

Geological Log Analysis with Neural Networks

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ABSTRACT: NeuroLog, a software tool developed by Systemforschung (Bonn, Germany) analyses log data by use of Artificial Neural Networks (ANNs). The mathematical method implemented, its flexibility and the underlying concept of regionalizability allows a significant improvement in retrieving useable information, compared to classical interpretational techniques. The tool was proven by data taken from different geological settings in various regions of western europe.

KEYWORDS: geology, geophysical log analysis, signal analysis, neural network

Introduction

One of the most important tasks in the exploration phase is to make an inventory of the strata found underground. The most exactest way to sample underground informations is to extract and analyse cores. These cores allow the investigation of the interesting physical, chemical, facial and sedimentological parameters by classical laboratory methods. As this is also the most costly and time consuming way, core-samples are taken generally at selected depths in limited numbers. For uninterrupted informations, sensors are lowered in the hole for recording physical and/or chemical data. The common problematic is to express these informations in more geological terms like lithology, facies etc. Apart from the meaning to the actual drilling (when to stop, presumable occurence) these informations are needed to plan the future strategy. The degree of use of information therefore is an important factor in minimizing the cost of the whole exploration program.

Classical Techniques of Log Analysis

Up to now most common techniques for log interpretation are methods, which use statistically or empirically derived formulae (such as Archie's equation, equation of porosity) which only use one or two of the measurements taken. Known disadvantages of the present solutions are:

- Use of relatively primitive empirical equations.
- Limitations of possible input parameters.
- Necessary coefficients must be derived empirically.
- Little or nothing can be said about the quality of the solution.
- Regional or even local parameters can scarcely be taken into consideration.
- Only a fractional part of the information gained is used for interpretation.

More modern tools of analysis and interpretation use more complex statistical methods like cluster analysis, discriminant analysis and principal component analysis. These are known to have the following problems:

- They fail, if the correlation between input and output parameters is clearly nonlinear.
- If input and/or output are n-dimensional vector spaces, they are difficult or even impossible to handle.

Geology and Artificial Neural Networks (ANNs)

The subject of geological log drillings, the earth's upper crust, is an example of a complex, heterogenous system, which, in itself, falls into subsystems of arbitrary low order. All observations and measurements always represent the influence of the specific regional geologic setting, e.g. mineralization, natural radiation, pressure and the composition of the fluids. For more precise questions and refined models the analytic system needs a detailed knowledge of these regional and local geological environments. If it was enough in earlier days during the exploration on hydrocarbons just to recognize a lithological unit as sand, today's exploring geoscientist needs more information about its origin, whether it may be in marine, fluvial or deltaic environment.

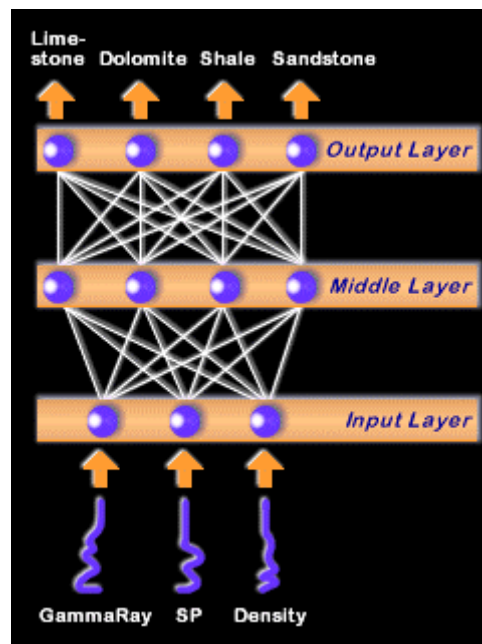


Figure 1: Schematic model to solve analysing geophysical borehole data with neural networks.

In recent years, Artificial Neural Networks (ANNs) have proven to be worthwhile in many fields of interpretation and diagnosis of systems, where you find complex dependencies and fuzzy relations which can hardly be covered by classical mathematical models. A widely known and very successful use of ANNs is pattern recognition in speech and images. The most fascinating aspect of ANNs, the capability to learn and to adapt to new situations, is based on the cooperation of independent, communicating mathematical units.

NeuroLog

With NeuroLog, Systemforschung presents a tool for log analysis based on ANN methods. NeuroLog learns correlations between input and output data from existing, geologically defined logs and given aims of learning and is able to apply this knowledge to this or a similar geologic setting again and again. Because of its use of a dynamic ANN, NeuroLog has the following special features:

- NeuroLog allows the free choice of learning targets (e.g. lithology, physical or technical parameters).
- Number and type of log measurements considered are optional.
- NeuroLog makes a clear statement about the quality of the solution.
- New data can be added to the knowledge base of NeuroLog by specifically learning only these.
- Even aims of learning with gaps in the combination of characteristics (XOR-problem) can be learned correctly e. g. measurements in and out of an aquifer, sands of different origin).

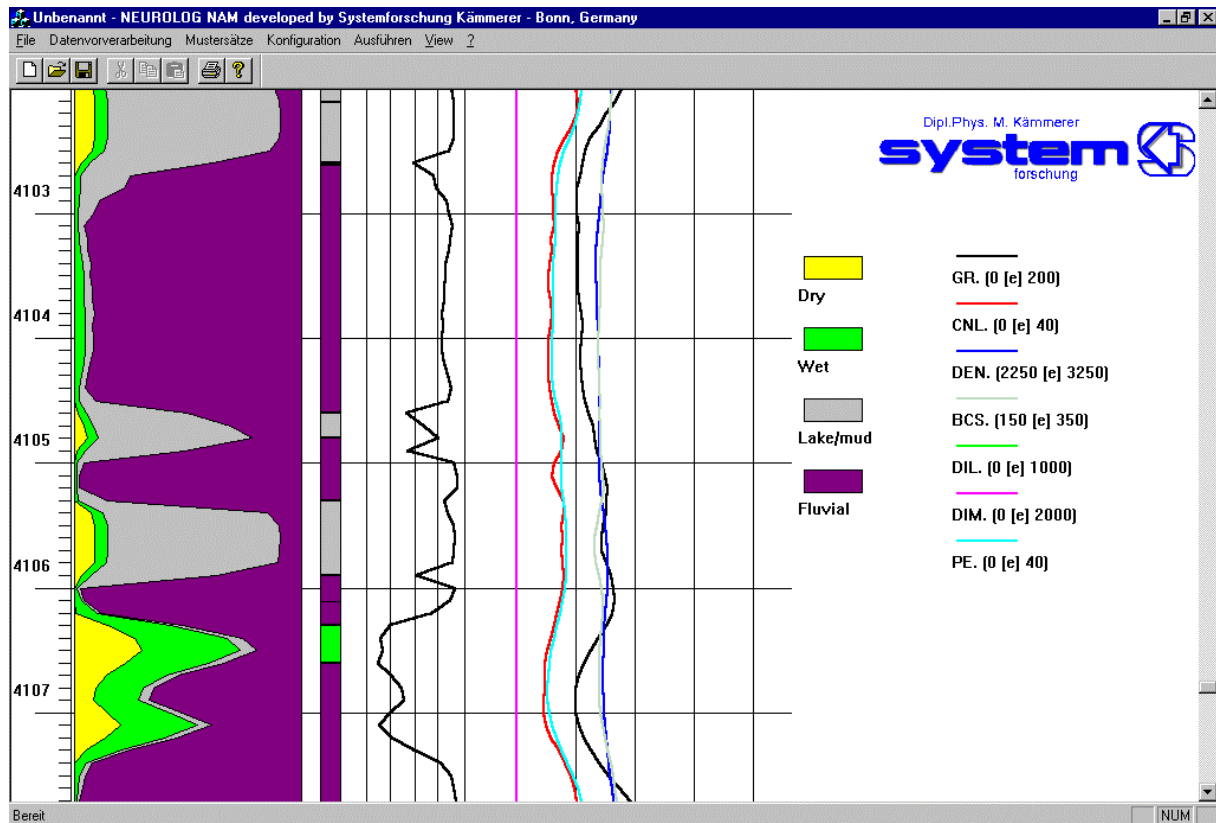


Figure 2: In this application fluvial and lacustral permic sediments are classified. On the left side you see the depth-scale followed by the class probabilities estimated by the neural network. The most probable class is shown additionally. In the middle of the chart the seven log-signals are presented on which the estimation based.

NeuroLog learns the relation between log measurements and the parameters in demand by a set of learning data specifically configured. The physical properties of documented strata necessary could be obtained e.g from a previous log or from laboratory core analysis. The training of NeuroLog is offered as a service by Systemforschung. A highly qualified team of mathematicians and engineers, experienced in the technique of Artificial Neural Networking, lead by a geologist, is available for support.

NeuroLog holds the knowledge learned in the form of always retrievable configuration files. The visualization of the interpreted log data is done by an intuitive and easy-to-use program running on Windows '95. The graphic representation is fit to the needs of a geoscientist and makes it possible to easily and continuously scroll through the whole log.

Application results

Figure 2 shows an interpretation example. The aim was the classification of sandstones with regard to their sedimentation environment. For this relation physically motivated formulae are unknown. We used about 70 samples with known classification and expanded them to an uninterrupted interpretation of 1100 m of the interesting drillhole-segment. As learning data turned out to be inconsistent in some cases, no exact classification border was formed. The neural network was trained to estimate classification probabilities for the four classes. On the test sample we achieved more than 90% correct classifications.

	deviaton on learnset		deviation on testset	
	neural network	linear regression	neural network	linear regression
carbonates	7.78	12.15	13.94	17.57
clay-minerals	7,79	9.62	11.59	20.36
quartz	5.68	5.82	7.71	30.70

Figure 3: Comparison between non-linear model and linear regression in classifying mineral components.

Figure 3 shows the estimation results of mineral components. In corporation with NAGRA (Switzerland) we took about 120 analysed samples drawn from 3 drillholes. With this data we compared linear regression models with a backpropagation neural network. The deviation between estimated percentages and the laboratory results is shown in Figure 3.

The distribution of classified geophysical data is often strong non-linear. The differences of the testing deviations between a non-linear and a linear model are often even more significant than with learning data. The quality of a nonlinear model is often 2 to 5 times better than the competitional linear model. Therefore, neural network techniques are in worldwide progress to analyse geophysical datasets.