Seismic Horizon Tracing with Diffusion Tensors

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Motivation

Seismic interpretation as the first step in building a geological model for efficient oil and gas exploration is becoming more and more important with the decreasing availability of fossil fuels.

Computer-aided analysis of the subsurface is widely used to reduce drilling costs and obtain detailed information about the size and location of oil and gas reservoirs.

The interpretation is often done manually, working from slice to slice in the *inline* or *crossline* directions, i.e., parallel to one of the main axes. With growing data sizes, manual interpretation becomes less feasible, and therefore image processing techniques are used to aid the interpretation process.

In this work, we propose a novel workflow for seismic interpretation, based on working from well log to well log, instead of in axis-aligned slices, and we present an automated tracing algorithm that exploits diffusion tensors.

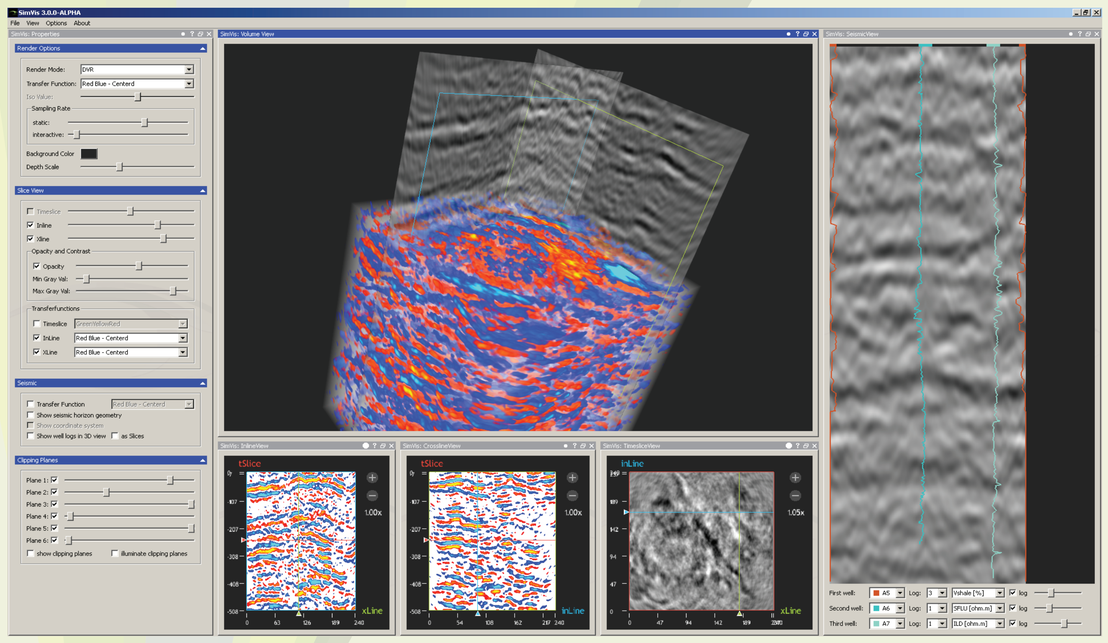


Figure 1: Our PlugIn in the SimVis [1] Framework

Workflow

- Proposed workflow based on well-logs instead of axes-aligned *inline* and *crossline* slices
- User selects wells, defining the sides of an n-sided prism
- Prism is unfolded onto a single plane for interaction
- Horizon is traced automatically starting from a user-selected seed point around the prism faces

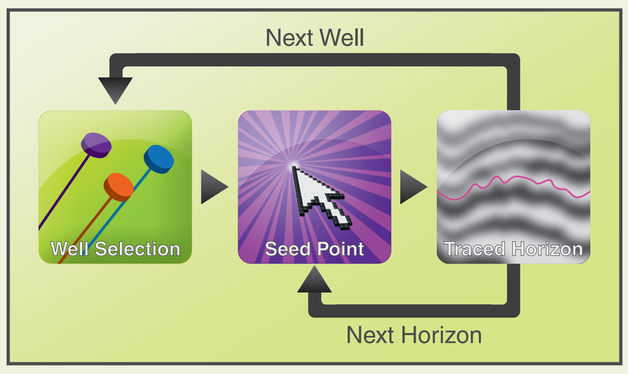
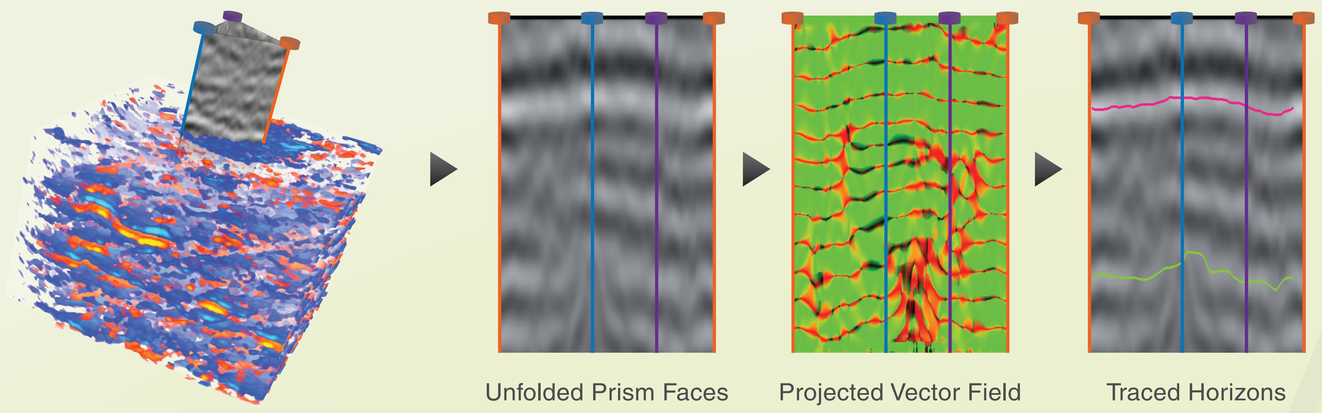


Figure 2: The Well Log Based Workflow

Tracing Pipeline



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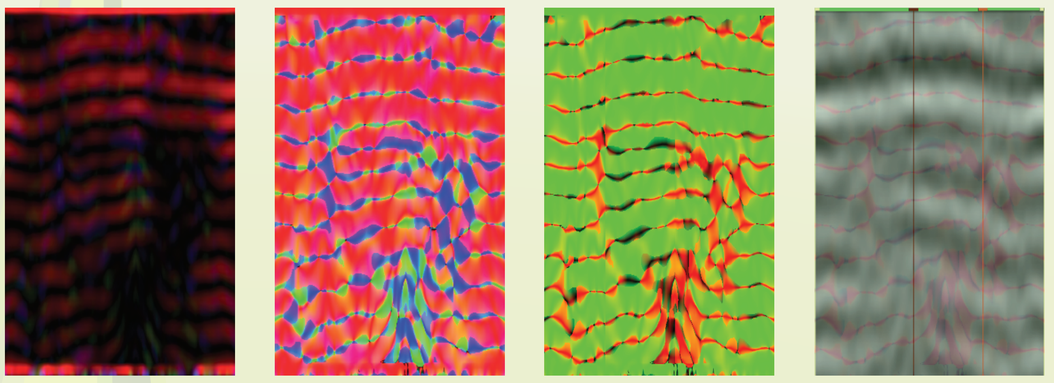
- For every sample point the gradient and a diffusion tensor [4,5] are computed
- Gradient is computed with a 7x7x7 Gaussian derivative kernel
- Two different tensors were implemented:
  - Edge-enhancing, using the main direction of a smoothed Gaussian and two orthogonal vectors as basis
  - Coherence-enhancing, using the eigenvectors of the structure tensor as basis
  - Implementation as well computational complexity for edge-enhancing tensor is way below coherence-enhancing tensor
- For tracing, the resulting vector field is numerically integrated (Euler / Runge-Kutta) from a user-selected seedpoint



a) smoothed gradient map — b) gradients • diffusion tensor — c) result from b) projected onto 2D image plane — d) result from c) blended over scalar field

Figure 3: Comparison of the vector fields in different steps of the pipeline. Components of the vectors encoded in RGB channels in a) & b) and RG channels in c) & d) respectively

Results

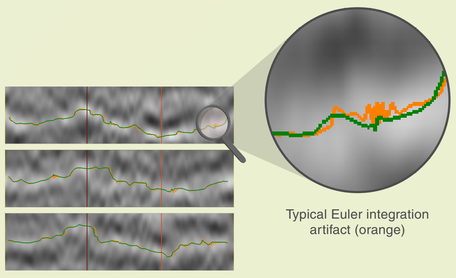


Figure 4: Euler (orange) vs. Runge Kutta (green) integration

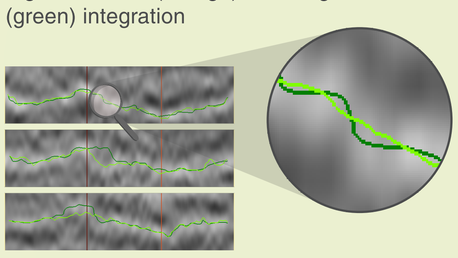


Figure 5: Edge-enhancing (dark green) vs. Coherence-enhancing (light green) Tensor

Figures 4 to 6 show exemplary results of the different tracing algorithms.

The higher-order Runge-Kutta integration results in much smoother horizons than simple Euler integration for all three test traces. Typical Euler integration Artifacts can be seen in the zoomed view of Fig. 4.

Comparing tracing using the edge-enhancing diffusion tensor with the coherence-enhancing tensor (Fig. 5) shows that the former is a little closer to the actual areas of maximum amplitude and more responsive to changes in the horizon direction.

The difference between both incorporating the snapping to maximum intensity values is very small (Fig. 6). For both the correctly traced parts are closest to the actual horizon of all compared methods. However, the deviation from the vector field there introduces a much higher chance of false classification.

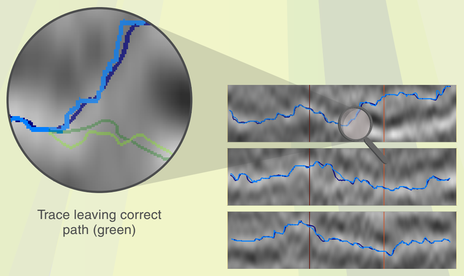


Figure 6: Edge-enhancing (dark blue) vs. Coherence-enhancing (lig blue) Tensor with snapping

References

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