Exploratory Visual Modeling and Analysis of Microseismic Events

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GeoConvention 2012:Vision

Summary

Microseismic monitoring of reservoir processes is important for understanding hydraulic fracture geometry, estimating stimulated reservoir volume (SRV), and optimizing long-term field development. The analysis of data sets with many attributes, however, is still a challenging problem in the context of information and scientific visualization. We propose a new set of interactive visualization tools that combine existing and novel visualization techniques that we have developed. The main goal is to provide expert users with a more integrated visual analysis environment so they can interact, manipulate, explore and gain new insights concerning complex microseismic data. The proposed microseismic visual-analysis framework has two main components: (1) an interactive filtering view using synchronized parallel coordinates with 3D visualization, so that the user can easily focus his/her work on a desired subset of the microseismic events; (2) interactive selection of microseismic events for estimating the SRV, using sketch-based interaction and modeling techniques. These tools are deployed in both desktop and interactive multi-touch display technologies. Our proposed framework allows a more intuitive data manipulation and exploration, by assisting expert users in filtering/selecting/changing event attributes to guide the SRV estimation process.

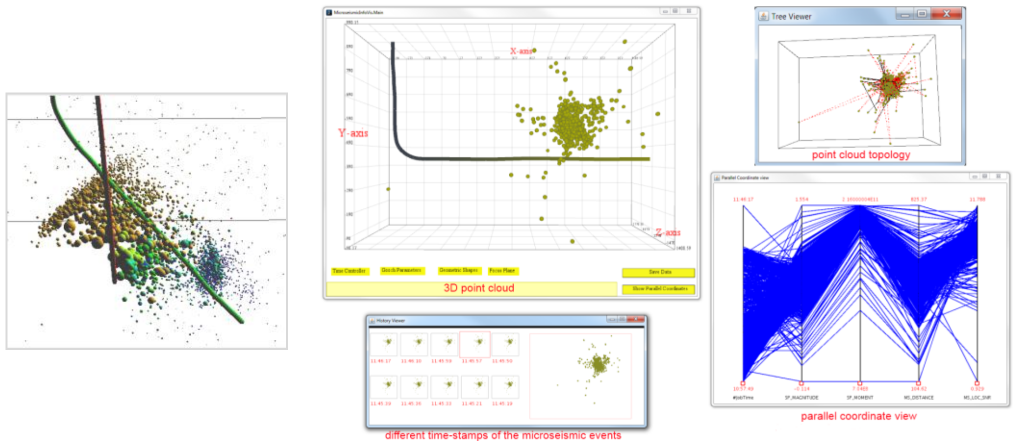
Introduction

Different specialists use microseismic data with different interests. Domain experts can use many of the microseismic events attributes to create correlations and improve the calculation of the Stimulated Reservoir Volume (SRV) [1]. We propose a novel set of tools which combines modern techniques of information visualization and sketch-based interaction and modeling (SBIM) [2] with the support of multi-touch collaborative environment [3].

Theory and/or Method

We propose a hybrid (interactive and automatic) exploratory visualization environment operating over the microseismic dataset provided by our industry partners. This dataset consists of the microseismic event point cloud and corresponding attributes. The system provides multiple synchronized views, each presenting the data in a different way, allowing the user to link and relate the meaning gained from one view with the other (Figure 1).

The main idea is to provide the user with a flexible way of filtering the data while keeping the context (i.e. overall 3D spatial distribution of the data), so any further processing or analysis (i.e. SRV calculation) can be done over a subset of the data that capture and reflect the important events.



(a) (b)

Figure 1: (a) The microseismic point cloud data with the related wells; (b) Synchronization of the parallel coordinates view (b1) with other data visualization components: (b2) 3D point cloud, (b3) different time-stamps of the microseismic events and (b4) the point cloud topology.

Examples

The 3D visualization component (Figure 1 (a) and (b-1)) displays every event point as a sphere with surface-color relative to the event's time-stamp value (Figure 1 (b3)). The goal of this type of visualization is to represent the data in its spatial distribution, providing basic insights about its geometry. This view also provides the user with the ability to specify a region of interest (ROI) where further processing will only be applied to events located inside that ROI. Finally, it provides the user with flexible graphical user interface (GUI) to explore the point event's connectivity in different geometric representations such as ball/tree structure [4] (Figure 2).The user can also separate the geometric representations in a custom view to prevent cluttering.

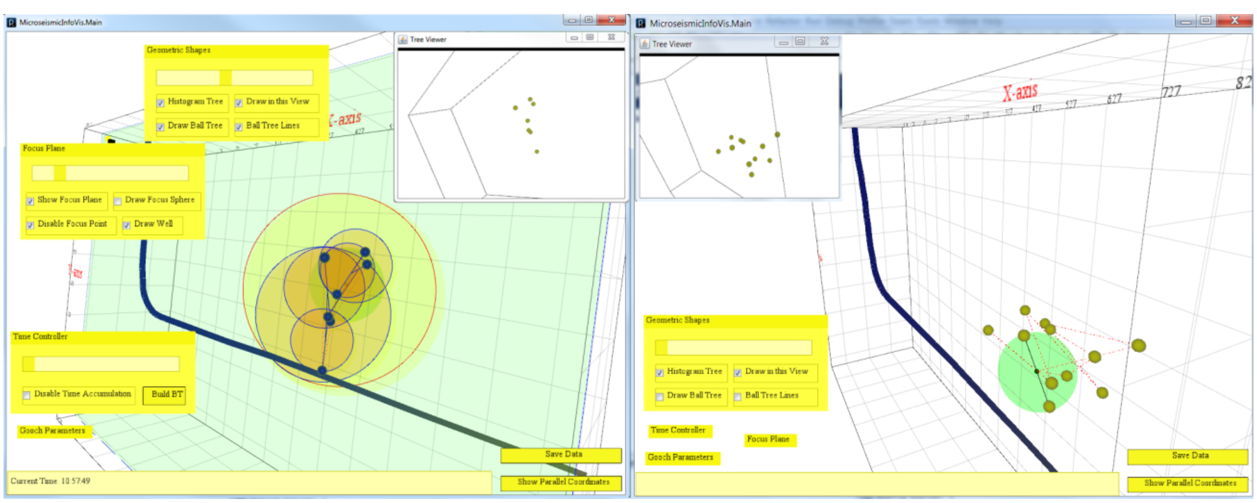


Figure 2: Ball-tree structure (left) and Histogram-tree structure with ROI in light green (right).

The Parallel Coordinates technique integrated in our system allows the visualization and analysis of high-dimensional data; it is an intuitive way to understand the main trends or relations among the high-dimensional data attributes. It consists of a 2D projection of the multidimensional data by representing every attribute/dimension as vertical axis [5]. We improved parallel coordinate's implementation by adding the concept of filter boxes over the 2D view so the user can interact and filter the data attributes in a more natural way (Figure 1(b1) and 3).

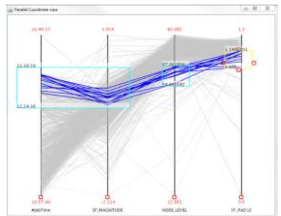


Figure 3: Parallel coordinates view with filter boxes that allow intuitive filtering over the attribute's dimensions.

It is also desirable to provide the expert user with an interactive tool, allowing interactive direct data manipulation and additional filtering based on user's interpretation of the data. Sketch-based interfaces and modeling approaches [2] were integrated so the user can sketch directly on the screen using pointing devices to select events to be removed or to be kept in the subset (Figure 4)

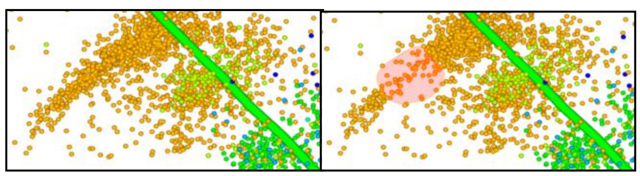


Figure 4: The user sketches an area on the screen (left) and removes 80% of the events in that region (right).

The traditional techniques for calculating SRV (i.e. binning or shrink-wrapping) are limited in terms of geometry [1]. To avoid the limitations imposed by these volume reconstruction methods we developed a new approach to calculate the SRVs by using alpha-shapes [6]. The alpha-shapes approach will allow more general geometry, such as torus like shapes, leading to a better control of the volume shape by the user and as a result a more precise reconstruction of the SRV. Figure 5 illustrates the SRV reconstructed with our approach.

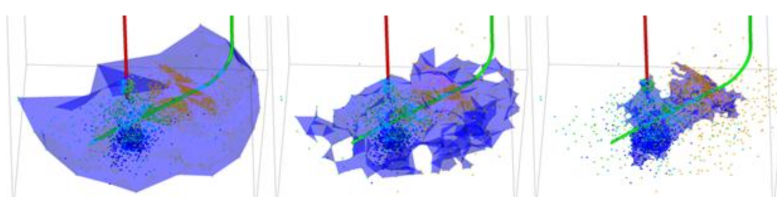


Figure 5: SRV calculation using different values for alpha.

To enrich user experience, we also implemented a tabletop version of the system (figure 6). The tabletop interface differs from the regular interface by using different input types like direct touch by fingers, hands and tangible devices (tags + physical objects) that are used to control visualization parameters. The tabletop interface also allows more intuitive navigation, manipulation and interaction with the 3D visualization and natural sketch using a finger. Finally, multiple users can work together by visually analyzing different attributes, filtering and sketching leading to improved productivity.

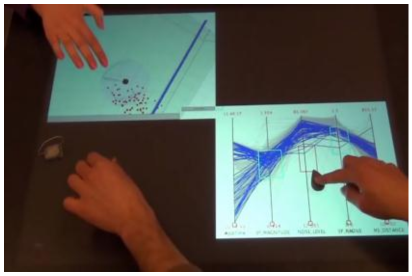


Figure 6: Users collaboration over Microsoft Surface; one user is filtering the microseismic events while the other is exploring the 3D resulted visualization.

Conclusions

We present a set of tools to visualize the multidimensional microseismic events in a more intuitive and flexible way. The proposed tools use parallel coordinates to (1) present the microseismic events attributes in parallel axis allowing the user to correlate the different data types and events (2) allow the user to easily filter the microseismic events and create a new set of microseismic events that can be used to calculate the SRV. SBIM-based tool allows users to direct manipulation of the data. The SRV is automatically calculated using alpha-shapes for a more precise SRV reconstruction. The use of tabletops was explored to provide a more natural and collaborative environment for users.

Acknowledgements

We thank ConocoPhillips for providing the microseismic data set. This research is supported by the NSERC / Alberta Innovates Academy (AITF) / Foundation CMG Industrial Research Chair Program in Scalable Reservoir Visualization.

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