# An iterative method for identifying seismic objects by their texture, orientation and size.

*Paul Meldahl* and Roar Heggland, Statoil, Bert Bril, De Groot-Bril Earth Sciences*

**Summary**

The trend in seismic interpretation is shifting away from horizon-based towards volume-based work. This trend increases the complexity and magnitude of identification and mapping work and therefore asks for faster and better tools.

Since the identification is non-trivial due to low signal to noise ratio and non-uniqueness in the problems we believe that the detection tools should be iterative and steered by the interpreter.

Therefore we have developed an iterative method for semi-automated identification of seismic objects and interfaces such as faults, reflectors, chimneys, time-laps differences, stratigraphic features and direct hydrocarbon indicators. The method includes a flexible processing workflow using directive seismic attributes (i.e. attributes steered in a user-driven or data-driven direction), neural network technology and image processing techniques (Meldahl et. Al., 1999).

The workflow can be steered by the interpreter simply by pointing at examples of the type of object to be detected. The users' steering and control of the processing, interpretation, tying and correlation of detected objects is supported by flexible visualization functionality. If the interpreters like to do more creative interpretation or they like to speed up the routine work, these flows can quickly be tailor made by script programming. The effects of such iterative work are both predicted and exemplified.

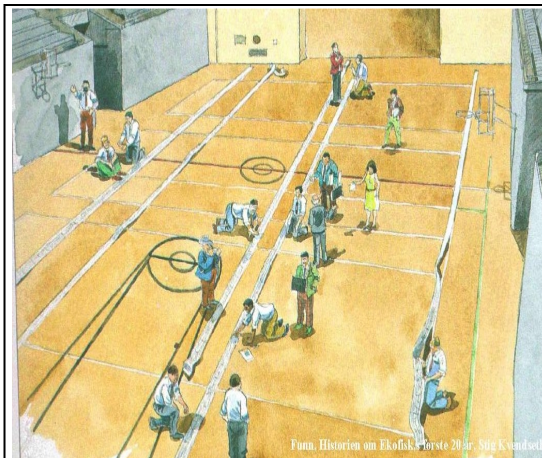

Figure 1. A Painting from a Phillips meeting in Adam's Hall in Bartlesville where the interpreters are lying on their knees in front of the seismic lines. The meeting decided to drill the first well on the Ekofisk field. From Stig Kvenseth, "The History of Ekofisk, the first 20 years "

**Introduction**

Modern visualization and image processing techniques are revolutionizing the art of seismic interpretation (See painting in **Fig 1**). Emerging technologies may allow us to interpret more data with higher accuracy in less time.

The shift away from horizon-based work towards volume-based work where objects are highlighted or extracted from the seismic data volumes give new insights gained by studying objects of various geological origins and their spatial interrelationships.

This change in technology from picking of a few surfaces to extraction of 3D objects need new tools to cope with the new challenges related to more objects and the extra object dimension.

We have developed an iterative method for semi automated identification of 3D objects by their texture, size and orientation.

***The problem***

The standard way of highlighting objects is through seismic attribute analysis. Various attributes are tested in a trial and error mode and one is selected as the optimal representation of the desired object. First of all these different attributes give different views of the objects thus confusing the interpretation and turning a basically simple approach into an expert's job. Secondly the object images in the attribute cubes are very fragmented and distorted by noise and therefore they become difficult to extract.

What is needed is a method that produces more accurate results and does not require an expert to run.

***Concept***

The method described below uses the noise reduction potential present in directive and iterative processing sequences. Unlike in acquisition and processing (e.g. Meldahl, 1998) we do not need to limit the directivity strength to avoid smearing, because we can focus on specific object types and their individual orientations. In the latter case they follow the assumed or calculated local dip and azimuth of the seismic object. By using an iterative approach the increasing amount of knowledge of objects can be used to focus the detection.

**The method**

Seismic attributes play a key role in our method. In principle single- and multi-trace attributes are selected that have a potential to increase the contrast between objects and their surroundings. The detection power of (combinations) of attributes is greatly improved by designing the attribute extraction windows to match the size, orientation and extent of the targeted objects. If this is the case we speak about directive attributes. Directivity in attributes increases the signal to noise ratio, sometimes dramatically.

Seismic objects are two-, or three-dimensional bodies characterized by a certain seismic response that differs from the surrounding response. The difference in response can be highlighted by various attributes. Each attribute contains information on the object that we wish to detect. None of the attributes is expected to be sensitive to the targeted object only. This means that other objects are highlighted by the same attribute.

In our method we can separate bodies from different origins by using a Neural Network trained on the (directive) attributes to recognize objects that have been identified in a seed interpretation. The network transforms all attributes into one new attribute, which indicates the probability of the presence of an object of this type at the seismic positions. The resulting object-probability cube can be further enhanced by image processing techniques (Tingdahl 2001).
Knowledge on the objects' shapes and orientations can be fed back to the process either to increase the detection strength or to increase the resolution of the highlighted objects. The object detection method is schematically depicted in **Fig. 2.**

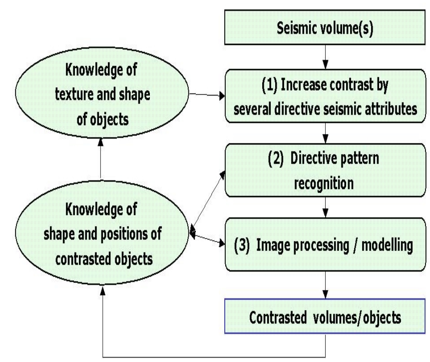


Figure 2. Workflow: the contrast in seismic data volumes is increased by knowledge and data driven transformations.

The first iteration may overlook very small objects due to the focus on enhancing large objects using e.g. strong vertical directivity. The next iterations could therefore focus on small objects, for example those that only leave a footprint along the reflectors. By steering the detection along all of the detectable reflectors a greater part of the objects in the seismic volume can then be extracted. This work can be automated by first enhancing sub-volumes which contain a reflector or reflector fragment, then calculate the reflector orientations and finally steer the detection along these volumes.

If detected objects consist of many separated fragments a tracking process can be very time consuming. Doing more iterations can fill in gaps between fragments since the attributes could be steered outside the fragments along the fragments orientations. Steered attributes could even identify weaker object texture in the seismic volume and therefore reduce the fragmentation of the objects. (**Fig 3.** contains results of a first iteration showing fragmented faults)

The actual work sequence is very intuitive. The interpreter targets a particular object (response) that should be highlighted. He or she then supplies the basic information in the form of examples and attributes. Default attribute sets exist for different types of bodies. The network takes over part of the role of the expert by combining the information in an optimal way. Networks are not very sensitive to redundant information, which means that a few additional attributes do not affect the end result. Attributes can have fixed shapes and orientations, or they can have data adaptive shapes and orientations. In the latter case they follow the local dip and azimuth of the seismic object.

The following steps are done in each iteration:

1. Only one type of geological object or detection goal is targeted at the time. This leads to a sub-selection of attributes with the potential to enhance the objects.
2. A neural network is trained on attributes extracted at example object and non-object positions selected by the interpreter or given by a previous iteration of the detection.
3. The trained network is applied to the seismic cube or applied only to objects that were detected in a previous iteration, to produce high values at positions where the objects is recognized.
4. Optionally image-processing techniques are applied to improve the neural network generated output and to calculate object orientations for a next iteration.

Each new iteration is constrained by the knowledge gained in the previous process and the interpreters needs.

**Applications**

The primary applications are expected to be as a toolbox for the interpreter while identifying and extracting of seismic information and building geological models. We also feel that this method could be useful within seismic imaging. For example in seismic processing the iterative model building by repeated interpretation of preprocessed data is a very time consuming. We expect that for example reflector detection can speed up this part of the processing work. Tying of P- and S-reflectors is a time consuming and difficult part of building processing models for multi-component seismic data. Reflector detection followed by enhancement of the reflector characteristics is expected to be useful for these tying purposes.

**Conclusions**

An iterative and directive method for identifying seismic objects was presented. Improvements due to strong user steering and iterative processing is predicted and then illustrated by examples.

The method, which has wide applicability in seismic processing and interpretation, is characterized by:

1. Extensive use of the iteration principle to either shift the detection goal, or to strengthen the detection using knowledge gained after the previous iterations.
2. The focus on one detection goal in each iteration
3. Easy tuning of the detection process
4. Fast visual inspection of detected objects vs. input seismic

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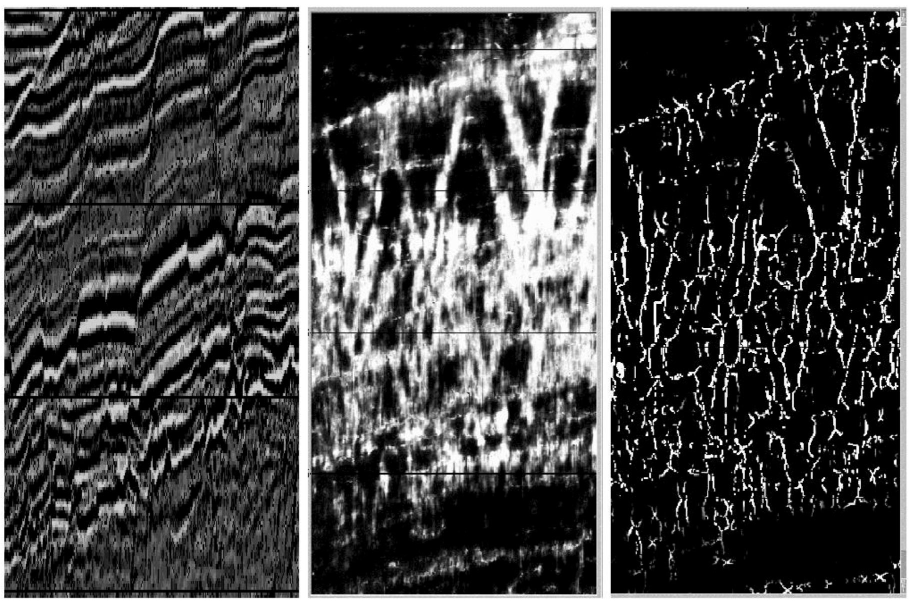

Figure 3. Results of fault enhancement. a) Input seismic, b)Output from the neural network c) The result of image processing b)