Comparison and Application of Neural Networks in LWD Lithology Identification

CHEN Gang¹,²*, CHEN Long, and Li Quanxin

¹ College of nuclear science and technology, Lanzhou University, Lanzhou, Gansu, 730000, China
² CCTEG XI’AN Research Institute, Xi’an, Shaanxi, 710077, China
*Corresponding author’s e-mail: chengang@cctegxian.com

Abstract. Aiming at the problems of poor fault tolerance, low automation and low interpretation accuracy of traditional lithology identification methods, through the application of neural network autonomous learning prediction analysis methods, different neural network prediction methods were compared to select a more suitable field practical method for the logging-while-drilling (LWD) system. It has been found that, with the same prediction method and the same logging curve, the more training samples obtained in the standard interval, the higher the accuracy. The result is obtained through comparison: the PNN probabilistic neural network method has better effect in production application, high recognition accuracy, and the shortest training recognition time. It can still maintain a high recognition level when acquiring fewer logging data information.

1. Introduction

Lithology identification is the first step in reservoir evaluation and parameter determination, and it is also the basis for acquiring other reservoir information. At present, among various geophysical methods, relying on logging data is the main way to identify the lithology of deeper horizons. Due to the complexity of the sedimentary environment and the heterogeneity of the real stratum distribution, the traditional lithological identification methods such as intersection maps, probability statistics, and cluster analysis cannot meet the mapping relationship of the nonlinear multi-dimensional space of the log data, and the identification accuracy is limited, which cannot meet the actual production needs [1]. With the continuous progress of computers and information processing technology, artificial intelligence neural networks are used to perform automatic lithological prediction and recognition of logging data. The neural network model has strong fault tolerance and can improve the degree of automation and interpretation accuracy of lithological identification [2]. Martin WoLLF et.al first proposed the first automatic lithology determination method in 1982 [3]. Since then, artificial intelligence neural networks have developed vigorously in the direction of lithology identification, and many new breakthroughs have been made. They can not only be automated but also cooperate with logging while drilling equipment to achieve real-time prediction and identification, and provide technical support for drilling geosteering [4].

The LWD curve is generally the same as the wireline logging curve in the overall trend, but there are actual differences. The main sources of its impact are several aspects. First, the LWD detector is mostly installed in the drill collar, whose wall thickness and material have a great influence on the detection effect. Second, LWD is mostly used in highly deviated wells and horizontal wells. The
formation interpretation model can no longer be approximated to be vertically symmetrical and radial uniform, and the instrument is difficult to maintain compared to straight well, so the logging curve is greatly affected. Third, LWD is almost not affected by mud invasion, but is affected by the mud fluid, such as the natural gamma LWD. The gamma value increases with the increase of mud mineralization. For this situation, different companies have different calibration templates for logging tools. In addition, there are fewer measurement curves available in LWD, which also brings new challenges to logging interpretation. In order to select an optimal lithology prediction and recognition method, two neural network methods and two non-neural network methods would be compared.

2. Overview of identification methods

2.1. Support Vector Machine
Support vector machine SVM is a supervised learning model in the field of machine learning. It is usually used for regression analysis, classification, and pattern recognition. It is a new method proposed in recent years\(^5\). The core idea of SVM is summarized as follows: For the linear inseparable case, by using a nonlinear mapping algorithm, the linearly inseparable samples in the low-dimensional input space are converted into high-dimensional feature spaces to make them linearly separable. Linear analysis of the non-linear characteristics of the sample becomes possible.

The SVM classification prediction method was used to identify the lithology of 2 and 3 logging curves 6 times respectively. The results are shown in Fig. 1. From the figure, the consistency of the 6 predictions is not satisfying, and the prediction accuracy of the same sample is 9% different.

![Figure 1. Comparison and prediction of SVM classification of different logging curves](image)

2.2. PNN probabilistic neural network
It is equivalent to the optimal Bayes classifier in classification function. Its essence is a parallel algorithm developed based on the Bayesian minimum risk criterion. At the same time, it is not like the traditional multi-layer forward network, which requires the BP algorithm to calculate the backward error propagation, but a completely forward calculation process. It has a short training time, not easy to produce local optimization, and its classification accuracy is high, regardless of classification problems. No matter how complicated it is, as long as there is enough training data, the optimal solution under the Bayesian criterion can be guaranteed.

The PNN (Probabilistic Neural Network) method was used to identify the lithology of 2 and 3 logging curves 6 times respectively. The results are shown in Fig. 2 and it can be seen from the figure that the prediction consistency of 6 times is good.
3. Comparison of discriminating methods

3.1. Single well lithology identification and comparison

In order to study the prediction effect of each method under different conditions and explore their respective advantages and disadvantages, 4 representative intervals of sandstone, mudstone, coal and aluminum mudstone in the Gaojiabao mining area were selected for the experiment. The same data is used as the sample, the training sample adopts two methods of random selection and manual sieving, and the same normalization method is used to predict and analyze the same logging data. The comparison results are shown in Fig. 3.

![Figure 3. Accuracy comparison of different classification and prediction methods](image)

It can be seen from the comparison chart that the two classification prediction methods of SVM and PNN have the best recognition effect, and the prediction accuracy rate is above 75%. However, the training prediction of SVM takes up to 20 minutes (Fig. 4).

The judgment basis of various prediction and identification methods is based on the learning and analysis of existing data. In order to study the effect of logging information, the classification predictions of two logging curves and three logging curves are compared. The comparison results are shown in Fig. 5.

The experiment proves that the prediction effect of SVM and PNN is 15% ~ 30% higher than BP under the same experimental conditions.
3.2. **Comparison of regional lithology identification**

Through collating and analyzing the logging data of 11 wells in Huangling Mine, the three classification prediction methods of SVM, PNN and BP were used to conduct a comparative study on the regional lithology prediction. The original sample training data is used to perform reverse verification for each method using the trained network. The lithology of the test interval is: siltstone, fine sandstone, mudstone, coal.

Two logging curves are selected: gamma + resistivity curves; three logging curves are: gamma + resistivity + acoustic curves. It can be seen from the experimental results in the following figure: the prediction accuracy of three logging curves is 56.25% ~ 86.59%, the prediction accuracy of two logging curves is 51.55% ~ 84.55%, and the average prediction accuracy of three logging curves is about 10% higher than that of two curves. The average prediction accuracy of the PNN method we used for three log curves is 71.27%, and the average prediction accuracy of the PNN method for two log curves is 63.73%. The comparison result is shown in Fig. 6. Considering the accuracy, consistency and timeliness, it is better to choose PNN probabilistic neural network.

![Comparison of training and prediction time of different classification and prediction methods](image1)

![Accuracy comparison of different classification and prediction methods for different curves under the same experimental conditions](image2)
4. Conclusion
a. Through the comparative analysis of different classification prediction methods, the BP recognition accuracy is slightly worse, but the training prediction time is short; the recognition effect of the two classification prediction methods of SVM and PNN is the best, and the prediction accuracy rate within a single well and a few wells is above 80%, the prediction accuracy rate is 65% ~ 75% in the whole area.

b. The longest time for training prediction of SVM is nearly 20 minutes. Considering the timeliness of LWD and the comprehensive prediction accuracy, it is better to use PNN probabilistic neural network; if the timeliness factor is not considered, SVM method can be used.

c. When using three and two logging curves for comparative analysis of prediction, the prediction effect of the two is close, but overall, the prediction accuracy of the three logging curves is slightly higher. Through practical application, the effect in the coal seam is obvious, and the sand and mudstone will be affected. It can be seen that obtaining more formation physical information is helpful to identify lithology. However, considering its multi-solution, whether the more curves the better, it needs to be verified.

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