Offshore®

Seismic attribute analysis can benefit from unsupervised neural network

Process identifies anomalies from original data without bias

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The primary task facing a seismic interpreter is to recognize and attribute a geologic significance to observable patterns in the seismic response. The most apparent patterns are found in seismic reflections. In recent years, the industry is using more subtle patterns and connecting them to such attributes as porosity, lithology, and fluid content, as well as underground structure.

The separation of such patterns and their use as potential identifiers of subsurface characteristics comprises attribute analysis, a customary instrument in the geoscientist's toolkit.

Over the years, seismic data volumes have increased in terms of geographic area covered, depth of interest, and the number of attributes. New and potentially disruptive technologies have developed to take advantage of all the attributes available in the seismic data.

One new technology, based on unsupervised neural networks (UNN), reveals deeper insights into the seismic response and thereby reduces exploration risk. Unsupervised neural network technology can help interpreters recognize seismic anomalies that may indicate the presence of hydrocarbons, often when conventional techniques fall short. This new technology may also find application in the prediction of lithologies and fluid properties, as well as in estimating the size of reservoirs.

The self-organizing map (SOM), a form of UNN and a powerful pattern recognition method, was initially developed by Prof. Teuvo Kohonen of Finland during the 1970s-80s. Based on this approach, UNNs assist the interpreter in prospect evaluation by:

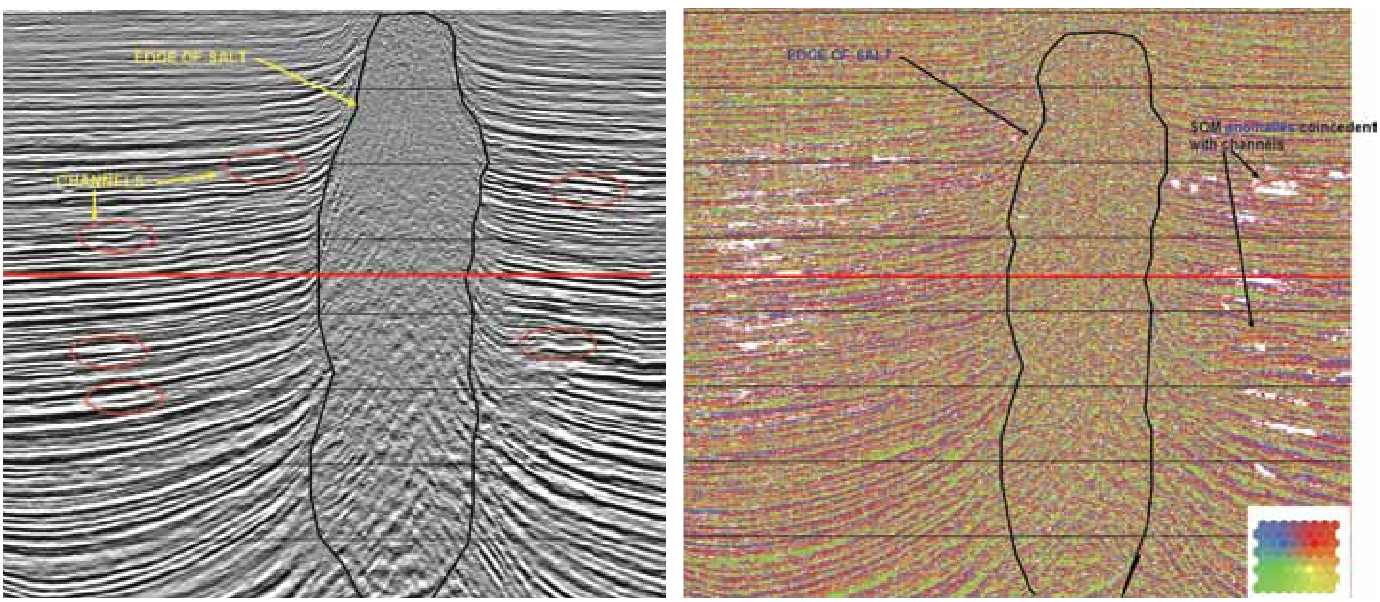
- Enabling the rapid comparison of large sets of seismic attributes
- Indentifying combinations of attributes that reveal seismic anomalies
- Distilling the interpretation process to identify hydrocarbons with greater speed and accuracy.

Supervised vs. unsupervised UNNs

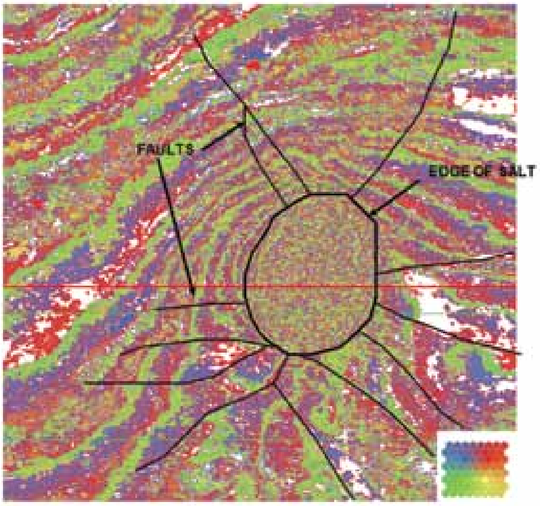
For several years there have been a few commercial tools in the upstream industry that are based on "supervised" neural networks. A supervised neural network (SNN) operates on data that has been classified, i.e., "ground truth" is known in specific locations, providing reference points for calibration of the network. In terms of seismic data, for example, a segment of a seismic survey at each logged well is employed to calibrate the SNN. Supervised neural networks unite the seismic data at the well to the known conditions from the well, while inferring geophysical properties away from wells.

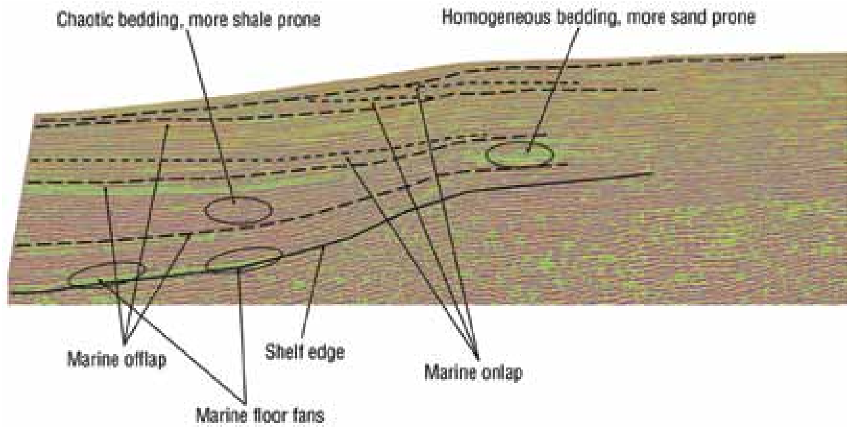
But what happens if there is no well log or other forms of ground truth available, such as in a greenfield exploration?

This is the advantage of unsupervised neural networks, which do not need an "answer" beforehand and cannot, therefore, be biased.



(Left) This represents a conventional seismic interpretation of a vertical amplitude section across the center of salt dome in the Gulf of Mexico, provided courtesy of Fairfield Nodal. (Right) The same data after UNN processing shows edge of the salt, and the anomalous areas shown in white are obvious.





(Left) Horizontal time-slice of the red line shown after UNN processing.
(Above) UNN analysis from data taken offshore West Africa. The classification result may not show any anomalous areas, but the resultant vertical slice from the neural network volume shows significant stratigraphic details and areas for the interpreter to investigate further.

UNNs can be applied to "unclassified" data, which operates on the seismic data response alone. Hence, the technology can be used to identify where even exploratory wells should be drilled by identifying geobodies that are different than their surroundings.

Offshore examples

The edge of salt has been interpreted in this example along with several channel systems working through the data. Operating on this same data using an UNN produces results where the same edge of salt outline can been seen, but "anomalous" areas (in white) stand out.

A few geobodies are associated with the previously interpreted channels in the original amplitude data. The red horizontal line across marks the time slice which displays a horizontal view of the same salt dome. In this time slice, the edge of the salt body has been interpreted along with a few of the major faults created by the salt uplift.

The white regions have been identified by the UNN as "anomalies" that have distinctly different properties than their surroundings, potentially indicating the presence of hydrocarbons. These would be regions that deserve further analysis by the interpreter.

The UNN analysis also yields a classification volume in which the interpreter can see in greater detail stratigraphic and structural elements that might not have been interpreted in the original amplitude volume.

The UNN process

The following four tasks comprise a thorough analysis using an unsupervised neural network:

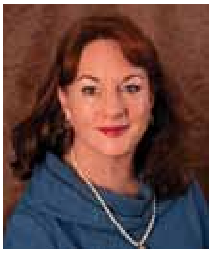
- Carry out an assessment that reveals the right choice of seismic attributes
- Perform an appropriate interpretation of attributes for the geologic trends of interest
- Select the well information, where available, and calibrate the data
- Generate new attribute volumes – The UNN classification and classification reliability.

One key to an effective analysis and interpretation is selection of the best seismic attributes, exposed by a systematic assessment of the data. Using Eigenvalue and Principal Component Analysis (PCA), it is practical to ascertain the relative contribution for each of the attributes to help guide the selection process. Running multiple UNN analyses using differing sets of attributes also may help understand their impact and if the results change with different sets of atttributes.

A major transformation is required to take full advantage of the explosion of data in the oil field. Unsupervised neural network technology facilitates greater insights into all forms of data, but perhaps the greatest value to the oil and gas industry is derived from its application to seismic interpretation. The technology is proving to reveal new insights into interpretation and increasing the reliability of the results. Unsupervised neural networks can also be used to correlate well information with well log data while improving the value of reservoir simulation. This new technology has the potential to be "disruptive" to the industry by providing a tool that comes close to the direct detection of hydrocarbons.

The authors

Tom Smith received BS and MS degrees in Geology from Iowa State University. In 1971, he joined Chevron Geophysical as a processing geophysicist. In 1980 he left to pursue doctoral studies in Geophysics at the University of Houston. Dr. Smith founded Seismic Micro-Technology in 1984 and there led the development of the KINGDOM software suite for seismic interpretation. In 2007, he sold the majority position in the company but retained a position on the Board of Directors. SMT is in the process of being acquired by IHS. On completion, the SMT Board will be dissolved. In 2008 he founded Geophysical Insights (www.geoinsights.com) where he and several other geophysicists are developing advanced technologies for fundamental geophysical problems.
The SEG awarded Tom the SEG Enterprise Award in 2000, and in 2010, GSH awarded him the Honorary Membership Award. Iowa State University awarded him Distinguished Alumnus Lecturer Award in 1996 and Citation of Merit for National and International Recognition in 2002. Seismic Micro Technology received a GSH Corporate Star Award in 2005. In 2008, he founded Geophysical Insights to develop advanced technologies to address fundamental geophysical problems. Dr. Smith has been a member of the SEG since 1967 and is also a member of the HGS, EAGE, SIPES, AAPG, GSH, Sigma XI, SSA, and AGU.



Deborah Sarcey is a geologist/geophysicist with 34 years experience. She received her degree in Geology from the University of Oklahoma in 1976 and began with Gulf Oil. In 1983 she became chief geologist for Peko Oil and Gas. In 1988, Peko merged with Weeks Exploration Co. Sarcey started her consulting business in 1990. Deborah specializes in 2D and 3D interpretation along the Texas and Louisiana Gulf Coast.

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Neural network notices anomalies in seismic data

Tom Smith and Geophysical Insights are bringing an advanced mathematical analysis method to bear on seismic interpretation. The concept of unsupervised neural networks is being extended to seismic interpretation to speed interpretation and direct the interpreter's attention to the key areas in the data that represent the anomalies being sought as indicators of possible hydrocarbon-bearing zones.

To get a better understanding of the process, *Offshore* magazine visited with Smith to peek behind the curtain to see how a self-organizing map can benefit exploration.

Offshore: When you say neural network, what do you mean? How does it work?

Smith: The inspiration for the fellow who had this breakthrough was inspired by the brain and the visual cortex in particular. The big breakthrough was to think about a learning process which would be incorporated into a two-dimensional map of neurons – computer "neurons" in this case.

Here we're thinking about a neuron as a little depository of information. That repository is based upon what gets to it. The neuron network is presented a set of information and the neurons adapt themselves to the information presented to them.

The neurons adjust to the characteristics of the data following a set of straightforward rules. This results in what are called self-organizing maps (SOMs).

The input data can be completely unclassified (without reference "ground truth") and the learning progression is unattended.

Large volumes of data can be evaluated by an unsupervised neural network quickly, making their use reasonably practical. They can also be programmed to operate unattended and report by exception when anomalies are detected.

The unsupervised neural network works without any supervision at all. Wells are not required for this process.

Offshore: What data do you start with?

Smith: Normally these days we might start with four or five cubes of data, each a seismic attribute. The old standard is the seismic amplitudes. Today, interpreters work commonly with at least five and as many as 30 different attributes, all derived from a single amplitude. Those are then all input into this unsupervised neural network process.

There are two parts to this process. The first part is the learning. That literally is taking the attribute cubes and presenting those to the neurons. You end up with an SOM. After this self-training, the second step is to then apply the results of the two dimensional map.

How we apply it is to go back to the data cube and take every single data point from those original data cubes and compare them to the neural network result. We find the neuron that is the closest…that learned it was the best match to that particular sample. We keep this process up. We go through all the samples in the original data, not just the amplitude but all the attributes, and we do a comparison. This is the classification process. Once we're done with that we will have taken every piece of our input data and found it nearest neighbor…the neuron that is the closest match.

Offshore: What about the math involved in the program?

Smith: If you think about a particular point in a 3D survey, if you've got five attributes, you've got five numbers associated with that point in the image. Mathematically, that just a little column vector. So if it's five attributes, the neuron is also a column vector that has place for five numbers.

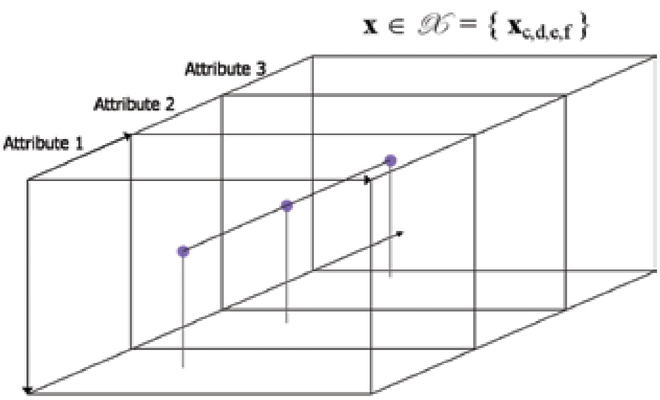
We have done a good deal of design and development of the technology. Today, we are delivering the results of our analysis to clients on a turn-key basis. We also have been making substantial investments in research and development. Going forward, Geophysical Insights will announce a dramatic, commercial-grade software framework and applications that use unsupervised neural network technology.

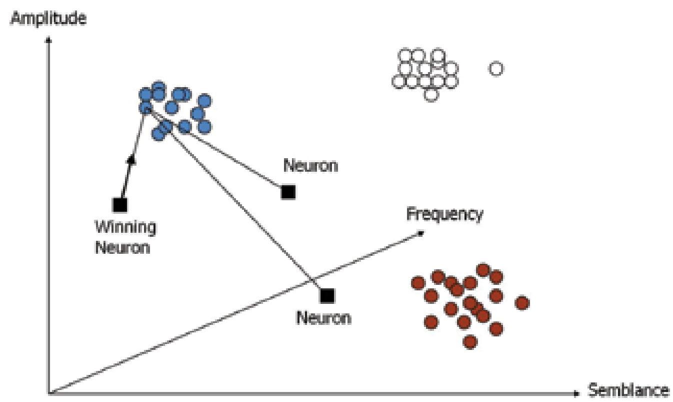
So, our work in geobodies has demonstrated the ability to automatically identify areas that don't fit, where the material is substantiallly different than its surroundings, and differentiate between noise and valuable information. We find those areas, the dimensions, and rank them as to size and shape, and deliver those. Once we have a geobody, we go back and post it in the original volume. If this is a geobody with some shape, that's what makes it an anomaly.

Offshore: Why is your technology being called "disruptive"?

Smith: We have good evidence that it will substantially reduce the risk and time associated with the interpretive process. This new technology has great potential to "disrupt" the industry by providing a tool that comes close to the direct detection of hydrocarbons. ○

Editor's note: *For more, see story on page 40.*





(Left) SOM survey space perspective. This depicts three attributes from one 3D survey. The three points near the middle highlight one data sample for three associated attributes, aligned as parallel rectangular blocks. A 3D survey with a single attribute provides a limited understanding of seismic properties. Today, we work with multiple attributes, often as many as 25 at a time.

(Right) Converting the three attributes into a SOM attribute perspective. Each point sample is plotted in attribute space along three attribute axes, resulting in a natural cluster of related characteristics. The natural clusters comprise regions of higher information density and may indicate seismic events or anomalies in the data.

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