Integration of Multi Scale Data in Facies Modeling using Neural Network

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Summary

One big and common challenge is the integration of multiple scale data to create one reliable facies models. In this work we will present how to integrate, high resolution data such as core descriptions and open hole logs, with low resolution data such as seismic to produce a medium resolution 3D facies model. The methodology is based on four steps. The first step uses a neural network to combine the core descriptions and the open hole logs to generate a facies-log for the non-cored well-intervals. In the second step a neural network model is created from the correlation between seismic attributes and the facies-logs. The neural network modeling generates probabilities for each of the facies over seismic volume area (inter-well). Step 3 involves creating horizontal variograms from the facies probabilities. In the forth step the facies probabilities are incorporated with a sequential indicator simulation to produce a stochastic facies model.

Introduction

The facies modeling is a critical step in the life cycle of the reservoir characterization process. All our petrophysical modeling is based on facies, our geometric distributions are determined by our geologic knowledge of the facies deposition and the flow units controlling the production of a reservoir are generated directly from facies, or are a representation of the facies distributions.

Even with years of experience and production we still struggle to produce a reliable 3D facies model to guide our field development plans and strategies. One common reason is that we are not integrating all the available data, such as core, logs and seismic. Large amounts of money are spent to shoot seismic, drill wells, cut cores and acquire logs, but often the facies reservoir model used for reservoir engineering is based on core information only.

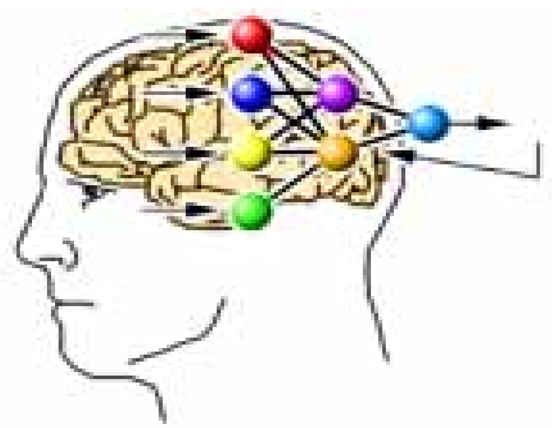
Theory

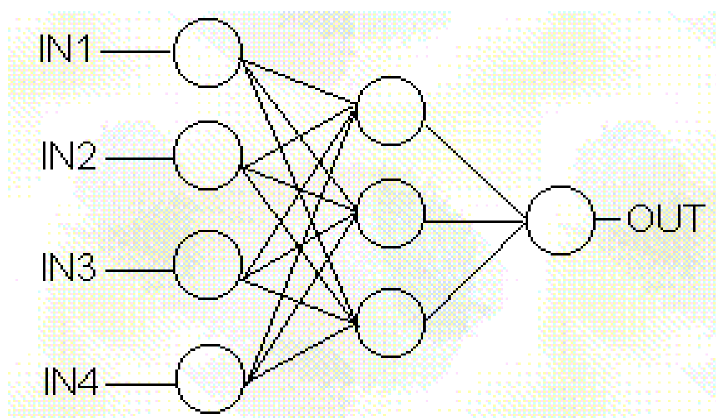
In this paper we will be presenting an easy, quick methodology to integrate all the available data to produce a reliable 3-dimensional facies model. This new approach is applicable to most cases. Even though, we are using a neural network for correlating data and a guided sequential indicator simulation (SIS) for modeling, we could easily use the fuzzy-logic method instead of a neural network. This approach consist of four steps.

1. At the well level: A neural network is used in supervised mode, with open hole logs as the inputs. The facies descriptions from core are used to supervise the training of the model. The result is facies determinations for wells that do not have core data. The facies are based on the supervised combination of the open hole logs and the core descriptions.
2. At the 3-dimensional grid level: Another neural network is used in supervised mode, with seismic volume attributes as the inputs. The facies logs from the previous step are used to supervise the training of the model. The result is a probability cube for each facies code and a 3-dimensional facies model.
3. At the 3-dimensional grid level: Horizontal variograms for each facies code are created from the probability cube for that facies. Vertical variograms are created from the facies well logs of step one.
4. At the 3-dimensional grid level: Sequential indicator simulation (SIS) is used to populate a 3-dimensional model. The inputs to the SIS are the facies logs from step 1, the variograms from step 3 and the facies probability cubes from step 2. The facies probabilities are used as global probability for the SIS.

What is Neural Networks background

Mathematical models that emulate some of the observed properties of biological nervous *systems:* parallel information processing, adaptative learning...





A neural network is an algorithm that takes multiple inputs and returns one or several outputs. These inputs may be coincident log values, coincident seismic attributes, coincident surface values or properties from the same cell.

Each input is multiplied by a weight, the result is summed and the result passed through a nonlinear function to produce the output.

$$O = F\left(\sum i_n . w_n\right)$$

O =output

F()= a nonlinear function

i_n= the nth piece of input data

w_n= the assigned weight for the nth piece of input data

To make the model produce the required output, the correct weights must be selected. This process is called training.

Step one: Facies log for the non-cored intervals.

Core are the best source of data we can have however, it is not available everywhere or in every well. We need to use some secondary data to estimate the facies. The second most reliable data source is the open hole well-logs. For practicality we use only the logs that are most affected by facies changes, these are GR, RHOB, DT, and NPHI. These processes are followed:

1. Open hole logs are cleaned and corrected for borehole effects.
2. Cross plot and correlate the core facies and open hole logs. (This is used to choose which logs are to be used, and which facies codes should be merged, if logs do not show a difference.)
3. Run the neural network in supersized mode with a probability threshold to create a NN_facies log
4. The core facies are merged with the NN_facies, with priority to the core facies, to produce the Final_facies log.

Step two: Facies from the seismic attributes.

Which seismic attributes will be used is the most challenging part. We generate many attributes and select the inputs based on the cross correlation matrix. The selected attributes should have a low correlation so that each attribute is providing new or additional data to the neural network. As expected the seismic to facies correlation is often low but can give an indication of facies. The presentation will discuss how to improve this correlation. The results of the neural network are shown below:

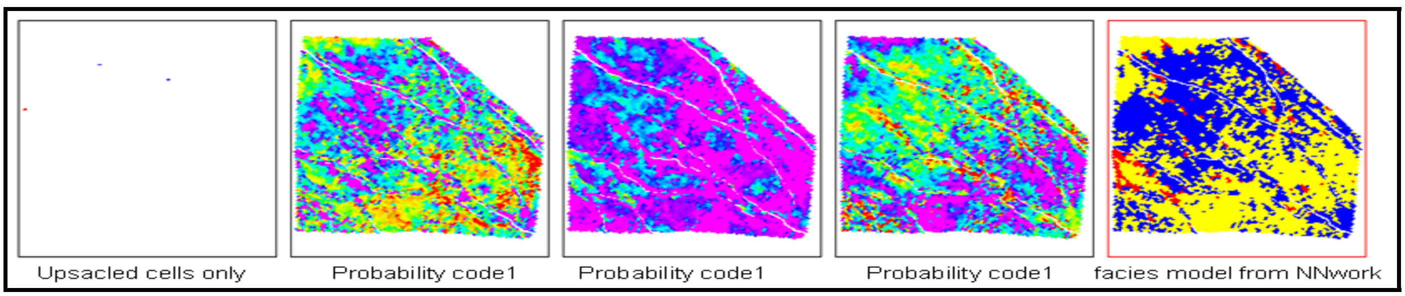


Figure 1: Neural network results.

Step three: Variogram information from the NN results

The probability cubes will be used to generate information for the horizontal variogram. For each probability a variogram map is created to determine the anisotropy and help guide the horizontal variogram ranges, since horizontal ranges can be difficult to determine from sparse well data.

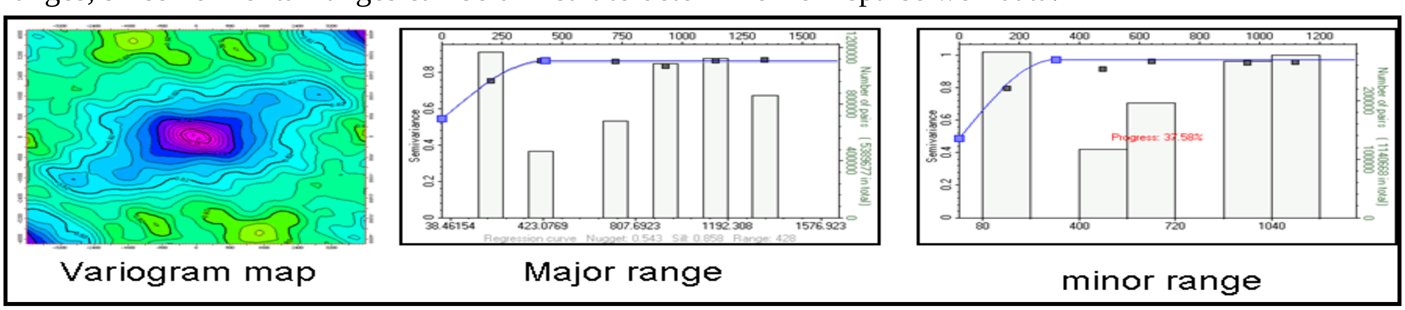


Figure 2: extract variogram information from NN results.

Step four: Sequential indicator simulation (SIS):

The SIS algorithm (found in all modeling software) is based on the estimation of the facies probability using the up-scaled cells and variogram information. SIS provides the capability of using secondary probability data to adjust the SIS results. The figure below shows clearly that the vertical resolution is preserved even though it is guided by low resolution seismic attributes.

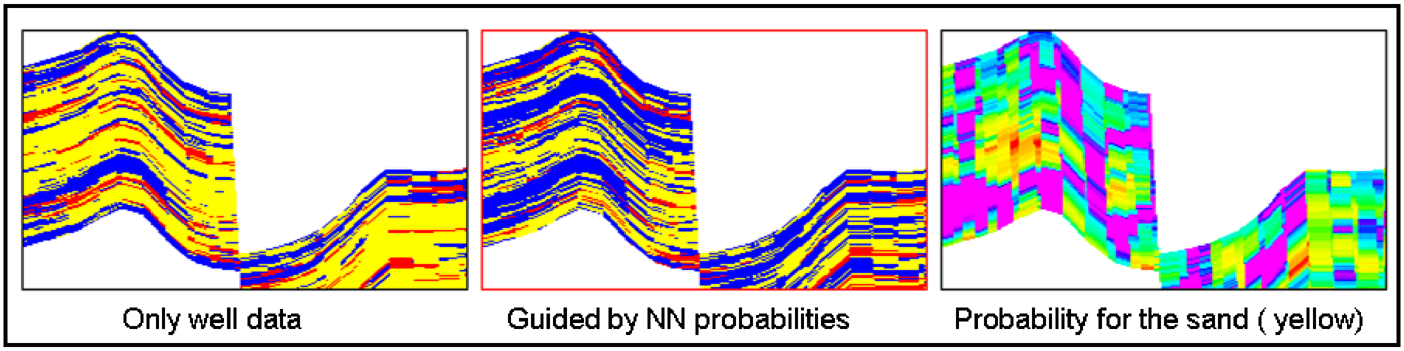


Figure 3: 3D facies with and without seismic.

Conclusions

Data with multiple scales exist for every field, and geo-modelers are finding it difficult to integrate this data. In the presented approach we showed an easy and quick way to integrate these data in a soft manner. If the probabilities from the seismic attributes is too high it will guide the resultant facies will. If the probabilities are low, the results will be dominated by the variogram parameters