

The research of the interval density cluster method for piecewise linear membership function determination

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Abstract

Triangle and monotone membership functions have simple forms and clear physical meaning, which are commonly used in the research work. In this paper, a density clustering method based on the interval is brought forward, which has avoided the cluster results falling into a local minimum, also by using this method, the cluster center can be quickly obtained. Through simulation, the piecewise linear membership function of variation of total volume in petroleum drilling is determined, which solves the problem that the function is hard to be defined.

Keywords: piecewise linear membership function, interval, density cluster, cluster center, petroleum dril ling, variation of total volume

1 Introduction

The research of phenomenon and things with uncertainty is significant [1]. Doctor Zadeh put forward the membership degree [2] to express the uncertainty. There are two main forms of membership function [3]: piecewise linear function and nonlinear function. But how to determine the membership function [4] has not been fundamentally resolved, in practice, it is unreliable to determine the membership value subjectively, if using the statistical method, it will not only cost too much, but also can not be achieved sometimes.

Fuzzy clustering analysis is the foundation of classification and system modeling problems. The purpose of fuzzy cluster is to extract the inherent characteristics from a large data set, and obtain the compact representation of the system behavior. Doctor Bezdek put forward a Fuzzy C-mean Clustering method, which is a mature method at present [5]. But there are some shortcomings in this algorithm, for example, it is particularly sensitive to cluster center, and is easy to fall into a local minimum [6]. If the cluster center is chosen randomly, the objective function is obtained by multiple exercises, but which still costs much time and can not completely avoid the local optimization. In this paper, an interval density clustering method based on interval density is put forward, by using this method, the cluster center of the data is quickly obtained, and the piecewise linear membership function is determined too, in a word, this is a relatively simple and fast algorithm [7].

2 Piecewise linear membership function

There are some piecewise linear membership functions, such as triangle, monotone, ladder, in which, triangle and

monotone membership functions have simple forms and clear physical meaning, and they are commonly used in the research work. In this paper, the determination of triangle and monotone membership function is mainly studied [8-23].

The expression of the triangle membership function is shown as Equation (1), which is suitable for the middle linguistic value modified by middle and more, here, the function is determined by parameters a, b, c , shown as Figure 1.

$$f(x, a, b, c) = \max \left\{ \left[\min \left(\frac{x-a}{b-a}, \frac{c-x}{c-b} \right) \right], 0 \right\}. \quad (1)$$

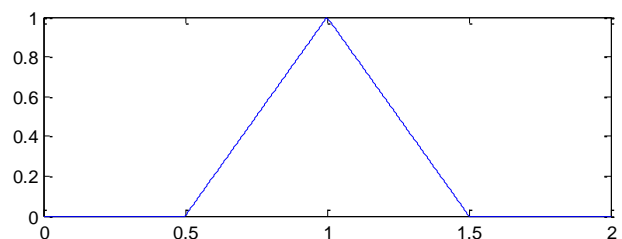


FIGURE 1 Triangle membership function

The expression of the monotone membership function is shown as Equation (2), which is suitable for the bipolar linguistic value modified by very and very not, here, the function is determined by parameters d, e shown as Figure 2.

$$f(x, a, b) = \begin{cases} \max \left\{ \left[\min \left(\frac{x-d}{e-d}, 1 \right) \right], 0 \right\}, & \text{Single increasing} \\ \max \left\{ \left[\min \left(1, \frac{e-x}{e-d} \right) \right], 0 \right\}, & \text{Single reducing} \end{cases}. \quad (2)$$

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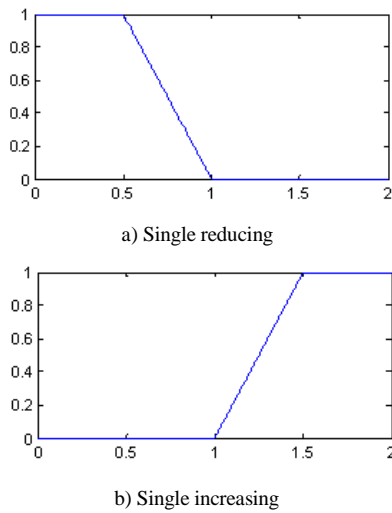


FIGURE 2 Monotone membership function

3 Density clustering method based on the interval

In this paper, a density clustering method based on the interval is brought forward, first, according to the interval density, the data is classified, and then the clustering center is obtained by the density, which effectively avoids the cluster results falling into a local minimum.

For the data $X = \{x_1, x_2, \dots, x_n\} \subset R$, the density clustering method is expressed as follows:

Step 1: Set threshold τ of the interval density, and number of cluster center q ;

Step 2: Set width d of the interval, and divide the data set X into interval S_i with width d ;

Step 3: Scan the data, and get the density of the interval, that is the number of the data in each interval;

Step 4: Select the interval S_k with the largest density, and search S_{k-1} from the left, if the density threshold is larger than τ , search S_{k-1} until the density threshold is smaller than τ ; search S_{k+1} from the left, if the density threshold is larger than τ , search S_{k+2} until the density threshold is smaller than τ ; at last the continuous intervals l with density threshold larger than τ is obtained.

Step 5: Calculate the density index of each data x_i :

$$D_i = \sum_{j=1}^n \exp \left[\frac{-\|x_i - x_j\|^2}{(0.5r_a)^2} \right]. \quad (3)$$

Select the data x_{c_i} with the largest density as a cluster center, and delete the continuous density interval l .

The field radius r_a in Equation (3) is:

$$r_a = \frac{l}{2} \times d. \quad (4)$$

Step 6: Execute step 4 and 5 continuously until the cluster center q is obtained, and define the cluster center as $w_m, m = 1, 2, \dots, q$.

In the above method, r_a represents radius of the continuous interval l , and is always decided by Equation (4). In practical analysis, the cluster center q has no effect on the cluster results, as a result, radius r_a is determined by Equation (4), and the computational

complexity is smaller, the center appears earlier.

4 Simulation

There are lots of accidents in the petroleum drilling, such as well kick, lost circulation, drilling puncture, drilling string broken off, drilling pipe sticking, drilling wearing, drilling sloughing, hydrophthalmus sloughing, abnormal ground pressure, hydrophthalmus blockage, churn drill, slip drill and so on. Also there are many discriminant parameters in the accident forecasting process, for example, for the well kick accident, diagnosing parameters are flow out rate, total volume, casing pressure, export density and export conductivity, but in all of these parameters, total volume and export flow are the most important.

In this paper, the sample data is used to determine the membership function, which avoids the problem that real-time data is not representative, not stable and has slow clustering speed.

By using the density cluster method based on the interval to get the cluster center, the piecewise linear membership function can be obtained. In this paper, the total volume data EB_Da51 from the petroleum drilling [7] in Hubei province are selected, and the piecewise membership function of variation of the volume are determined by Matlab. Some data of EB_Da51 are shown in Figure 3, in which the ordinate represents variation of the total volume, and the unit is m^3 .

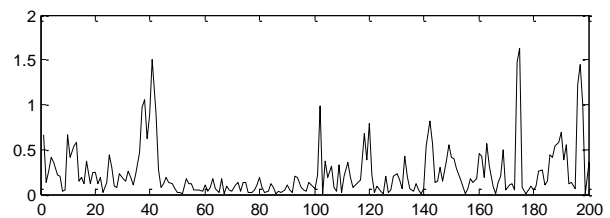


FIGURE 3 Change of volume data EB_Da51 from the petroleum drilling

On the basis of the initial cluster center q obtained by the density clustering method, the cluster center w_m and some other parameters, the concrete process of piecewise linear membership function is described as follows:

Step 1: Unify universe of the data, and determine the number of the linguistic value. In this paper, membership function of the change of the total volume in petroleum drilling is seek, and data EB_Da51 is mapped to a unified universe space, there are four linguistic values: none, small, middle and large, that is to say, $c, 1 \leq k \leq q$.

Step 2: Determine the type of the membership function, that is to say, Small and Middle mean the middle linguistic value, which are expressed by triangle membership function, None and Large mean the bipolar linguistic value, which are expressed by monotone membership function.

Step 3: Calculate the clustering center w_m by the piecewise density cluster, and the obtained centers are $w_m = 0.0786, w_m = 0.3044, w_m = 0.6607, w_m = 1.4180$.

Step 4: According to the vicinity principle, the parameters of the triangle and monotone membership function are shown in Table 1.

TABLE 1 Parameters of piecewise linear membership function

	Linguistic value	Type of the function	Parameter
1	None	monotone	$d = 0.0786$ $e = 0.3044$
2	Small	triangle	$a = 0.0786$ $b = 0.3044$ $c = 0.6607$
3	Middle	triangle	$a = 0.3044$ $b = 0.6607$ $c = 1.4180$
4	Large	monotone	$d = 0.6607$ $e = 1.4180$

Step 5: According to the parameters in Table 1, the membership function is shown in Figure 4.

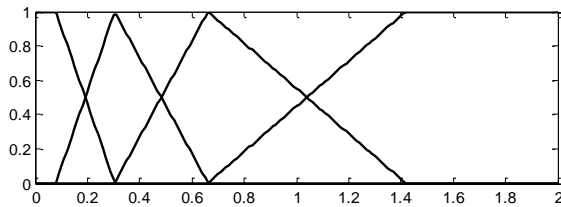


FIGURE 4 Piecewise linear membership function of the total volume

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5 Conclusion

According to the case study, the density cluster method brought forward in this paper has no iteration, in this method, the initial cluster center is obtained by the density of interval, which can effectively solve the problem that fuzzy c-means method heavily depends on the initial cluster center randomly generated, and obtain the center rapidly. By using the density cluster method proposed in this paper, the triangle and monotone membership functions of the change of total volume in petroleum drilling are obtained, which is a simple and fast method to get the piecewise linear membership function.

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