Sobel Filtering Brings Edges Into Sharp Focus

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Mapping of geologic edges such as faults or channel levees forms a critical component in the interpretation on 3-D seismic volumes. While the more prominent features often can be easily visualized, smaller features important to understanding the structural and depositional environment can be easily overlooked.


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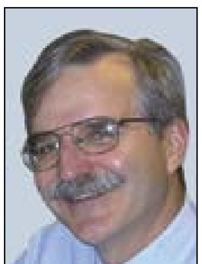
Careful manual interpretation of such features is both tedious and time consuming. A seismic coherence attribute that enhances edges not only accelerates the interpretation process, it also provides a quantitative measure of just how significant a given discontinuity is in relation to others.


MARFURT

Since the seismic coherence attribute extracts all subtle features in the seismic amplitude volume, preconditioning the data to enhance geologic edges and minimize edges due to acquisition and processing is key to accurate analysis.

We find that the application of a Sobel filter to energy-ratio coherence volumes significantly sharpens faults and channel edges of interest.

We demonstrate this simple cascaded workflow with examples from Canada, where one of the objectives is to provide improved attributes for subsequent automatic fault plane extraction.

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Sobel filters are one of many filters that are commonly distributed when one purchases a digital camera. For a flat photograph containing pixels of a given amplitude aligned along the x and y axes, the classical Sobel-filtered image is simply obtained by running a process equivalent to the square-root of the sum of the squares of derivatives of the amplitude in the x and the y directions.

Unlike a photograph, seismic images have a third dimension. A similar process (equivalent to the square-root of the sum of the squares of derivatives of the amplitude in the inline and crossline directions along structural dip) normalized by the RMS amplitude in the window of application to account for structural dip can be run on the seismic data. This normalization will enhance lower amplitude edges when applied to a coherence input volume.

In figure 1 we show the application of Sobel filtering on a 3-D seismic volume from Alberta, Canada, and compare it with an energy-ratio algorithm application for coherence attribute.

Notice that subtle stratigraphic features appear stronger on the Sobel filter display while the larger faults and fractures are much clearer on energy-ratio coherence. In this image, the two attributes are not redundant, but complementary.

Since the classical Sobel filter is routinely used in sharpening photographic images, we hypothesize that we can do the same by applying it to edge-sensitive seismic attributes such as coherence. We can achieve this goal by simply cascading the two attribute calculations.

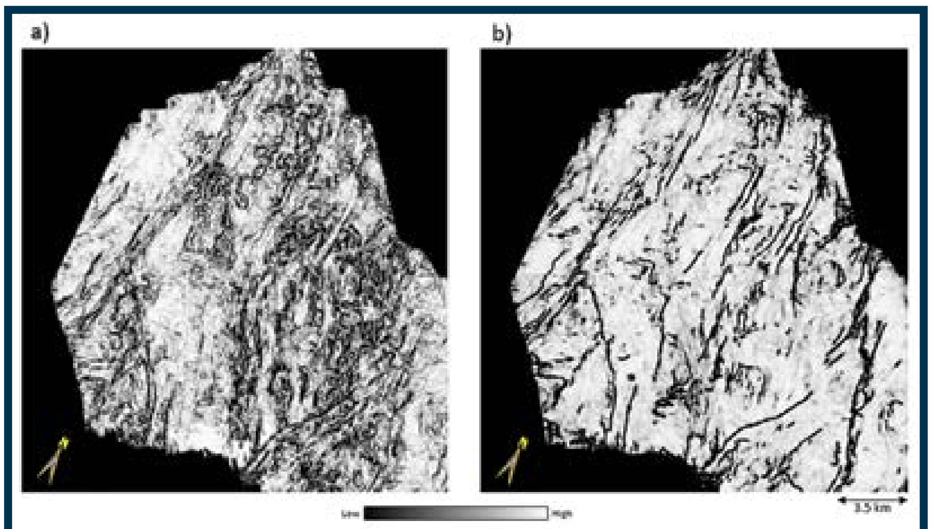

Figure 1 – Stratal slices from a horizon picked close to t=1200 ms through (a) Sobel filter similarity and (b) energy ratio coherence volumes. Although both "coherence" algorithms used the same structurally-oriented filtered data volume as input and the same 5-trace by ±10 ms analysis window, these two images are quite different, with the Sobel filter similarity showing more stratigraphic features and the energy ratio coherence providing sharper fault images.

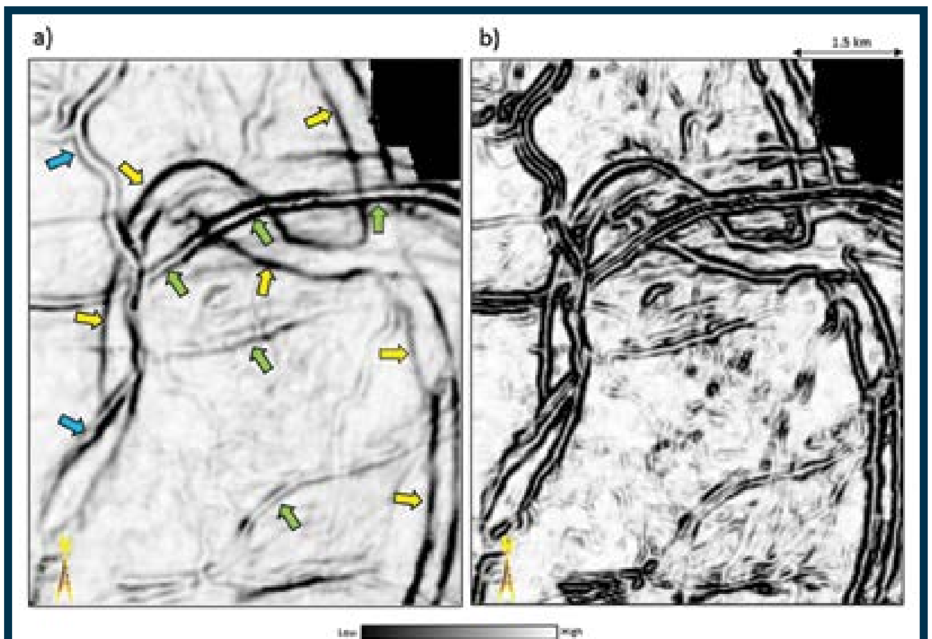

Figure 2 – Stratal-slices at a level close to a horizon picked at t=1020 ms through (a) energy ratio coherence volume computed from the seismic amplitude, and (b) Sobel-filter similarity computed from the coherence volume shown in (a). Notice the clarity with which the edges of channels seen in (a) are seen in (b).

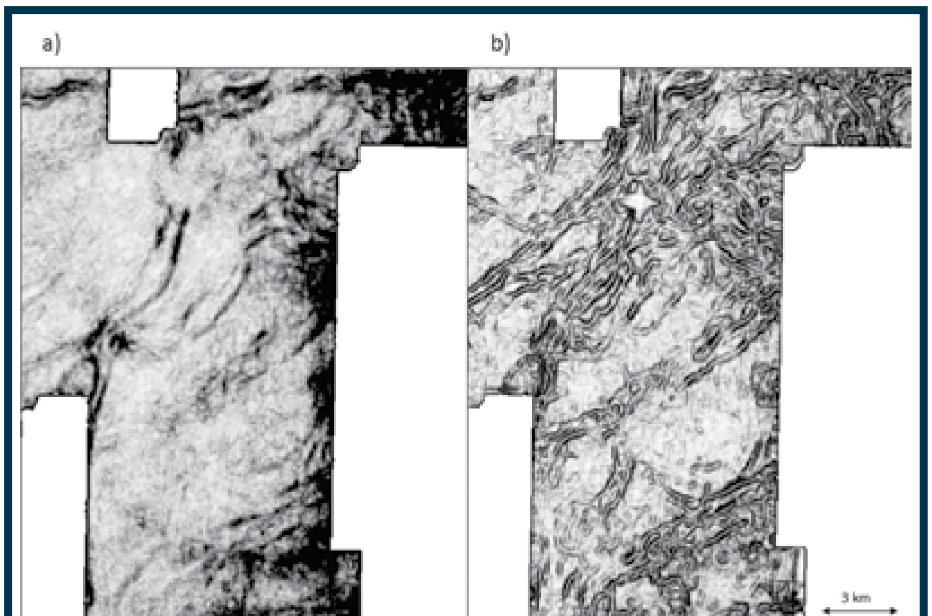

Figure 3 – Time slice at t=1020 ms from (a) coherence volume computed using the energy ratio algorithm, and (b) Sobel-filter run on the coherence shown in (a). Notice the clarity with which the edges of channels seen in (a) are seen in (b).

First we apply energy-ratio coherence to the original seismic amplitude to obtain good quality fault and channel edges.

We then take the output coherence image and use it as input to a Sobel-filter run along structural dip, thereby further sharpening any anomalies.

This workflow can be used to more rapidly delineate channels, or to automatically detect faults using modern image processing tools.

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The data going into coherence computation are usually preconditioned using structure-oriented filtering, reducing the risk of enhancing aligned noise showing up as edges.

In figure 2 we show a similar comparison of coherence run on a 3-D seismic volume from south central Alberta, Canada, but now with the objective of illuminating Mannville channels that traverse the display.

In addition to the two main channels indicated with yellow arrows, there are some thin channels indicated by green and blue arrows that crisscross the main channels at many places.

In figure 2b we show the result of applying the Sobel filter to the coherence volume.

Notice the crisp definition of the channels on this display. Besides the main channels many of the narrower channels are seen clearly. Invariably, the definition of all the channels on the display is very prominent.

In figure 3 we show a comparison of time slices from a 3-D seismic volume from central Alberta.

Figure 3a shows a time slice through a coherence volume calculated using the energy ratio algorithm where we see indications of some NE-SW trending channels. As this display is at the level of a coherent reflector, we see high coherence everywhere except at the location of the channels.

Figure 3b shows the result of applying a Sobel filter to the coherence volume. Notice the high definition and clarity with which the channels now show up, as well as some of the other events around them.

Such convincing displays of the application of Sobel filters to coherence volumes suggest that discontinuity features – such as channels as well as faults – can be enhanced, resulting in crisper and more focused images.

We believe such images provide superior input to modern object extraction software application, as well as in visualizing the channel features clearly.

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The present exercise can be easily extended to other features of interest, such as faults, which would be a useful input for automatic fault extraction software applications.

Such applications would definitely help with the geologic understanding of the subsurface area of interest. E

(Editor's note: AAPG member Kurt J. Marfurt is with the University of Oklahoma.)