

NEUTRAL NETWORK IN LITHOLOGY DETERMINATION

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Abstract. Application of artificial neural network in lithology identification has been developed in the recent years and plays an important role in Petroleum Industry in general and well logs interpretation in particular. In this paper, this ability of artificial neural network has been demonstrated by a case study conducted recently.

1. INTRODUCTION

Artificial neural networks are computer models (or computational systems) which attempt to mimic the workings of the human brain. They can learn from examples and experiences, and are extremely handy for automatically obtaining solutions of complex decision, prediction, control as well as classification problems. Up to this time, neural network technology has been applied to solving many real-world problems with remarkable success in diverse areas such as Computer science, Engineering, Cognitive science, Neurophysiology, Physics, and Biology.

In the petroleum industry, however, the application of neural networks (NN) is not well known. This paper, therefore, is intended to introduce in brief how neural network can be applied in Petroleum industry in general and in well logs interpretation in particular by a case-study of lithology prediction, which has been conducted by the author.

2. WHAT IS A NEURAL NETWORK?

Let us come back to clarify some concepts of a traditional NN. A NN is created with a serial or parallel analysis to simulate the interactions among neurons in a biological neural network. A NN is a computational system composed of nodes (or neurons) and the connections between these nodes in a complex manner via synapses. The NN can be programmed to recognize patterns, retrieve data, filter noise and complete missing information. They can learn, generalize and interpret whereas traditional computing algorithms and statistical methods have been insufficient. The advantage of NN, compared with sequential computer analysis where everything happens in an orderly sequence of operations, is performing non-computational operations in parallel. The NNs have no separate memory location for storing data: the data are presented to the network, which then responds to these input patterns or signals. A collection of nodes corresponding to neural cells in the brain is the basic processing element of NNs. All these nodes are interconnected with varying connection strengths and each of them operates by multiplying each incoming signal by a weight and then summing the weighted inputs. The network thus, is a non-linear system transforming input vectors with n components into an output vector with p components. A simplified NN is shown in figure 1.

3. PROBLEM OF LITHOLOGY DETERMINATION

In the petroleum industry, lithology determination using well log plays an important role. Rocks in the subsurface, from viewpoint of a petroleum system, are divided into three main groups: reservoir rocks containing hydrocarbons and/or water in their pore spaces and fractures, seal rocks preventing hydrocarbons to move out of reservoirs and source rocks producing hydrocarbons if they are mature enough. These rocks basically are sand, sandstone, limestone, dolomite, anhydrite, granite, shale, mudstone, clay, volcanic, salt, coal. What is the well log? That is the measurements recorded electrically from equipment lowered into the wellbore (drilling hole) on a wireline. Data from these

measurements reflect the physical properties of rock formations. Wireline data, therefore, can be used to determine lithology (rocks themselves). The first approach of well log interpretation is to identify what kinds of rocks are present in the whole logged interval in the borehole. Generally speaking, lithology prediction is complicated and is not simply delivered solely from Well-Log data. It needs to also integrate all of the data available including cores, cuttings, seismic, etc.

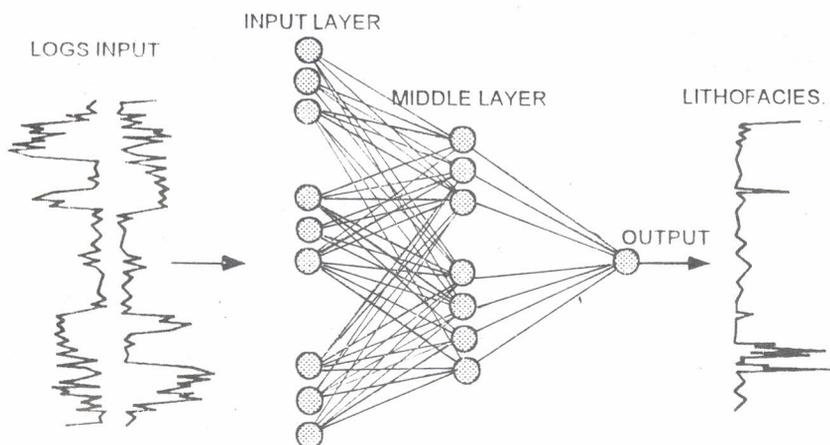


Figure 1. A simplified neural network

Until recently, essentially two broad classes of methods determined lithology from well logs: graphical cross-plotting and statistical methods. In the first approach, two or more logs cross-plotted to yield lithologies. These simple graphical methods, developed mostly in the 1960's, are still useful today for quick identification. The second approach, in which multivariate statistics is used, has several variations including principal component analysis, cluster analysis and discriminant function analysis. Baldwin and Wheatley (1990) [2] proposed a new approach, that of neural networks. They briefly described neural networks and applied the technique to determination of porosity and matrix density using back-propagation learning algorithms and determination of lithology from well-log data using a self-organization learning paradigm.

4. HOW TO DETERMINE LITHOLOGY USING NEURAL NETWORK

To solve the problem determination lithology from well logs using ModelQuest - an advanced neural network, the study was conducted using wireline logs from 4 wells, namely A, B, C and D, of an offshore area. Eight lithologies, including three types of shale, four types of sand and dolomite from an interval of 1600 meters in the well A were used to train NN with different input setting from the various wireline logs. The evaluation of the derived model resulted in prediction of lithofacies with moderate accuracy when applied to the the rest of the wells, where no lithological information was available.

The input used to train NN includes 6 wireline curves and 8 lithologies. These curves are: GR measuring Gamma Ray radioactivity, LLD and LLS measuring resistivity, DT measuring transit time of sonic waves propagating, NPHI measuring Hydrogen index and RHOB measuring bulk density of the rocks within logged interval. Since ModelQuest doesn't deal with non-numeric data, the lithologies have to be encoded as numbers. The encoding method is shown in table 1.

The ModelQuest, which is used in this study, differs from back-propagation neural network because it uses advanced statistical methods an applies a modeling criterion to select the network

structure automatically. The performance of ModelQuest is more simple and faster than the traditional neural network [3].

Table 1. Encoding lithofacies

Lithofacies	Numeric encode	Allowed range
Shale to slightly sandy shale	1	1.0-1.5
Sandy shale	2	1.5-2.5
Pyritaceous shale	3	2.5-3.5
Sandy, very argillaceous laminations	4	3.5-4.5
Sandy Laminations	5	4.5-5.5
Sideritic sandstone	6	5.5-6.5
Sandstone	7	6.5-7.5
Dolomite or compact bank	9	8.5-9.5

After ModelQuest has been trained, it produced an optimal network to determine lithology using 6 wireline curves as input. The model emerging from ModelQuest is a robust and compact transformation, implemented as a layered network of feed-forward functional elements. The derived network is shown in figure 2. The rectangular nodes of the network, in fact their algebraic form can be written in the equations depending on number of input goes into each node. The equations for 2 and 3 input as follows [3]:

$$2 \text{ input: } w_0 + (w_1 * x_1) + (w_2 * x_2) + (w_3 * x_1^2) + (w_4 * x_2^2) + (w_5 * x_1 * x_2) + (w_6 * x_1^3) + (w_7 * x_2^3) + (w_8 * x_2 * x_1^2) + (w_9 * x_1 * x_2^2).$$

$$3 \text{ input: } w_0 + (w_1 * x_1) + (w_2 * x_2) + (w_3 * x_3) + (w_4 * x_1^2) + (w_5 * x_2^2) + (w_6 * x_3^2) + (w_7 * x_1 * x_2) + (w_8 * x_1 * x_3) + (w_9 * x_2 * x_3) + (w_{10} * x_1 * x_2 * x_3) + (w_{11} * x_1^3) + (w_{12} * x_2^3) + (w_{13} * x_3^3) + (w_{14} * x_2 * x_1^2) + (w_{15} * x_1 * x_2^2) + (w_{16} * x_1 * x_3^2) + (w_{17} * x_3 * x_1^2) + (w_{18} * x_3 * x_2^2) + (w_{19} * x_2 * x_3^2).$$

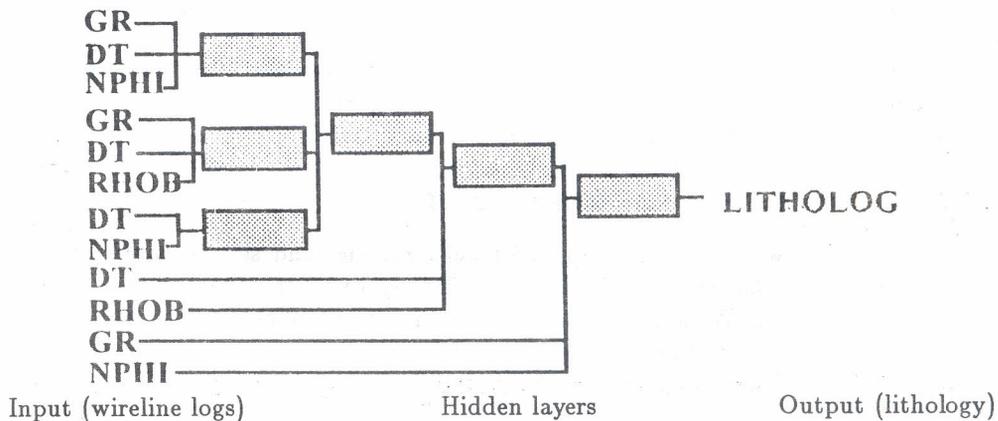


Figure 2. The network using 6 wireline curves to predict lithology

It is easy and convenient to use this network to predict lithology in wells B, C and D, it does not need any knowledge on well logs of the users. Figure 3 displays an example of predicted lithology of

well B. In the left column, GR curve is drawn and the right column shown lithologies with appropriate symbols.

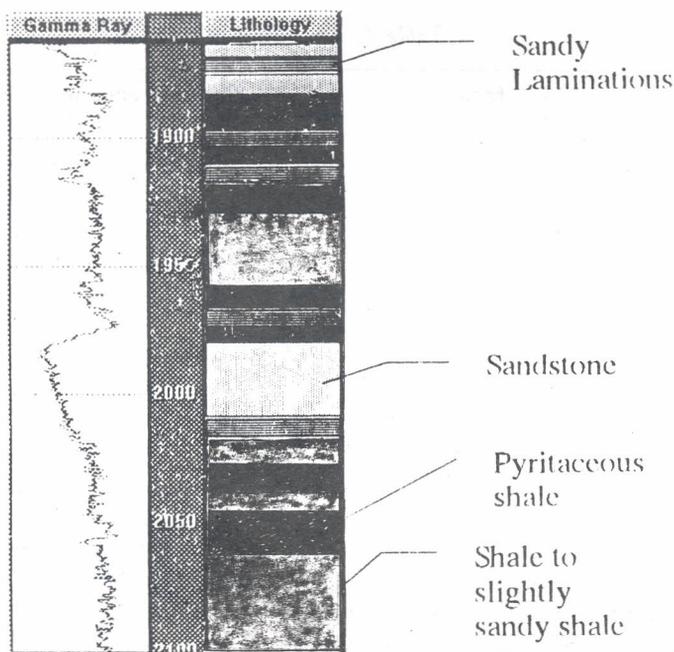


Figure 3. Predicted lithology of well B from 1850 to 2100 m

5. CONCLUSION

This paper has demonstrated the ability of neural network in determination of lithology from well logs. Applying neural network to predict lithology from a data set of wireline logs of 3 wells, which are without any information on lithology has great advantages compared with other conventional methods in term of time consuming and capacity to deal with a huge data set of logs. In Petroleum industry, this approach is suitable and plays significant role for lithofacies application in the exploration stage. The further application using its results can improve the interpretation of depositional environments, sequence stratigraphic as well as reservoir delineation frameworks, which are important in the later stages of petroleum exploration and production [1].

However, the use of neural networks does not replace human intelligence. Rather, their role should be that of intelligent human assistants. We need their thoughts as an extra source of information to be integrated into the final output.

REFERENCES

- [1] An L.H., Neural network technique applied to electrofacies and seismic interpretations of an offshore block Brunei Darussalam, M. Sc. Thesis, University Brunei Darussalam, 1998.
- [2] Baldwin J.L. and C.L. Wheatley, Application of neural network to the problem of mineral identification from well log, *The Log Analyst* **3** (1990) 279-293.
- [3] User's Manual ModelQuest Version 4.0, 1992-1996, AbTech Corporation.

Received May 18, 1999

Revised April 19, 2000

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