Semi-automated detection of seismic objects by directive attributes and neural networks, method and applications

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Summary

A method for semi-automated detection of seismic objects such as faults, reflectors and chimneys is presented.

The method increases the detectability and mapping efficiency of the desired objects by an iterative process comprising at least two steps: contrasting (i.e. texture enhancement) followed by object recognition.
Contrasting is performed by extracting several attributes from multiple windows and feeding these to either a supervised, or an unsupervised neural network. The size, shape and direction of the extraction windows as well as the attributes are chosen in relation to the objects we wish to detect. The windows may have a fixed shape and direction, or they have data adaptive forms. In the latter case they follow the local dip and azimuth of the seismic events. The resulting output is a texture-enhanced volume, which can be interpreted manually, used as input to the object recognition phase or to constrain a subsequent pass of the detection process.
The detection method is explained and examples of chimney -, fault - (Fig1) and layer detection are shown.
Several potential applications and improvements in seismic imaging, image processing, structural and litho-stratigraphic interpretation and reservoir characterization are discussed.

Introduction

Seismic attributes and supervised and unsupervised neural networks have become increasingly popular in recent years in the realm of quantitative interpretation. In this paper we extend the use of these techniques to iterative seismic object detection. Moreover, we discuss the concept of directivity in the attribute extraction process. Directive seismic source arrays have been used for many years to attenuate unwanted signals hence increasing the contrast between desired and unwanted energy. Since seismic acquisition must record all desired energy the source directivity is generally weak. Also in processing the concept of directivity is used to increase the contrast between objects and their background. Also these directivity processes are weak since they should not attenuate energy from seismic objects of interest. In this method we use directivity to detect seismic objects. The method is based on the following principles:

- focusing on one class of objects only
- using directive attributes to increase the contrasting power
- the use of neural networks to recombine the extracted attributes into new attributes with improved separation power

- working iterative by focussing on several detection issues and/or to learn more about the objects in order to optimize the next pass.

The target can be reflections, faults, chimneys, seismic anomalies or any other object of interest. The seismic texture, the spatial extension and orientation of each of these objects is different. Differences are both due to the seismic response and how the data has been handled in acquisition and processing.

Seismic objects

To detect seismic objects requires knowledge about texture, size, shape and direction of the objects. We have to ask ourselves what is characteristic of a fault, chimney or seismic anomaly in order to extract attributes that can separate the body from its surrounding. For each object we define such a set of attributes and use these to train a neural network to classify the seismic response into body and surrounding.

Examples of object characteristics

Faults are in general dipping more steeply then reflectors and the seismic response changes faster along fault planes than along reflectors. Since fast spatial variations are mostly degraded by inaccuracies in acquisition and processing we know that reflectors usually contain higher temporal frequencies than fault images. Seismic reflectors may have partly large amplitudes, a piece-wise strong continuity and largest temporal bandwidth and they usually are oriented more horizontal than faults.
Seismic chimneys on the other hand appear as vertically degraded zones in the seismic image. These zones can completely mask the reflection energy from the sedimentary sequence.
Other examples of seismic objects and their characteristics are: Direct Hydrocarbon Indicators (DHI)) and stratigraphic units. A DHI is a seismic anomaly, which is often characterized by a horizontal component, a change in amplitude and phase and a termination against other reflectors. A stratigraphic unit can have many different responses. Usually the response changes along the reflecting unit, due to changes in rock and fluid parameters.

Procedure

Attribute extraction

Once the decision is made which objects we wish to detect we make an intelligent selection of attributes that have potential to increase the contrast. Attributes can be amplitude, energy, similarity, frequency, phase, dip, azimuth etc. Moreover, attributes can be extracted (and merged) from different input cubes e.g. near - and far offset stack, inverted Acoustic Impedance etc. The attributes are made directive by the shape and orientation of the extraction window. The ideal extraction window for any attribute follows the desired object at every position. This implies that the extraction window should have a flexible shape, which follows the local orientation of the object. In the chimney detection example we use three vertically oriented extraction volumes to reflect that we are looking for vertically oriented bodies of considerable dimensions. We use knowledge about the characteristics of chimneys by calculating in each extraction volume such attributes as energy and various types of trace-to-trace similarity.
In fault detection, static, vertically oriented calculation volumes can also be used. To prevent non-vertical faults from "falling out of" the extraction volume(s) the vertical directivity can be reduced. Static windows do not give optimum resolution of faults. However the faults are enhanced so their direction can be estimated and fed together with the previous input data into a

second pass of the detection process. Steering the extraction windows along the estimated fault planes is then used to recalculate the original set of attributes.
The selection and tuning of attributes can be automated since the detection process enables us to compare attributes extracted inside and outside the objects. These attributes are then recombined into even better attributes via neural network mapping so that the objects can be detected in an optimal way.

Reflectors and auto tracking

To detect reflectors the calculation volumes may be oriented horizontally. Again since reflectors are not perfectly horizontal the directivity may be reduced. As in the fault detection case the attributes can be oriented along the direction of layers detected in a previous pass to improve the detection process.
Auto trackers are the standard method for detecting layers. A common problem with auto trackers is to find a tie between separated pieces of the reflector. In our proposed detection scheme we first detect more or less all (the strongest) pieces of reflectors and save these in separate volumes. The interactive tying process is then carried out using 3D visualization tools and image processing algorithms aimed at enhancing spatial patterns.
Even if we cannot tie the important pieces of reflectors we see great potential for seismic reflection volumes. For example to improve workflows in acquisition, processing, image processing, structural interpretation and characterization.

Neural networks

After the selected attributes have been extracted at a representative set of data points we will recombine these into a new set of attributes to facilitate the detection process. In this step we use supervised or unsupervised neural networks.
The main difference between supervised and unsupervised learning approaches lies in the amount of a-priori information that is supplied. Supervised learning requires a representative set of examples to train the neural network. The neural network is then trained to classify the input location as falling inside or outside the object. Application of the trained network yields the desired texture enhanced volume in which the desired objects can be detected more easily.
Edge detection algorithms and pattern recognition tools can now be applied to the texture enhanced volume to further improve the detectability of the objects. The concept of directivity can also be applied in these processes.

Conclusions

A semi-automated method on detection of seismic objects was presented. The method, which has wide applicability in seismic processing and interpretation is characterized by:

1. Focusing on one class of objects at the time
2. Extraction of attributes with potential to increase the contrast between desired objects and the background.
3. The use of directivity in the attribute extraction process.
4. The use of supervised and unsupervised neural networks to recombine the attributes into new attributes with improved separation power.
5. The possibility to iterate the process. First the texture of the objects is enhanced. The resulting cube can be further enhanced using edge detection - and pattern recognition techniques. Also the texture-enhanced volume can be used to steer the direction of attribute extraction windows in the next pass.
6. The ability to extract the detected objects and zoom in for detailed characterization work.

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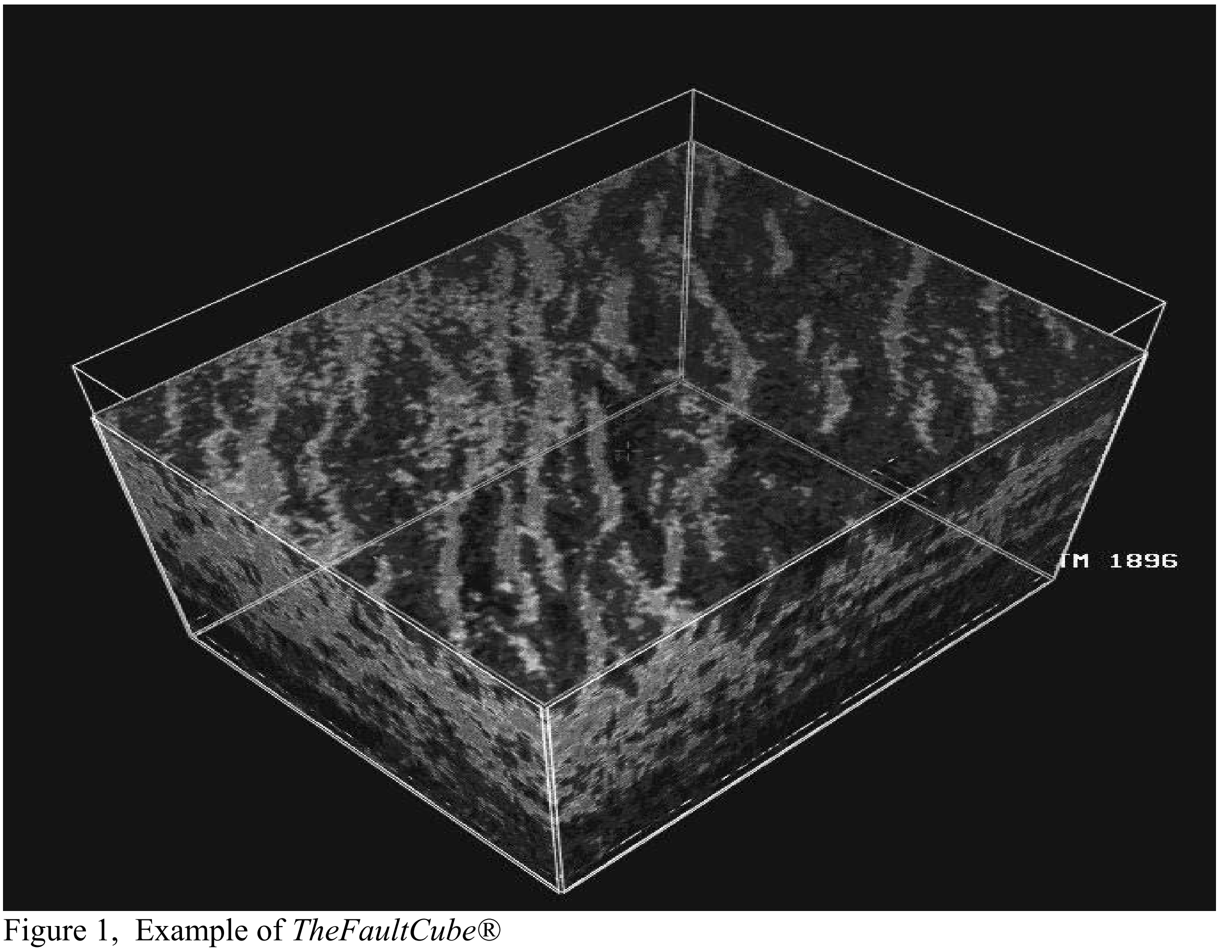

Figure 1, Example of *TheFaultCube®*