Study on Real-time Lithology Identification Method of Logging-while-drilling

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Abstract. In geophysical exploration and development, lithology identification is the basis for understanding the strata and solving the reservoir parameters. Through the comparative study of three popular lithology identification methods including SVM, GRNN and Elman, each method in the experiments takes the same logging data as a sample to predict and identify, and the most suitable identification method is selected and applied to the automatic identification of lithologic interpretation. It is found that the prediction accuracy of SVM is highest in automatic lithology identification, and the method is suitable for computer automatic analysis in terrestrial interpretation system.

1. Introduction
In geological exploration and reservoir evaluation, lithology identification is crucial and fundamental to solve the reservoir parameters and the comprehensive reflection of mineral composition and structure \cite{1}. However, due to the complexity of sedimentary environment and the heterogeneity of real strata distribution, the traditional lithology identification methods can not accurately reflect the reservoir lithology. SVM (Support Vector Machine) is a supervised learning model in machine learning, which is a new method applied for regression analysis, classification and pattern recognition in recent years. Compared with the difficulties encountered in the research of new machine learning methods like over fitting and under fitting, network architecture and local minimum point, SVM has many unique advantages in solving the problems of small sample size, nonlinear and high-dimensional pattern recognition. And the method can also be applied in other machine learning problems such as function fitting. Since then, SVM has developed rapidly and been successfully applied in many fields \cite{2,3}.

2. Lithology Prediction and Identification Method
In order to select an optimal method for lithology prediction and identification, several popular neural network methods and non-neural network models are studied compared with SVM. In contrast experiments, each method takes the same logging data as a sample to predict and identify to study the identification effect. In this paper, sample regression detection refers to the prediction of known lithology logging data after sample training, while sample prediction refers to the prediction and identification of unknown logging data by the trained model. Two well logs are gamma and resistivity curves, and three well logs are gamma, resistivity and acoustic curves.

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2.1. Generalized Regression Neural Network

Generalized regression neural network (GRNN) is developed in recent years, which is an important variant of radial basis function network (RBF) solving the function approximation problems [4]. Compared with RBF, GRNN is more effective in learning speed and classification, and possesses three characteristics of RBF: best approximation, nonlinear mapping and global optimal. The final optimization regression surface of the network is the largest accumulation of convergence samples, and the regression effect is more significant when the data is scarce. Besides, the output layer of GRNN network is a linear weight and adopt the linear weight learning optimization method to improve learning speed after selecting the action function center and the number of nodes in the hidden layer, which makes GRNN more effective for adaptive control [5-7].

2.2. Elman Simple Recurrent Neural Network

Elman network was first proposed by J. L. Elman and was first used in speech processing. It is one of the important theories of nonlinear system identification, and is a typical neural network of local recurrent [8]. An Elman network can be regarded as an BP neural network with local memory units and local feedback connection [9].

2.3. Support Vector Machine

Support Vector Machine (SVM) is a supervised learning model and new method proposed recently in machine learning, which is usually used for regression analysis, classification and pattern recognition [10]. The core of SVM is summarized as follows: for the linearly inseparable problems, using non-linear mapping algorithm transforms the linearly inseparable samples in the low-dimensional input space into the linearly separable samples in high-dimensional feature space, which makes it possible that using linear algorithm to analyze the nonlinear characteristics of samples in high-dimensional feature space [11].

3. Comparison of Lithology Identification Methods

The basic principles of four classification and prediction methods are introduced, and each method has its advantages and disadvantages. In order to compare the correct rate of each method, three representative well sections are selected for the experiment, which are G101 well, G121 well and G201 well. The representative intervals of the wells are sandstone, mud-stone, coal and aluminous mud-stone. In the test, the same data is taken as samples, and the same normalization method is used to predict and analyze the lithology. Two methods are used in the selection of training samples: one is random selection, the other is manual screening. The comparison results are shown in Figure 1.

![Figure 1. Comparison of accuracy of different classification prediction methods under the same experimental conditions.](image)

The prediction results show that SVM and GRNN have better effect of identification, and the correct rate of both methods is more than 70%, and SVM has the best identification effect.
Considering the influence of acquiring logging information, the classification and prediction of three well log curves are compared. Six predictions are made for each method, and the comparison results are shown in Figure 2.

![Figure 2. Comparison of accuracy of different curves and classification prediction methods under the same experimental conditions.](image)

The experimental results show that SVM and GRNN are the best methods for the identification of two or three curves. The average correct rate of two curves is 70% - 82%, and that of the three curves is 75% - 85%.

4. Application and Effect of SVM Method

Through the training and learning of the SVM model for the standard interval logging data, the lithology can be accurately predicted and identified, which is highly consistent with the actual strata lithology logging data, so the SVM method could be considered and applied to solve the problem of multi-well lithology identification in the region, environmental monitoring, hydrological investigation and other fields.

![Figure 3. Lithologic identification effect of well x07.](image)
mud-stone, and the black dot represents the sandstone. It can be seen from the effect diagram that the identified layers are almost divided by the half amplitude point of the curves, and conform to the physical characteristics of coal rock, so the identification effect of coal seam is better.

Figure 4. Lithologic identification effect of well x011.

5. Conclusions
Three different classification and prediction methods, different well log curves and the number of samples is used for the comparative study, and the conclusions are as follows:

1) The prediction results show that SVM classification and prediction method has the best identification effect. The prediction correct rate is more than 80% in small region and 65% - 75% in the whole region. The reason for the difference lies in that in the whole region, the lithology difference will not only change in the vertical direction, but also manifest in the radial direction.

2) When three and two well log curves are used for prediction and analysis, the prediction effect of the two is similar. But on the whole, the prediction correct rate of three log curves is slightly higher, which indicates that more physical information of strata is conducive to realize lithology identification. In addition, considering the prediction multiplicity, whether more curves are better is still needs to be verified by more research.

3) With the same prediction method and well log curves, the more training samples of standard interval are obtained, the higher the prediction correct rate is.

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