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Application of Fuzzy Inference Prediction Method in Petroleum Drilling Accident System

[1]Liu Qi and [2]Li Sheng
[1]School of Physics and Electronic Engineering,
Zhoukou Normal University, Zhoukou, Henan, China
[2]Department of Public Security, Railway Police College, Zhoukou, Henan, China

Abstract: The research on fuzzy inference prediction method is of great significance. In this study, Fuzzy Determined Parameters Means Clustering Method (FDPM) is proposed which determines the weighting exponent and the initial clustering center, solving the problems about excessive dependence of classification results on the weighting exponent m and the initial center of Fuzzy C-means Clustering Method (FCM).By utilizing the Fuzzy Determined Parameters Means Clustering Method (FDPM) algorithm presented in this study, it is conveniently realized to determine the membership function of the two important variables in the system of oil drilling accident forecast: the changing of total volume and the flow out rate of drilling slurry which has solved the problem that the membership function is hard to be defined. To forecast the well kick accident, the rules of fuzzy inference system are extracted. In the example of simulation, the forecast result is a fixed value. This is objectively consilient to uncertainty of accidents in the petroleum drilling.

Key words: Fuzzy determined parameters means clustering method, membership function, fuzzy inference system, petroleum drilling, uncertainty, accident prediction

INTRODUCTION

Phenomenon and things with uncertainty generally exist in the nature and society. How to express and deal with the uncertainty is a hot-spot and key point in the research on nature science which is also a blockage at the same time (Li, 2000). In all kinds of uncertainty, fuzziness and randomness are most important which are paid more attention to. In 1965, Doctor Zadeh published a seminal study on fuzzy set (Zadeh, 1965) and put forward a method using membership to signify the uncertainty but its definite method are not well solved, because using the statistic method, it will cost a lot and sometimes can not be achieved.

Petroleum drilling is a risky and costly system engineering. During the process of drilling, there is much uncertainty, such as fuzziness and randomness. In the process, all kinds of engineering accidents may happen and dealing with the troublesome condition and drilling accidents will cost lots of manpower and fund. There have been lots of research on petroleum drilling accidents domestic and aboard and have got rich achievements, in which the logical inference method (Aminzadeh, 2005; Li *et al*., 2009; Wang *et al*., 2007) is widely applied but can't reflect the uncertainty of the petroleum drilling.

The method of Fuzzy Determined Parameters Means Clustering Method (FDPM) is provided through our research and we get results of weighting exponent and the initial clustering center, solving the problems about excessive dependence of classification results on the weighting exponent m and the initial center Fuzzy C-means Clustering Method (FCM). Basing on this method. In this study, the membership function of two important variables in the system of oil drilling accident forecast are founded, variables are the changing of total volume and the flow out rate of drilling slurry (Aminzadeh, 2005; Rahmat and Jovanovic, 2006), the rules of fuzzy inference system are extracted. So that, inference result objectively conveys the uncertainty of accidents in the petroleum drilling.

MEMBERSHIP FUNCTION

There are several membership functions, such as Triangle, Monotone, Ladder, Gaussian, Sigmoid, S and Parabola. Membership functions of Gaussian and Sigmoid have is of well smoothness, that is to say, the figure of them have clear physical meaning and no zeros which are commonly used in the research work. And the determination of Gaussian and Sigmoid is mainly studied.

Corresponding Author: Liu Qi, School of Physics and Electronic Engineering, Zhoukou Normal University, Zhoukou, Henan, China

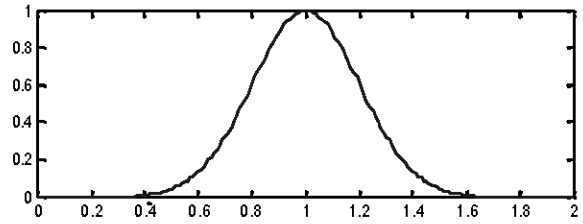

Fig. 1: Gaussian membership function

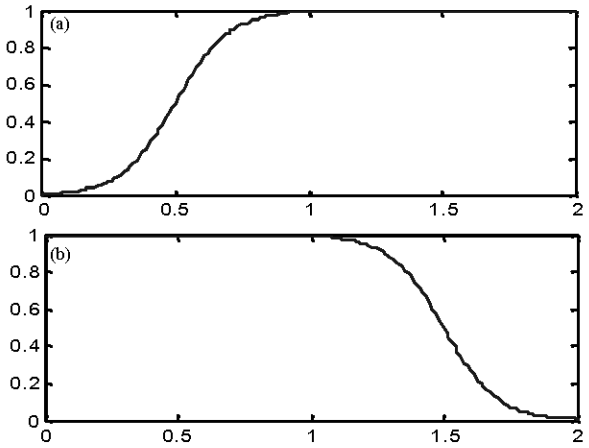

Fig. 2(a-b): Sigmoid membership function, (a) b>0 and (b) b<0

The expression of Gaussian membership function (Liu *et al*., 2013) is shown as Eq. 1 which is suitable for a membership function with intermediate language value and the main parameters are function center a and width of curve σ, such as Fig. 1:

$$y = \exp\left[-\frac{(x-a)^2}{2\sigma^2}\right] \quad (1)$$

The expression of Sigmoid membership function (Liu *et al*., 2013) is shown as Eq. 2 which is suitable for a membership function with bipolar language value. The equation is determined by b and c, if b is positive, the curve of it opens to right but if b is negative, the curve opens to left, such as Fig. 2:

$$y = \frac{1}{1+\exp[-b(x-c)]} \quad (2)$$

FUZZY DETERMINED PARAMETERS MEANS CLUSTERING METHOD (FDPM)

Fuzzy c-means clustering method: Bezdek provided the fuzzy-c-means clustering algorithm, in which the cluster degree is expressed by the membership function. In this method, vector group is divided into C parts and through calculating the clustering center, the smallest value function is achieved. The FCM method employs membership to characterize the degree which can get sufficient high calculation accuracy (Liu *et al*., 2012). Value function or objective function of FCM is:

$$J(U, c_1, ..., c_c) = \sum_{i=1}^{c} J_i = \sum_{i=1}^{c}\sum_{j}^{n} u_{ij}^m d_{ij}^2 \quad (3)$$

In which $u_{ij} \in (0, 1)$, c_i is the clustering center of ambiguity group i, $d_{ij} = \|c_i - x_j\|$ is euclidean distance from clustering center i to data j and $m \in [2,\infty)$ is a weighted exponent.

To reach the minimum of Eq. 3, the necessary condition is shown as below:

$$c_i = \frac{\sum_{j=1}^{n} u_{ij}^m x_j}{\sum_{j=1}^{n} u_{ij}^m} \quad (4)$$

And:

$$u_{ij} = \frac{1}{\sum_{k=1}^{c}\left(\frac{d_{ij}}{d_{kj}}\right)^{\frac{2}{m-1}}} \quad (5)$$

According to the necessary condition, the following steps are needed to obtain the clustering center c_i and membership matrix U in the FCM method.

Step 1: Initialize membership matrix U with random number from 0~1

Step 2: Use Eq. 4 to calculate the clustering center, c_i, i = 1, ... 1C

Step 3: Calculate value function according to Eq. 3. Compared it with the last value function, if the change is smaller than one threshold, the algorithm will stop and if not, return to Step 2

Step 4: Calculate new matrix U according to Eq. 5

According to the four steps, the classification results of depends on the optimized weighting exponent m and the initial center of Fuzzy C-means Clustering Method excessively.

Determining the weighting exponent m: The weighting exponent m is the key parameter of FCM and its value is able to the clustering fuzziness, the sharing degree among classes, the Objective Function and the convergence

method. Although the value range of m is [1, ∞), the fuzziness will disappear if m is too small, degenerating into hard c-means cluster, or the situation that data can not be classified if m is too big.

By Eq. 3, the there exist critical points of value function to m exists:

$$m = \left\{ m \left| \frac{\partial}{\partial m} \left(\frac{\partial J(U, c_1, ..., c_c)}{\partial m} \right) = 0 \right. \right\} \quad (7)$$

Concerning on the difficulties of determining membership function, the simplified way is shown in Eq. 8:

$$m = \arg \left\{ \min \left\| \left(\frac{\partial J(U, c_1, ..., c_c)}{\partial m} \right) \right\| \right\} \quad (8)$$

Determining the initial clustering center: Caculating every density index point's x_i:

$$D_i = \sum_{j=1}^{n} \exp \left[\frac{-\left\| x_i - x_j \right\|^2}{(0.5 r_a)^2} \right] \quad (9)$$

the field radius r_a:

$$r_a = \frac{R}{2} \times d \quad (10)$$

Selecting the highest density points x_{c_1} as the clustering center and deleting the continuous high density field which number is m; calculating continuously employing Eq. 9 until getting the amount of i clustering centers, defining c_i as the clustering center.

Fuzzy determined parameters means clustering method (FDPM):

Step 1: Initialize membership matrix U with random number from 0~1
Step 2: Determining m by Eq. 8
Step 3: Determining c_i by Eq. 9
Step 4: Calculate value function according to equation (3). Compared with the last value function, if the change is smaller than one threshold, the algorithm will stop and if not, return to Step2
Step 5: Calculate new matrix U according to Eq. 5

By Fuzzy Determined Parameters Means Clustering Method (FDPM), clustering center c_i and membership matrix Ucan be obtained and with these parameters, the membership function is determined.

MEMBERSHIP FUNCTION OF INPUT VARIABLE

In the Fuzzy Determined Parameters Means Clustering Method (FDPM) algorithm, firstly the number of clustering center should be appointed and in the accident forecasting process, there are four fuzzy linguistic variables: none, small, middle and large.

In this study, 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. In this article, field data from north Hubei is taken as the sample data and the research is based on the 2000 data taken from EB_Da51 of total volume and EB_Da36 of export flow, shown as Fig. 3.

Determination algorithms of the membership function are as follows:

Step 1: Change the sample data. Calculate the change percent of the total volume and flow out rate and respectively map to the unified universe space;
Step 2: Use Fuzzy Determined Parameters Means Clustering Method (FDPM) algorithm. Calculate the clustering center c_i and membership function U, C = 4
Step 3: Confirm the center a_i of each linguistic value, in which i = 1, 2, 3, 4. Arrange the clustering center by size, that is $c_1<c_2<c_3<c_4$, c_i is the center a_i which is a number of each linguistic value. The data corresponding to the row elements of U is the membership r_k and it is the membership of sample data on the linguistic value, in which k = 1, …, 2000
Step 4: Calculate the membership of each linguistic value, in which i = 1, 2, 3, 4. Use the expectation curve to approach the curve composed by the membership r_k of the sample data, in other words

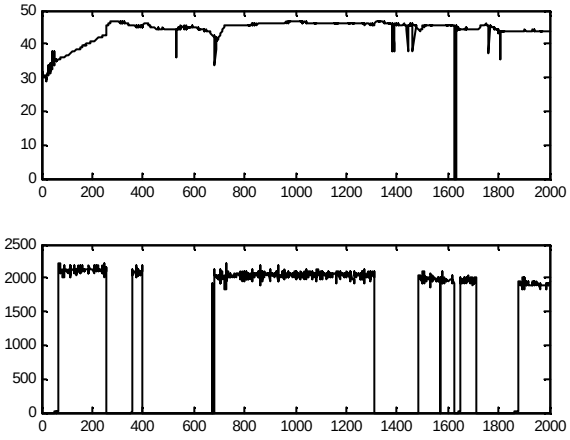

Fig. 3(a-b): Total volume and of petroleum drilling

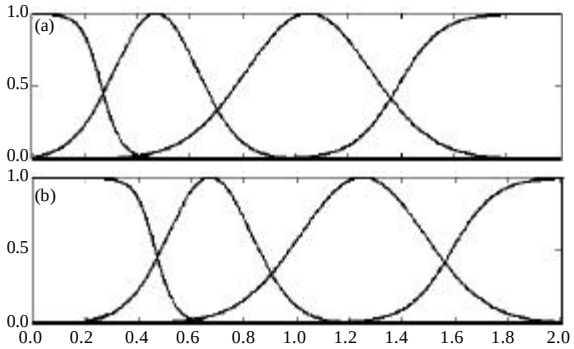

Fig. 4(a-b): Variable quantity of the total volume and the flow out rate

By using the above algorithm, the membership function of the total volume and flow out rate shown as Fig. 4.

FUZZY INFERENCE PREDICTION FOR PETROLEUM DRILLING ACCIDENT

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. To forecast the well kick accident, the most related parameters are used as inputs for the fuzzy inference system.

Fuzzy inference rules: The fuzzy inference rules used in this study are created by the experienced technicians, the definition is as Table 1.

There are 16 fuzzy rules in the above table and for each rule, fuzzy synthetic operation is made. Assume A and B are fuzzy sets of input variable and C is output, then fuzzy relation R of rule "if A and B then C" is:

$$R = (A \times B) \times C \tag{11}$$

Forecast result of the well kick accident: In the fuzzy inference system for forecasting the well kick accident, membership functions of the input variable: total volume and flow out rate are showed in Fig. 4, fuzzy inference rules are in Table 1.

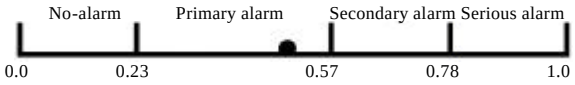

Fig. 5: Result of the fuzzy inference system

Table 1: Fuzzy inference rules

	None	Small	Middle	Large
None	None	Small	Small	Middle
Small	Small	Small	Middle	Middle
Middle	Small	Middle	Middle	Large
Large	Middle	Middle	Large	Large

According to Eq. 11, it is known that the inference result is a fixed value:

$$R(x) = \frac{\int_{x_1}^{x_2} x \bullet \exp\left[-\frac{(x-a)^2}{2\sigma^2}\right] dx}{\int_{x_1}^{x_2} x dx} \tag{12}$$

In the logging process of north Hubei, at a certain time, the increase of the total volume is 0.9 m^2 and the increase percent of flow out rate is 0.95%, according to Eq. 12 it is known that the inference result is a one-dimensional random number with expectation R (x) = 0.49.

The projection of the inference result for the well kick accident is first-order alarm which showed in Fig. 5.

CONCLUSION

In this study, using the Fuzzy Determined Parameters Means Clustering Method (FDPM) and the sample data taken from northern Hubei, the membership function of the two important variables is determined: the total volume and flow out rate, finally the fuzzy inference system is established and with this method which has solved the problem that the membership function is hard to be defined. In the system, forecasting result of the well kick is a fixed value which reflects the uncertainty of accidents in the drilling process and the result is beneficial to worksite decision.

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REFERENCES

Aminzadeh, F., 2005. Applications of AI and soft computing for challenging problems in the oil industry. J. Petroleum Sci. Eng., 47: 5-14.

Li, D.Y., 2000. Uncertainty in knowledge representation. Eng. Sci., 2: 73-79.

Li, Q., C. Du, Y. Xu, J. Tang and H. Liang, 2009. Drilling risk management system based on knowledge integration. Acta Petrolei Sin., 5: 755-759.

Liu, Q., H. Zhang, Y. Shao, K. Liu, J. Wang, Z. Chen and Z. Huang, 2012. A Method of neural network internal model control in unstable time-lag process. Int. J. Comput. Sci. Issues, 10: 183-188.

Liu, Q., K. Liu, X. Liu, J. Wang, Z. Chen and Z. Huang, 2013. Determination method of nonlinear membership function based on the fuzzy density means cluster. Res. J. Applied Sci. Eng. Technol., 5: 2504-2508.

Rahmat, M.K. and S. Jovanovic, 2006. Reliability and availability modelling of uninterruptible power supply systems using monte-carlo simulation. Int. Rev. Electrical Eng., 1: 6542-551.

Wang, J., D.H. Chen and X.D. Zhu, 2007. Oil drilling accident pre-warning system based on hierarchical fuzzy system. China Patent: 200710055178.6.

Zadeh, L.A., 1965. Fuzzy Sets. Inf. Control, 8: 333-353.