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Prediction of multivariable properties of reservoir rocks by using fuzzy clustering

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Abstract

Forecasting of geological parameters is very important for decision making on investment to exploration of new hydrocarbon structures and fields. On the one hand, the complexity of this problem is originated from the nonlinearity and uncertainty of behavior of an ensemble of interrelated parameters changing with respect to the depth. This phenomenon is considered analogously to time series, where the depth plays the role of time. On the other hand, the available data are irregular over the depth, as represent different geological bodies with distinct properties. These features mandate necessity to consider multivariable time series of geological parameters with irregular intervals. In this paper, we consider multilag forecasting of five geological parameters over the depth. As a model of forecasting, fuzzy c-means based fuzzy if-then rules are used and this allows better capture of high complexity of the considered phenomena than the classical precise forecasting model. The experimental data show validity of the suggested approach.

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1. Introduction

The prediction of reservoir rocks properties is an important part of preparation prior to make decision on start of an exploration works at new structures, considering high cost associated with the operations.

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The problem is quite actual for South Caspian sedimentary basin (SCB), considering the history of its development. Most of discovered oil and gas fields involved in production are located on the periphery of the SCB while a new perspective structures are found in weakly studied deep water part of the depression, relatively far away from the periphery of the basin.

The traditional approach for reservoir rocks parameters prediction is based on construction of relationship between the parameters and depth or effective stress (more often depth) and on establishing the approximation functions derived from correlation-regression analysis[1]. The satisfactory results obtained from this approach were considered acceptable assuming that the predicted parameter is only depends on depth or effective stress.

Another approach relying on multidimensional correlation-regression analysis could not be considered as confident for wider use because of requirement of known arguments in multidimensional equation.

It is well known that the reservoir rock properties developed under number of geological factors which role and magnitude varied in time and spatial during post sedimentation period. Therefore the prediction method should be designed to account the variation of geological parameters influenced to the predicted rock characteristics.

Let us discuss the state-of-the-art solution of the considered problem. The experimental studies on the rock samples from the SCB fields were performed and described by Buryakovsky and others[1]. The study based on the analysis of the core samples showed that the rock properties vary with increase of overburden stress representing the rock occurrence at different depths. The results indicated that the porosity decrease of 7% could happen if the overburden pressure increased to 100 MPa.

Buryakovsky and others[2] have paid a special attention to define the mathematical model of the compaction of sandstone and shale formations in SCB. The authors used statistical approach based on the empirical data and inference of interconnections through generalization, analysis, and comparison of the features of geologic systems at certain discrete moments of the geologic time. Approximation of the discrete data by a continuous function obtains an empirical equation for a parameter of the geologic object under study as a function of time. They constructed the model of the shale porosity in relation with depth of burial, formation geological age and lithology. The relationship between porosity of sand formations and burial depth was generated using correlation-regression analysis method. The obtained relationship was used to predict the petrophysical parameters including porosity up to 9000 m depth.

The paper[3] is dedicated to the prediction of main petrophysical parameters as porosity and permeability based on the real log data and utilizing the artificial intelligent techniques: Fuzzy Logic, Support Vector Machine and Functional Networks. The obtained prediction showed higher confidence in results for hybrid model rather than of individual technique.

The combination of type -2 fuzzy logic system and sensitivity based linear learning method (SBLLM) was used in work[4] as hybrid approach for prediction of the oil and gas reservoir permeability and PVT parameters in Middle East fields. The parameters in oil and gas industry are discrete and variable depending on number of parameters which in turn creates uncertainties. The uncertainty handling capability of type-2 fuzzy logic system was combined with generalization potential of SBLLM made the model more robust. The conclusion was made that the hybrid model has advantage over the separate usage of the methods; hence the prediction results has better correlation with real data and the machine learning and computation time is more convenient for implementation of the method in the industry.

The applications of fuzzy logic in petrophysics and the basic concepts behind the litho-facies, permeability and thin bed resolutions computation using fuzzy logic methods considered in paper[5]. The results of fuzzy logic prediction methods deployed at North Sea oil and gas fields data helped to conclude that the method can be used as a simple tool for confirming knowing correlations and as powerful predictor in uncored wells.

S. Cuddy[6] considers the fuzzy logic tool utilization for litho-facies and permeability prediction in North Sea oil and gas fields and comparison of fuzzy logic with other models. The litho-facies typing is used for well correlation and as input for building a 3D model of the field.

Arash Mirzabozorg and others[7] incorporated the reservoir engineering knowledge into history matching and optimization framework, by coupling a rule based fuzzy system with population based sampling method. The method was used for investigation of future performance forecast of the Teal South reservoir model.

The literature review shows that the prediction of geologic features is predominantly based on mathematical models utilizing traditional analytical and statistical approaches with a few attempts to use computational intelligence techniques. Due to the complexity and uncertainty related to rock properties' behavior, the use of fuzzy sets theory[8-10] would provide a more adequate basis for forecasting. In this paper we consider Fuzzy C-means clustering based prediction of multivariable properties of reservoir rocks.