Journal of Geography and Geology
www.ccsenet.org/journal.html
Vol. 1, No. 1
May 2009

Fuzzy C-means Clustering for 3D Seismic Parameters Processing

Fuqun Zhao & Liang Le
School of Education and Science, Xian'yang Teachers University
Xian'yang 712000, China
E-mail: fuqunzhao@126.com

Fund Project: Special scientific research funded projects in 2006 of Xian'yang Teachers University (Project Number:07XSYK224)

Abstract

3D seismic parameters can reflect the features of petroleum reservoir from different profiles. By analizing the 3D seismic parameters, we can assess the parameters of the reservoir characterization, such as deposition, structure and growth history, fluid saturation and so on. The traditional clustering methods can't capture the degree of similarity between reservoir parameters very well, so we introduced in this paper the application of fuzzy C-means (FCM) clustering for the processing of 3D seismic parameters. It begins with the analizing the relationship between 3D seismic parameters and reservoir characterization parameters, and then we process the 3D seismic parameters with FCM and assess the parameters of reservoir characterization. The testing results show that FCM can classify the 3D parameters more accurately and provide a good evidence for the research of petroleum reservoir.

Keywords: 3D seismic parameters, Structure and growth history, Fuzzy C-means clustering

1. Introduction

Fuzzy C-means (FCM) clustering is one of the essential branches of non-supervisory pattern and it was widely used in pattern recognition, data mining, computer vision, as well as in areas such as fuzzy control. Now, FCM has become a relatively mature technology. In the field of petroleum engineering, it has been widely applied to the evaluation of reservoir quality (Chen, Liang, 1997), reservoir classification, Petroleum exploration and decision-making (Zhu, Kejun, 1999) and so on.

In this paper, we introduced FCM to deal with 3D seismic parameters so as to assess some of the parameters of reservoir characterization, such as structure and growth history, permeability, fluid saturation, and master their distribution. First, we introduced the principle of FCM; then we use FCM to deal with three-dimensional seismic parameters; lastly, we make a summary.

2. The Principle of Fuzzy C-Means Clustering

Fuzzy C-Means (FCM) is a method of clustering which allows one piece of data to belong to two or more clusters. This method is frequently used in pattern recognition. It is based on minimization of the following objective function:

$$J_m = \sum_{i=1}^{N} \sum_{j=1}^{C} u_{ij}^m \| x_i - c_j \|^2 \quad (1)$$

Where m is any real number greater than 1, it was set to 2.00 by Bezdek; u_{ij} is the degree of membership of x_i in the cluster j; x_i is the i^{th} of d-dimensional measured data ; c_j is the d-dimension center of the cluster and ||*|| is any norm expressing the similarity between any measured data and the center.

Fuzzy partitioning is carried out through an iterative optimization of the objective function shown above, with the update of membership u_{ij} and the c_j cluster centers by:

$$u_{ij} = \frac{1}{\sum_{k=1}^{c} \left(\frac{\| x_i - c_j \|}{\| x_i - c_k \|} \right)^{\frac{2}{m-1}}} \quad (2)$$

$$c = \frac{\sum_{i=1}^{N} u_{ij}^m x_i}{\sum_{i=1}^{N} u_{ij}^m} \quad (3)$$

This iteration will stop when

$$\max \left\{ | u_{ij}^{k+1} - u_{ij}^k | \right\} < \varepsilon \quad (4)$$

Where ε is a termination criterion between 0 and 1 and k are the iteration steps.

This procedure converges to a local minimum or a saddle point of J_m.

The algorithm is composed of the following steps:

1. Initialize $U = [u_{ij}]$ matrix, $U(0)$

2. At k-step: calculate the centers vectors $C(k)=[c_j]$ with $U(k)$

$$c = \frac{\sum_{i=1}^{N} u_{ij}^m x_i}{\sum_{i=1}^{N} u_{ij}^m} \quad (5)$$

3. Update U(k) , U(k+1)

$$u_{ij} = \frac{1}{\sum_{k=1}^{c} \left(\frac{\| x_i - c_j \|}{\| x_i - c_k \|} \right)^{\frac{2}{m-1}}} \quad (6)$$

If $\| U(k+1) - U(k) \| < \varepsilon$ then STOP; otherwise return to step 2.

3. FCM for 3d Seismic Parameters Processing

In the 3D Seismic Parameters Processing, we first import a potentially large number of independent data (such as seismic amplitude), and quickly assess which are most related to the dependent data (such as porosity-thickness) with FCM, then produce a cluster pattern map of those most-related independent data or any user selected data contained in the imported file (correlation and ranking is provided as output). The FCM is very robust as it works well in cases where the dependent data (well control) population is small. In addition to producing a cluster map, an output file can be generated that contains grid location(x, y), cluster rank and cluster mean-value from the dependent data.

Here, we give you an example. The data in table 1 is a portion of input data used for testing. It was used as input data. In the table, the rows A and B are the coordinates, row C is numeric well identifier, the row D and E are well information, those are dependent data. Rows from F to L are independent data, those are seismic time information.

The figure 1 is the clustering results map with FCM, and it contains four parts: the coordinates of the independent data (x, y), the clustering map, the cluster groups and the clustering ranks. These cluster groups represent areas of similar structural growth history. The thinnest areas, with maximum growth, are ranked as 1, here is cluster 3 on the map, the quality of the reservoir is the best. The thickest areas, with minimum growth, are ranked as 3, here is cluster 2 on the map, the quality of the reservoir is the worst . The quality and the growth history of the reservoir ranked 2 are between cluster 2 and cluster 3.

4. Conclusion

The purpose of FCM is to find a reasonable classification system for a given sample with mathematical method, and solve the classification problem in the reservoir description. In this paper, we introduce fuzzy C-means clustering method to the study of dealing with three-dimensional seismic parameters. The experiment results show that, it can deal with the three-dimensional seismic parameters effectively, so we can analize some of the reservoir characterization parameters, master the distribution of the reservoir caracterization parameters, and improve the exploration and development effectiveness of the oil and gas reservoir.

References

Fan, Ji-zong. (2002). *Cluster Analysis in Reservoir Classification*. Inner Mongolia Petrochemical, (29):124~126.

Gao, Xin-bo. (2004). *Fuzzy Cluster Analysis and Its Applications*. Xidian University, 1~5, 6~28.

Mark A.Sippel. (2001). Intelligent Computing System for Reservoir Analysis and Risk Assessment of the Red River Formation.

Mohanad Alata, Mohammad Molhim, and Abdullah Ramini. (2008). *Optimizing of Fuzzy C-Means Clustering Algorithm Using GA.* Proceedings of World Academy of Science. Engineering and Technology, 29(5): 224~229.

M. M. Saggaf & Ed L. Nebrija. (2003). *A fuzzy logic approach for the estimation of facies from wire-line logs*. The American Association of Petroleum Geologists, 87(7):1223 ~1240.

Table 1. Portion of Input Data Used for Testing

	A	B	C	D	E	F	G	H	I	J	K	L
1	1212821	149427	3.3E+09	-6066.8	-1747.3	652	991	1120	1554	1618	1713	1805
2	1212474	145067	3.3E+09	-6059.4	-1750.7	645	989	1118	1546	1612	1707	1799
3	1211646	144209	3.3E+09	-6052	-1752	642	993	1118	1548	1613	1708	1799
4	1212374	144767	3.3E+09	-6052.4	-1753	643	990	1117	1547	1612	1707	1798
5	1215767	142373	3.3E+09	-6060.4	-1757.3	652	997	1126	1553	1615	1713	1801
6	1214184	150850	3.3E+09		-1759.1	660	996	1125	1561	1623	1713	1807
7	1207014	152537	3.3E+09	-6119.93	-1762.45	643	984	1117	1551	1614	1703	1803
8	1216262	152792	95	-6184.9	-1831	666	1005	1129	1568	1635	1783	1831
9	1207727	148819	1555			635	984	1112	1545	1612	1708	1803
10	1206414	148488	1554			636	983	1115	1541	1610	1710	1803
11	1209040	148488	1553			636	982	1108	1554	1613	1708	1801
12	1206414	148819	1552			636	984	1116	1544	1613	1712	1804
13	1704742	148488	1551			636	982	1114	1593	1609	1709	1803
14	1207070	149482	1550			637	987	1118	1551	1617	1715	1805
15	1208055	148819	1549			637	983	1113	1548	1614	1710	1802
16	1210025	144847	1548			637	988	1119	1552	1613	1706	1800

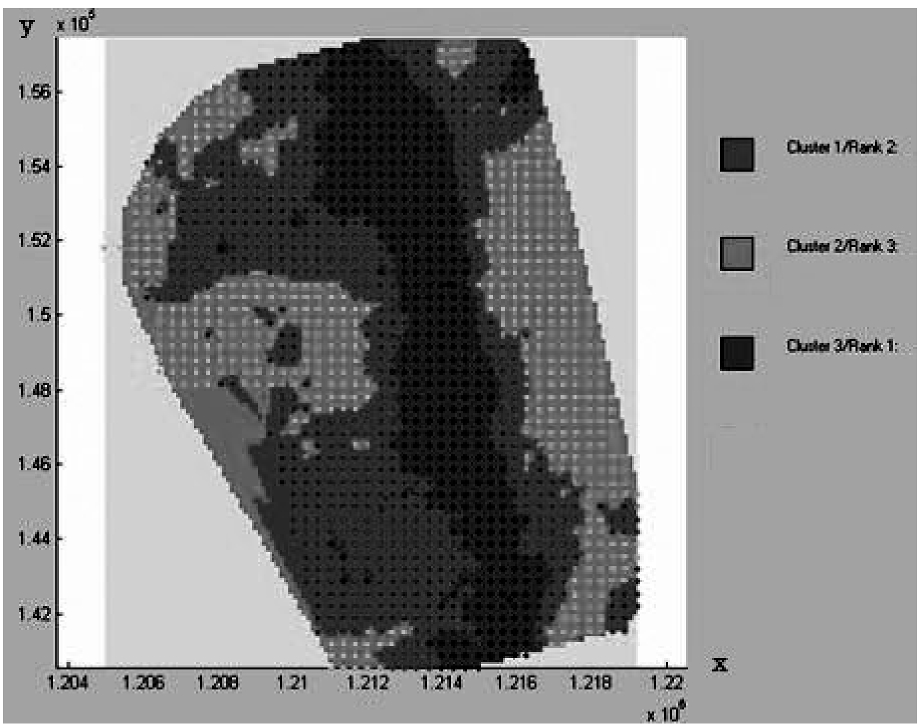

Figure 1. The Clustering Results