Advanced volume visualization—new ways to explore, analyze, and interpret seismic data

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Tracing fibrous objects such as well paths or channels through a dense 3-D volume is difficult in geologic/geophysical image analysis. Traditional methods involve detecting outlines of fibers in 2-D volume slices and reconstructing 3-D models from the 2-D information. This paper discusses using a virtual environment to solve this problem.

Virtual environments are interactive, head-referenced visual systems. When combined with stereoscopic visual and audio systems, they produce the illusion that you are inside a 3-D world (Figure 1).

Virtual environments create unique challenges. The most difficult is providing an intuitive method for navigating through space. Generally, virtual environments allow you to walk in a limited local region and some way of "flying" to a new location. Geologic VR requirements are slightly different than simulated reality applications because you are navigating through a scientific data set. Such data sets are not like our daily environment because they lack the intrinsic geometric references of real environments (such as up and down). When you get lost, there are few clues to orient yourself (no chairs, doors, walls, cars, trees, etc.)

Seismic volumes, coherency, and velocity cubes pose additional challenges to visualization. Isosurface generation and polygon rendering do not work well when you are trying to find a thin channel in a dense, noisy material.

In this paper we describe GeoTracker, a new tracking tool that attempts to address the 3-D navigation problem and provide acceptable volume-rendering speeds for virtual reality applications.

Volume rendering is the process of obtaining images from 3-D data volumes. The 3-D data is a type of cloudy material, the transparency of which can be adjusted by changing the transparency of each voxel (volume pixel element) in the volume. For seismic data, each sample to display represents a voxel. Each value in the data volume is assigned a color and opacity. Display raypaths are calculated for each pixel in the volume. Color and opacity are sampled at evenly distributed points along the rays. These samples are composited by using standard techniques to produce the cumulative color and opacity that reach the viewer.

Volume visualization usually involves creating images from 3-D data to aid in comprehension. In geophysics, the challenge is to generate meaningful images from extremely large data sets at interactive rates. As a result, research concentrates on creating new visualization algorithms and techniques to "render" these 3-D data sets.

The four most frequently used presentation techniques for rendering volume data are:

- slicing and dicing (probe) through the data (Figure 2 shows dicing; the cover of *TLE*'s January 2000 issue shows slicing)
- reconstruction of surfaces through autopicking, manual picking, and/or seed detection
- visualization as semitransparent gels (Figure 3)
- presentation of arbitrary oblique cuts in combination with one of the above

Most slicing or probe tools are difficult to manipulate in 3-D. On a workstation, controlling lateral displacement of such planes or cubes is easy, but depth displacement is often impossible. Most importantly, in a slice-based interpretation, picking is often interrupted by the need to reposition the slice(s). Repositioning the slice requires manipulation of

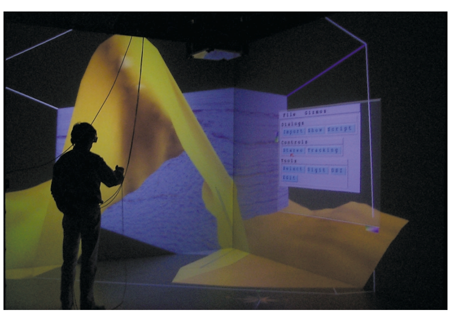

Figure 1. Immersive g0cad VR in ARCO's IVE visualization room.

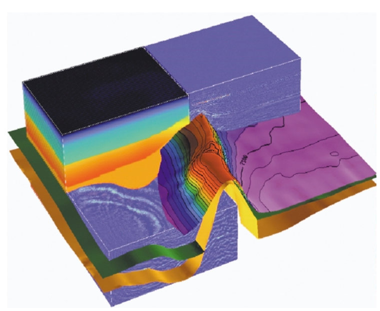

Figure 2. Dicing through seismic and velocity cube (courtesy of Elf).

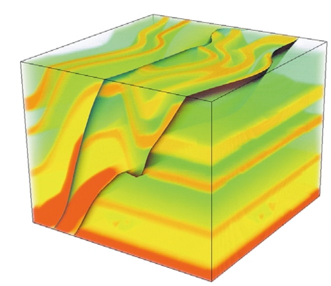

Figure 3. Volume rendering of the velocity cube of the SEG/EAGE overthrust model.

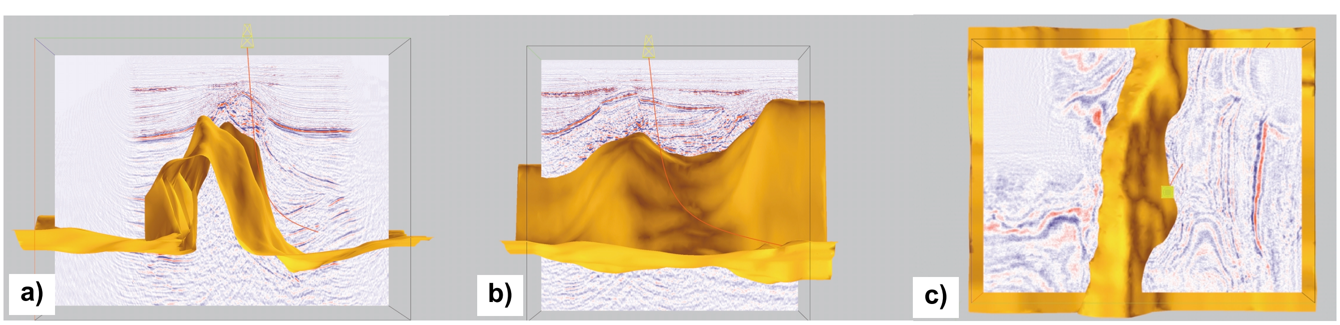

Figure 4. Using GeoTracker to face an in-line, cross-line, and depth slice.

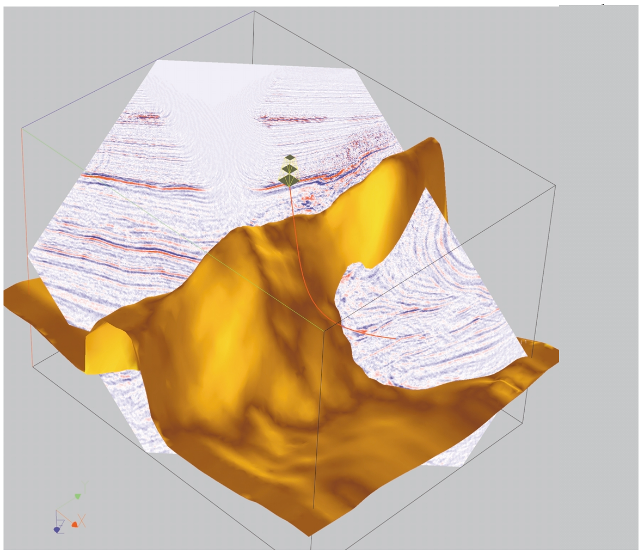

Figure 5. Arbitrary viewing angle; an oblique slice is extracted.

interface (difficult in VR), and the user often loses sight of the picking. Slices are usually in the main direction of the cube, and positioning oblique slices becomes a 3-D challenge for the interpreter. It is one reason that arbitrary oblique cuts have been the least used of the available techniques, although it is well recognized that they can display more coherent structures than arbitrary slices.

By analyzing these techniques, we get the impression that the 3-D volume visualization tool and interpretation must be tightly coupled. One way to achieve this goal is to fix the slicing tool at a given distance from the user. Therefore, if you move inside the data set, you visualize different parts of the volume. In g0cad VR, our tool makes visualizing in-lines, cross-lines, or time slices simple—you simply face the given direction (Figure 4). In the VR world, the user walks around looking at the data at a certain distance along a given axis and can easily browse through the volume by moving forward or backward.

In addition, we have developed a technique to extract oblique slices. Extracting oblique slices is then just a matter of facing the right direction. It is now possible to smoothly move from an in-line slice to a cross-line or time slice and to

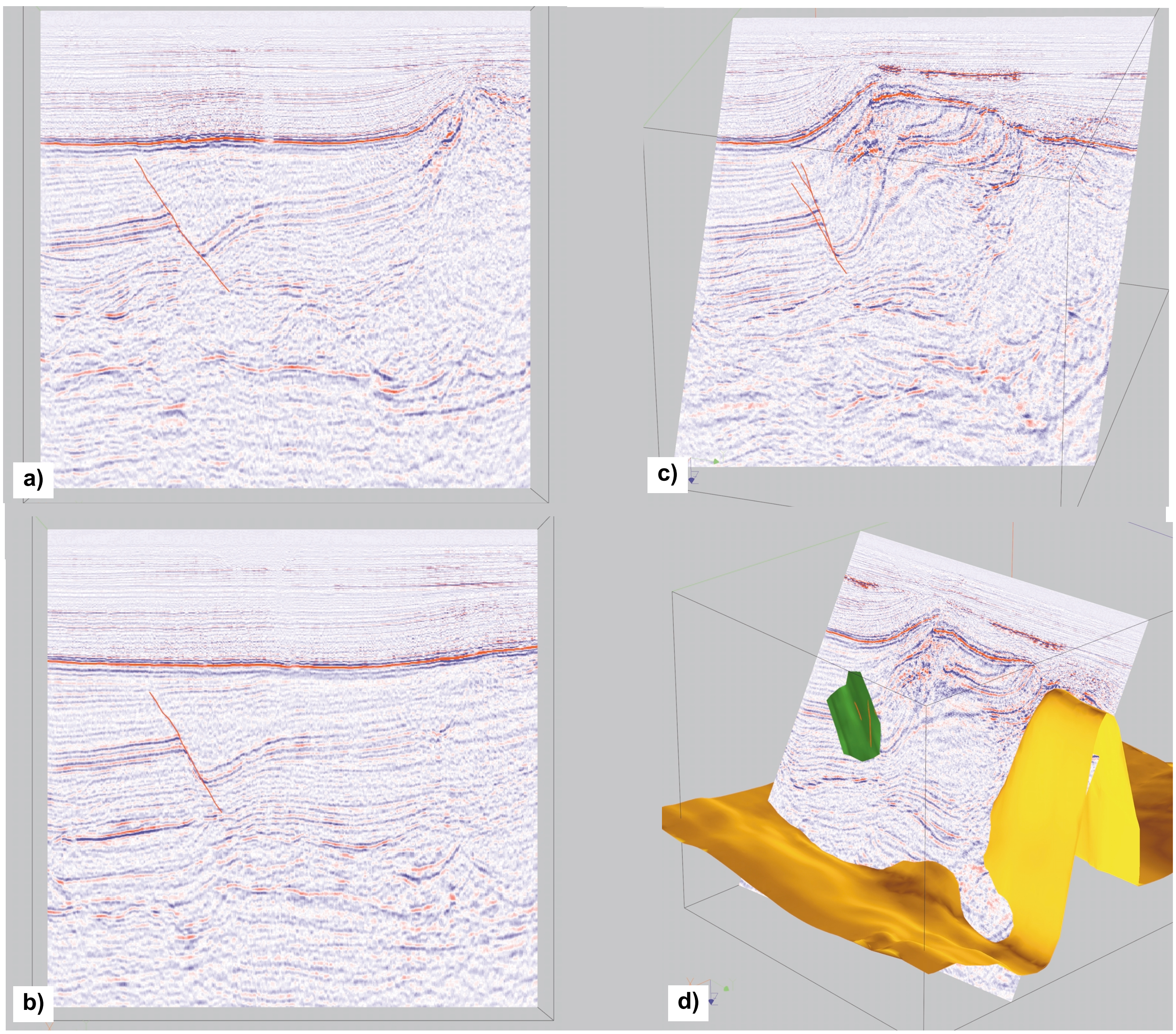

Figure 6. Picking a fault in 3-D: (a) interpret the fault on one slice; (b) step through the volume and interpret on the new slice; (c) move around your previous interpretations and interpret on an oblique slice; (d) build the fault.

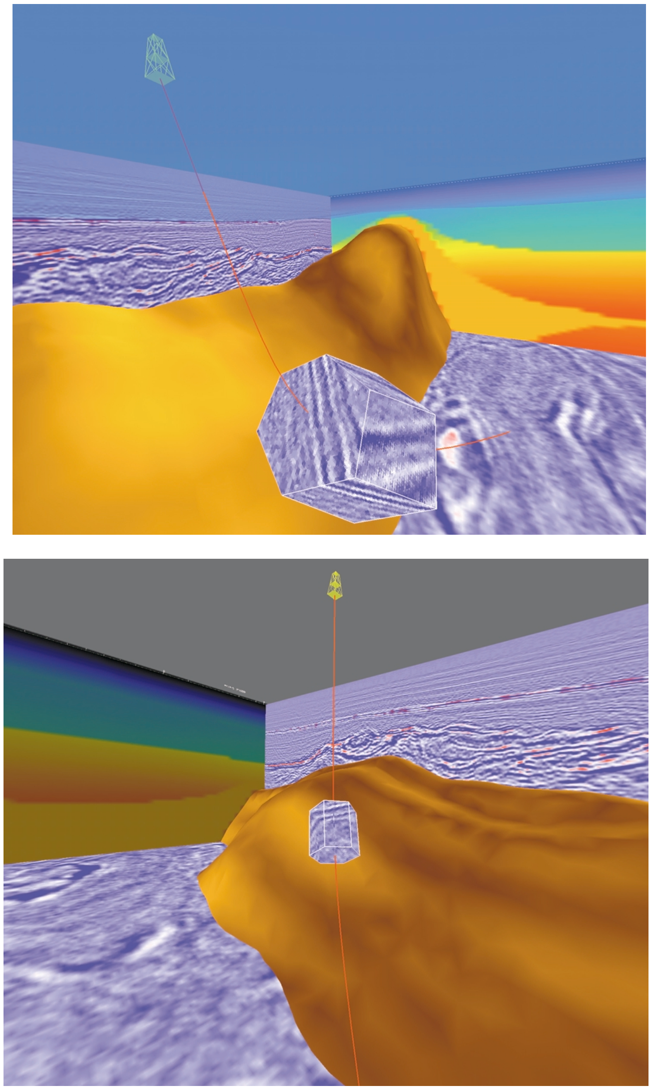

Figure 7. Probe moving along a well.

keep the eyes focused on the feature. In the VR world, you walk around the feature. It can greatly help you to interpret faults clearly visible in one direction but difficult to see in others (Figure 5).

Other objects can be added in the 3-D scene—wells, previous interpretation, or other fixed slices—that can help you position yourself. This assists in determining such matters as how far you are from a well or on which side of a fault you are standing. Seeing the previous fault interpretation in a totally different viewing angle while still showing the seismic data is very valuable to interpret the fault in this new oblique slice (Figure 6).

Depth can be added to the tool, therefore extracting thick slices and eventually the full volume.

A major problem in applying VR to subsurface visualization is the lack of scale and references. That is why in g0cad VR we have added the flexibility of using an existing object as a reference. You can follow a well, channel, or mine gallery while viewing other information in real time. You can stop the animation and get off the guided path at any time. This feature, for example, allows validation of planned wells. Because you are at the drilling head and looking at the volume characteristics near the well, you have a unique view of the reservoir (Figure 7). E

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