DNA 코딩 최적화에 의한 독립 배열구조의 퍼지규칙 설계

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Design of Fuzzy Independence Array Structure using DNA Coding Optimization

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Abstract - In this paper, a new fuzzy modeling algorithm is proposed : it can express a given unknown system with a small number of fuzzy rules and be easily implemented. This method uses an independent array instead of a lattice form for a premise membership function. For the purpose of getting the initial value of fuzzy rules, the method uses the fuzzy c-means clustering method. To optimally tune the initial fuzzy rule, the DNA coding method is also utilized at same time. Box and Jenkins's gas furnace data is used to illustrate the validity of the proposed algorithm.

1. Introduction

In recent fuzzy applications and theories, it is getting more important to consider how to design optimal fuzzy rules from short training data, in order to construct a reasonable and suitable fuzzy system model for identifying the corresponding practical system. To design the fuzzy rule which has the same operating result as real operator's controlling result, many engineers have researched new methods that control the fuzzy rules.

The conventional method decided a premise membership function at each input space and mapped fuzzy rules by their combinations. Therefore, fuzzy rules were regularly arranged as a lattice form. This array of fuzzy rule is very simply and very efficient at a same time. Then it can be used frequently. But the method has fault, according as increased input numbers, that must generate many new rules additionally.

In this paper, a new fuzzy modeling algorithm is proposed. It can express a given unknown system with a small number of fuzzy rules and be easily implemented. This method uses an independent array instead of a lattice form for a premise membership function. For the purpose of getting the initial value of fuzzy rules, the method uses the fuzzy c-means clustering method. Especially, it has another merits that the value of center point for fuzzy rule is easily found by a designer. because the value of center point by the clustering method is a center point value of independent fuzzy rule. To optimally tune the initial fuzzy rule, the DNA coding method is also utilized at same time. This method also uses fuzzy singleton-type reasoning in consequent membership function. The inferred value will be obtained easily and rapidly. Box and Jenkins's gas furnace data is used to illustrate the validity of the proposed algorithm.

2. The Array Generation of Independence Fuzzy Rules

To improve the problem of the array generation of conventional fuzzy rules, the array generation of independence fuzzy rules are needed for each rule. It was shown in Figure 1. Here, the shadow part is input space and the membership function is expressed by an elliptical form with the center point at "•". The fuzzy rule can be expressed as follows:

$$
\begin{array}{lll}
RULE\ 0: & IF\ (x_1, x_2)\ is\ A_0 & THEN\ \ y\ is\ y_0 \\
RULE\ 1: & IF\ (x_1, x_2)\ is\ A_1 & THEN\ \ y\ is\ y_1 \\
RULE\ i: & IF\ (x_1, x_2)\ is\ A_i & THEN\ \ y\ is\ y_i \qquad (1) \\
\cdots & & \\
RULE\ m: & IF\ (x_1, x_2)\ is\ A_m & THEN\ \ y\ is\ y_m
\end{array}
$$

where, (x_1, x_2) is input value, i is the i-th rule, and m is the number of rule.

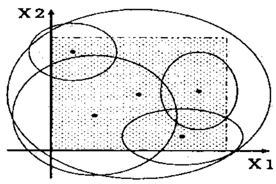

Figure 1. Array method of independent rule and reasoning

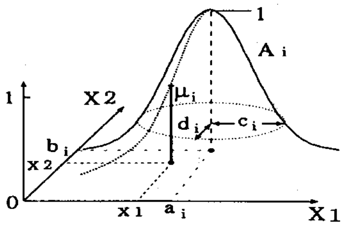

Figure 2. Independent gaussian membership function

The premise A_i of $RULE\ i$ is two dimension fuzzy set. It is defined by Gaussian membership function like in Figure 2. Gaussian membership function form A_i is expressed by four parameters of fixed point (a_i, b_i) and width (c_i, d_i). The grade u_i of Gaussian membership function form A_i at any point (x_1, x_2) is obtained as

$$u_i = \exp\left(-\frac{d_i(x_1-a_i)^2 + c_i(x_2-b_i)^2}{c_i d_i}\right) \quad (2)$$

The consequence can obtain fuzzy singleton-type reasoning method.

Using the grade $u_0, \cdots, u_m$ of each rule and the real value of consequence $y_0, \cdots, y_m$, at any point (x_1, x_2), inferred value y^* is defined as

$$y^* = \frac{\sum_{i=0}^{m} u_i y_i}{\sum_{i=0}^{m} u_i} \quad (3)$$

Here, introduce briefly the fuzzy c-means clustering algorithm(FCM), which is widely used in the treatment of classifications[3]. FCM algorithm is performed by the general procedures. Then the center points of fuzzy rules can be obtained through the FCM method.

3. The Fuzzy Singleton-type reasoning and The DNA Coding Optimization

First, consider fuzzy singleton-type reasoning method[1], in which the fuzzy model has m input linguistic variables and l output variables. In the fuzzy singleton-type reasoning method by Mizumoto [1],[2], which can adjust the weights of the consequent parts of fuzzy rules, the fuzzy inference conclusion can be well improved because of the flexibility of the method. Also, it shows better fuzzy control results than the case of simplified fuzzy reasoning. Like other fuzzy reasoning methods, it is necessary and important to learn the fuzzy rules of fuzzy singleton-type reasoning method for a practical problem, when the construction of a fuzzy system model is difficult by human being. Usually, a fuzzy model with m input linguistic variables x_m and l output variables y_l can be expressed by fuzzy singleton-type reasoning method, as follows[1]:

$$\begin{array}{l} RULE\ 1: A_{11k} \text{ and } A_{21k} \cdots \text{ and } A_{m1k} \Rightarrow w_{1k}/y_{1k} \\ RULE\ 2: A_{12k} \text{ and } A_{22k} \cdots \text{ and } A_{m2k} \Rightarrow w_{2k}/y_{2k} \\ \cdots\cdots \\ RULE\ i: A_{1ik} \text{ and } A_{2ik} \cdots \text{ and } A_{mik} \Rightarrow w_{ik}/y_{ik} \\ \cdots\cdots \\ RULE\ n: A_{1nk} \text{ and } A_{2nk} \cdots \text{ and } A_{mnk} \Rightarrow w_{nk}/y_{nk} \end{array} \quad (4)$$

When an observation $(x_1, x_2, \cdots, x_m)$ is given, a fuzzy inference value y can be obtained by using fuzzy singleton-type reasoning method in the following way:

$$h_{ik} = A_{1ik}(x_1)\ A_{2ik}(x_2) \cdots A_{mik}(x_m) \quad (5)$$

$$y_k = \left(\sum_{i=1}^{n} h_{ik} w_{ik} y_{ik}\right) / \left(\sum_{i=1}^{n} h_{ik} w_{ik}\right) \quad (6)$$

where h_{ik} ($i=1,2,\cdots,n$; $k=1,2,\cdots,l$) is the agreement of the antecedent of i-th fuzzy rule. As a simple explanation of fuzzy singleton-type reasoning method,

Next, consider a DNA coding method based on biological DNA, pseudo-bacterial genetic algorithm (PBGA) and a mechanism of development from the artificial DNA[3]. A chromosome consists of combinations of four bases, A, G, C, T. The chromosome has many redundant parts. The codons also correspond to amino acids. Unlike the biological amino acid, each artificial amino acid has several meanings, and the meanings of a gene is determined by the combination of the amino acids. An amino acid can be translated as an input variable of a form of membership function, and so on. A sequence of amino acids makes a fuzzy rule. The DNA chromosome makes up sets of fuzzy rules for modeling a gas furnace process.

4. The Fuzzy Modeling by Independence Array

Once an identification methodology has been established, it can be proceeded with intensive experimental studies. In this section, we execute the experiments, using well-known data set of gas furnace
data process, prove the performance of the proposed method.

4.1 Gas furnace data

In this section, the fuzzy modeling for non-linear gas furnace process is executed to estimate the performance of the proposed method. The independence fuzzy rule arrangement is applied to the time series data of gas furnace utilized by Box and Jenkins. They used 296 pairs of input-output data relationships. Input variable $u(t)$ is the flow rate of methane and output $y(t)$ the density of CO_2. As shown in Figure 3, a half of the whole data are training data and the rest are testing data. In this paper, especially, MISO gas furnace process is transformed into two-input-one-output form, namely, two input $u(t-3)$ Figure 4-(a), $y(t-1)$ Figure 4-(b) and one output $y(t)$ Figure 4-(c). The Performance Index (PI) used in the numerical experiment will be as Euclidean distance, that is,

$$PI = \frac{1}{N}\sum_{i=1}^{N}(y_i - \hat{y}_i)^2 \quad (7)$$

where, y_i is the real output, $\hat{y}_i$ is the output of fuzzy model, and N is the total number of data.

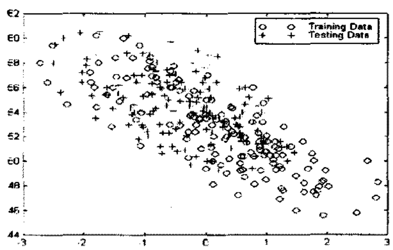

Figure 3. Gas furnace data

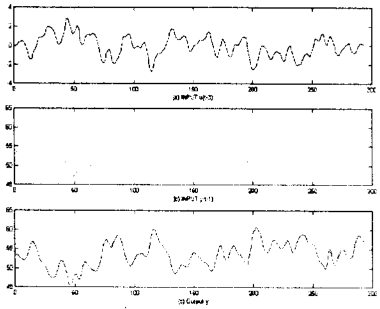

figure 4. Gas furnace input & output

4.2 Initial value setting of the premise membership function

Through FCM, the center points of training data is found out and then their values is like Table 1. When the points is displayed to the distribution of training data in Figure 5, these exist in the large circle and become the centers of independence fuzzy rules.

Table1. Values of center point

-1.3558	58.3164
-0.8305	55.9694
0.0976	53.1157
0.8541	50.5093
1.5749	47.7480

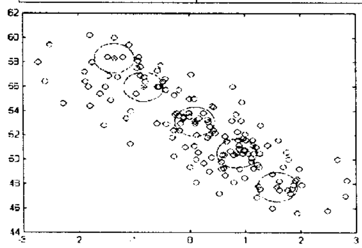

Figure 5. Clustering point

4.3 Results of modeling and testing

Figure 6. shows the real output and training output Table 2. is real value of identified parameters of fuzzy rules.

Table 2. Parameter of identified parameters

Center point of membership		Width of membership		Real value of conclusion
2.8264	49.1031	3.4868	15.7449	46.0959
-1.3437	60.2921	3.7239	13.2539	60.8677
0.1493	55.1229	2.5493	10.8736	53.1951
1.5232	51.8306	2.5625	11.3622	51.7608
-0.5008	57.5361	2.9068	11.9086	56.7321

In Figure 6, Performance Index is 0.0354. It shows no difference between conventional fuzzy rule method and proposed method. However, as 25 parameters is identified at the same time, this method have the problem that spends more time to identification.

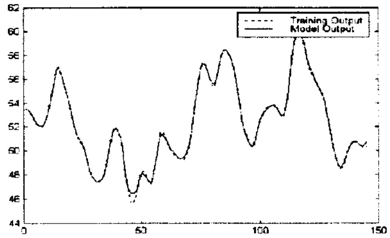

Figure 6. Training Output

In Figure 7, Performance Index is 0.2957 at testing data. This value shows more performance than other method. However, we does not think it is best value.

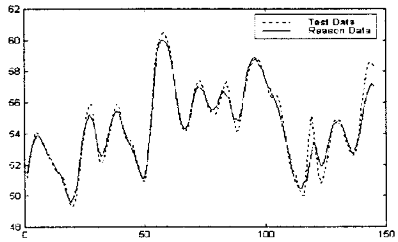

Figure 7. Output of testing data.

3. 결 론

In this paper, a new fuzzy modeling algorithm was proposed. The inferred value was obtained easily and rapidly.

To prove the high performance, Box and Jenkins's gas furnace data was used to illustrate the validity of the proposed algorithm, and its computer simulation is carried out.

The simulation results are as follows:

1. This method make easily the generation of fuzzy rules.
2. This method could express a given unknown system with a small number of fuzzy rules and be easily implemented.
3. Especially, this method had another merits that the value of center point for fuzzy rule was easily found by a designer. because the value of center point by the clustering method was a center point value of independence fuzzy rule.

[참 고 문 헌]

[1] M. Mizumoto, "Improvement of fuzzy controls (VI), Case by fuzzy singleton-type reasoning method", Prod. of the 8th Fuzzy System Symposium, Hiroshima, pp. 529-523, 1992(in Japanese).

[2] M, Mizumoto, and M. Iwakira, "Self-generation of fuzzy rules by fuzzy singleton-type reasoning method", Proc. of the 9th Fuzzy System Symposium, Sapporo, pp. 585-588, 1993(in Japanese).

[3] J.K. Park, S.M. Ryu, S.K. Oh and T.C Ahn, "A New fuzzy modeling by independence array", To be appeared.