Interactive Modeling, Visualization & Visual Analytics Challenges for Smart Oil/Gas Exploration & Production

Mario Costa Sousa, Department of Computer Science, University of Calgary
smcosta@ucalgary.ca

Summary

Exploration and Production (E&P) of oil/gas involve economically valuable but complex tasks. They comprise workflows with pipelined processes and inter-related disciplines (Geophysics, Geology, Reservoir and Production Engineering, Business and Economic Analysis) throughout the E&P life cycle of exploration, appraisal, development and production. In this cycle, the available data presents various levels of inaccuracies, sparseness, scale, uncertainty, and interactive modeling and visualization requirements.

Creating Reservoir Geoscience and Engineering (G&E) software applications allowing users to gain insightful and actionable information from such vast amounts of datasets is a challenging problem. Visualization technologies play a critical role in such applications. The fundamental goal is to present, transform and convert data into an efficient and effective visual representation that users can rapidly, intuitively and easily explore, understand, analyze, and comprehend. As a result, data is transformed into information and then into knowledge.

Visualization in oil and gas E&P began with the introduction of interpretation workstations in the early 1980s, progressing towards 3D voxel-based visualization and interpretation technology in the early 1990s. Advances in the fields of scientific & information visualization, computer graphics, high-performance computing, and human-computer interaction have enabled a significantly large range of reservoir visualization tasks. Today, visualization in reservoir G&E faces greater challenges due to the intersection of these advances with access to a broader *range of* data and application integration, the increasing uncertainty and complexity on the available information, and multi-disciplinary collaborative decision-making.

In this presentation I will discuss and motivate research and development on key issues about these categories of challenges and the requirements for novel interactive exploratory and scalable modeling, visualization and visual analytics solutions. I will bring specific examples from our recent works on key project themes that have been identified in conjunction with participating companies, as necessary to advance the interactive visualization, analysis, and understanding of oil and gas reservoirs within the E&P life cycle. I will discuss how these tools can benefit the E&P business by enabling better reservoir modeling and integrated workflows, creating new engineering opportunities and improving the collaborative interaction, exploratory visual data analysis, and decision-making process.

Key Research Problems and Challenges

(1) Data Integration – In the petroleum industry, visualization technology is considered a key integration tool for cross-discipline and cross-company collaboration, enabling the aggregation of numerous data sets into one environment. This creates the potential to bring major impacts to a variety of aspects of the industry from improved day-to-day communications to a better technology transfer and

increasingly powerful interpretive capabilities. Integrating workflows and datasets is non-trivial. Computationally expensive algorithms and a very large number of diverse complex, multimodal, and multi-scale datasets characterize oil/gas reservoir E&P systems. Unified reservoir models would support higher quality exploration and analysis of variability and uncertainty for better insights into the problems of visualizing and modeling reservoirs from cross-disciplinary perspectives. To meet this challenge, new techniques, methods and tools are required to enable scalable integration and management of reservoir data. Novel visualization systems are also required to allow integrated reservoir data management, visualization and interaction to work together smoothly and efficiently.

(2) Available Information – Existing reservoir visualizations can be complex, difficult to interpret and not completely applicable to the available information and visualization requirements of the different states and characteristics of the field development cycle: (1) early exploration, with limited data availability, high-level of uncertainty and the requirement of visualizing and interpreting the "big picture"; (2) exploration & drilling appraisal and field development, with medium levels of data availability, uncertainty and details to be visualized; and (3) production, with large data availability, a reduced level of uncertainty and requiring visualizations for insight and interpretation over a multitude of details. To meet this challenge, novel types of interactive visualization systems and techniques are required to reflect the state of field development and available (increasingly more complex) data and information. In addition, these novel visualization tools should allow for interactive visual exploration and analysis of the data, guiding the user through complex work processes, expressing the level of uncertainty from visual anomalies to detailed interpretations of reservoir G&E datasets.

(3) Multidisciplinary Users – In the E&P process, it is necessary to communicate with an assorted group of individuals who are involved in different stages of field development and decision-making. The background and knowledge about the field is diverse due to the wide reaching skill set needed to see these projects through. Geologists, geophysicists, engineers, business and project managers, accountants, and public relations individuals as well as many others make up the group. All these individuals comprise and guide a complex work process and they need an effective process to share information with each other. Visualization creates a dissemination method that everyone can understand regardless of background. The challenge is to determine the appropriate visual interaction and representation of the information for the user, their experience, and their role/task. The creation of effective interactive visual representations needs to be based on the intended user and their intended use of the system.

Key Research Themes and Projects

(1) Interactive Rapid Reservoir Modeling and Visualization from Uncertainty for Flow Simulation Studies – Develop tools to allow the rapid prototype modeling of structurally complex reservoirs integrated *with* flow simulators. These reservoirs contain an array of uncertain, complex geological heterogeneities that are at or below the resolution of seismic data. These heterogeneities may be structural, stratigraphic, sedimentologic and/or diagenetic in origin, and often impact flow behavior and hydrocarbon recovery; hence they must be modeled accurately.

(2) Interpretive Reservoir Visualization of Fused Multidisciplinary Data – Integrate multi-modal, multi-scale heterogeneous data from different disciplines (geophysics, geology, geochemistry, GIS) in 2D and 3D, allowing fast throughput and interactive exploratory visual analysis and direct manipulation with the data, deployed in a variety of integrated input/output technologies to allow collaborative visual analysis, data exploration and decision-making.

(3) Interactive and Intuitive Post Processing of Reservoir Simulation Results – Develop the next-generation of post processing reservoir visualization technology addressing: (1) the growing scale and complexity of reservoir simulations; (2) the need to integrate, visualize and explore a broader *range of*

data fused with the post-processing simulation; and (3) the need for multi-disciplinary collaborative exploratory visualization, analysis and decision-making. Four main specific goals include: (1) visualizing multiple aspects of the reservoir model integrating data from other disciplines and workflows; (2) determining a better understanding of the hidden dynamics in the reservoir; (3) defining how to interact directly and intuitively with the data; (4) efficiently handling large simulation files and multiple datasets.

(4) Exploratory Visual Analysis of Multiple Reservoir Simulation Runs – Develop novel visual analytics tools and solutions to support uncertainty quantification for automatic and assisted history matching and oil field optimization. Comparison of multiple runs produced from history matching and visualization of simulations will allow the user to maximize the available information and facilitate decision-making. This project serves as a basis for a more generic framework for the large number of opportunities for optimization during field development cycle (with or without historical data).

(5) Interactive Computational Steering Framework for Reservoir Flow Simulators – Develop interactive software tools that support a generic framework for interactive visual steering to be integrated with existing high-end commercial reservoir simulators for black oil, compositional, thermal, streamline simulation studies. The user will have the flexibility to compare different alternatives, to correct an unacceptable reservoir dynamic behavior or to seek an improved development alternative.

Acknowledgements

This research is supported by the NSERC/Alberta Innovates Technology Futures (AITF)/ Foundation CMG Industrial Research Chair program in Scalable Reservoir Visualization.