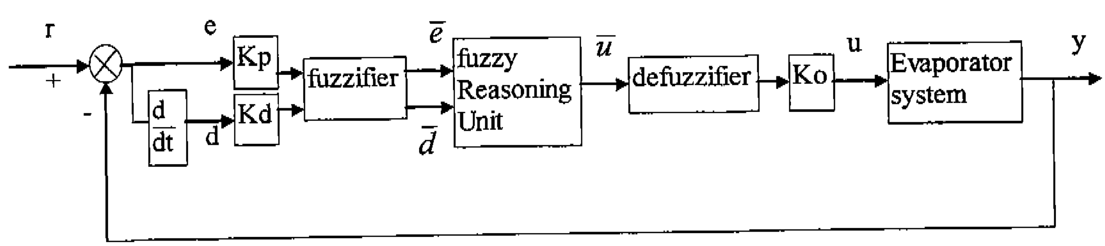

Fig. 2 The block diagram of a fuzzy control system

Five fuzzy subsets NL, NS, Z, PS, PL are defined for the input universe of discourse, superheat deviation, derivative of superheat deviation, and output universe of discourse, valve open change. Their membership functions are shown in figure 3.

The control rules are summarized in table 1.

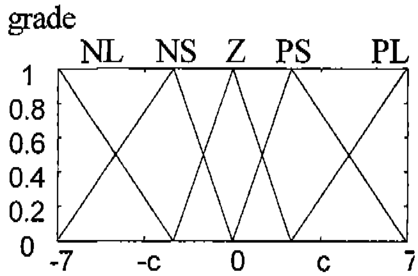

Fig. 3 Membership functions

Table 1 Control rules

U		E				
		NL	NS	ZZ	PS	PL
D	NL	NL	NL	NS	NS	ZZ
	NS	NL	NS	NS	ZZ	PS
	ZZ	NS	NS	ZZ	PS	PS
	PS	NS	ZZ	PS	PS	PL
	PL	ZZ	PS	PS	PL	PL

Max-min algorithm is used as fuzzy reasoning method, and weighted combination method is used as defuzzification strategy.

For simplicity, we adopt triangular completeness overlap membership function, shown in figure 3. So there is only one adjust parameter for five subsets in each discourse universe. The total optimization parameters are c1, c2, c3 three parameters. Our destination is to optimize the c1, c2, c3 to obtain better performance, by using Genetic algorithms.

Optimization procedure of c1, c2, c3 by using Genetic algorithm[3]:

1) Coding

Represent the each c1, c2, c3 with 3 bits binary codes respectively, and joins together into one composite string, called trial.

2) Initial population

Generate an initial random population of trails. Here, the number of trials is 10.

3) Evaluation

Define the index function for optimization, and evaluate the performance of each trial.
Sort trials according to their index function value. The Fitness value of each trial is:

$$f_i = e^{3(n-i)/n}, \quad i = 1,2,\ldots,n \tag{1}$$

where, f is the fitness value, n is the number of trails, i is the index number.

4) Reproduction

Trials are selected as parents from population using the probability distribution,

$$p_i = f_i \Big/ \sum_{i=1}^{n} f_i, \quad i = 1,2,\ldots,n \tag{2}$$

where, p is the probability of being selected, f is the fitness value, n is the number of trails, i is the index number.

Select two parents at random to reproduce new offspring by crossover method.

5) Crossover

A breakpoint is random chosen at which the parents bits are alternately passed on to the offspring.

6) Mutation

Transform the bits of each offspring trial random, replacing 1 with 0 and vice versa. The probability of mutation is 0.001 to 0.1.

7) Selection

New population is selected from the parents and their offsprings.

8) Terminate condition of iteration

Goto procedure 3 until the convergence criterion is reached.

9) The best triaisre selected from the final population. Transform the coding into optimal parameters.

RESULTS AND DISCUSSIONS

As mentioned above, a roughly model of process is necessary to design a fuzzy control. Superheat control model adopted in this paper quote reference [2]. This model is obtained from the step response experiment of expansion valve, the inlet temperature and outlet temperature response of evaporator are all modelled as first-order plus time delay:

$$T_{ei} = \frac{0.02e^{-25s}}{1+25s} \quad (3)$$

$$T_{eo} = \frac{-0.225e^{-20s}}{1+40s} \quad (4)$$

where, Tei and Teo is the transfer function of evaporator inlet temperature and evaporator outlet temperature. s is the laplace operator.

The index function is the usual performance criteria, ISE: $I = \int_0^t e^2 dt$

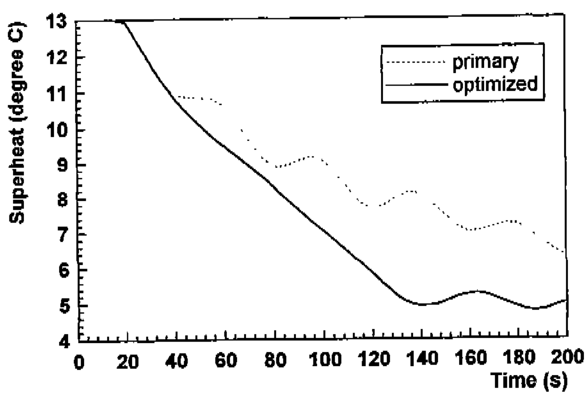

Fig. 4 Superheat response

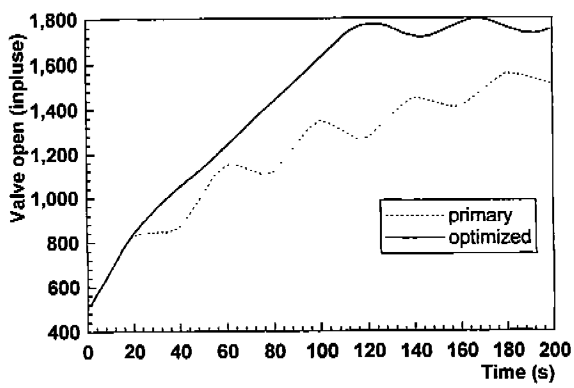

Fig. 5 Valve position change

The parameters c1, c2, c3 of primary membership function is all 3.5. The parameters c1, c2, c3 of optimized membership function is 1, 6, 5 respectively. Performance of primary and optimized fuzzy controller is shown in figure 4 and 5. Figure 4 shows the superheat response and figure 5 shows the valve position change. It is obviously that the optimized fuzzy controller performance better than the primary controller.

There is only one adjust parameter for five fuzzy subsets in each universe of discourse. It limited the fuzzy controller performance. If more parameters can be adjusted, the performance of fuzzy controller could become better.

CONCLUSION

The principles and implement procedure of Genetic algorithm are introduced in this paper, and are applied to optimize the parameters of fuzzy controller used to control the superheat of evaporator in refrigeration system. Simulation results shows it can improve the performance of fuzzy controller by optimizing the parameters.

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