Touching the Depths: Introducing Tabletop Interaction to Reservoir Engineering

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ABSTRACT
Modern reservoir engineering is dependent on 3D visualization tools. However, as we argue in this paper, the current tools used in this domain are not completely aligned with the reservoir engineer's interactive needs, and do not address fundamental user issues, such as collaboration. We base our work on a set of observations of reservoir engineers, and their unique interactive tasks and needs. We present insightful knowledge of the domain, and follow with a prototype for an interactive reservoir visualization system, on the Microsoft Surface. We conclude by presenting a design critique we performed using our prototype, and reflecting on the impact we believe tabletop interaction will have on the domain of reservoir engineering.

Keywords: Tabletop, Collaboration, Reservoir Engineering, Visualization System, Tangible User Interface

INTRODUCTION
Reservoir engineering is a domain that greatly relies on 3D visualization tools. The reasoning is clear: the processes being followed and the decisions being made are all taking place deep underneath the engineers' feet, accessible only via remote sensing and probing. Still, the tasks at hand are all but abstract, ranging from drilling wells to extracting oil/gas resources. The complex and interdisciplinary nature of the activities resulting from the reservoir engineer's decisions, together with high operation costs, require meticulous decision making process, strong collaboration, effective communication, as well as a clear and common understanding of what is happening in the oil/gas reservoirs.

The reservoir engineer's awareness of the oil/gas resources being explored is based solely on abstractions: a set of virtual computational models representing the reservoirs, explored via sophisticated visualization and simulation tools. Following this inherent importance of interactive visualization tools to reservoir engineers, we are interested in gaining more insight on how this group of users approach their unique task. Which interactive tools can make their actions more effective, efficient and intuitive? How can advances in human-computer interaction, 3D visualization and automation enhance the quality of their development cycle and analytic results? These simple questions guide our groups' research on new interactive solutions for reservoir engineering.

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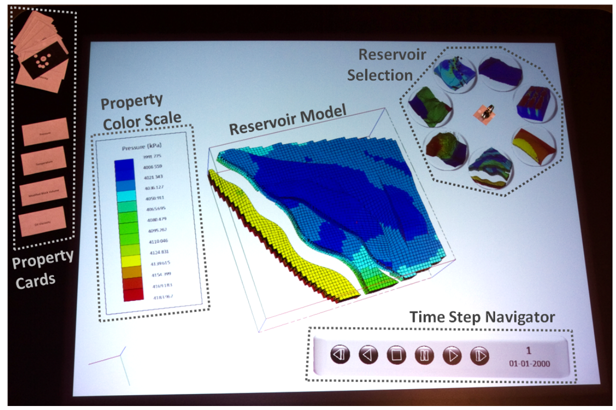

Figure 1: The components of our tabletop-based reservoir engineering visualization system.

We conducted a set of user observations and collected expert feedback to help shed light into the use of reservoir interactive visualization tools, and gain understanding of some of the needs not being tackled by the current tools. Several interesting characteristics arose from our observations, particularly poor interactivity and a strong, but weakly supported, collaborative task aspect. Following that, we argue that many of the currently unaddressed interactive needs of reservoir engineers can be mapped to the benefits of tabletops: direct multi-touch interaction on large displays, tangible user interfaces and face-to-face collaboration.

In this paper, we discuss our tabletop design approach for a fully functional prototype of a reservoir visualization interactive tool, based on user observations and expert interviews, and followed by an evaluation via a design critique. We believe that tabletop interaction affords a completely new, highly promising, and mostly unexplored modality for reservoir engineering.

RELATED WORK
Several interactive visualization technologies have been explored in the petroleum industry, including visualization rooms, stereoscopic viewing, immersive virtual reality environments, and haptic devices [5, 9]. Many of these technologies aim at supporting multiple user awareness and viewing of oil and

gas exploration and production; however, most of them are limited to single-user interaction.

There is little work related to petroleum engineering domain and related applications on interactive digital tabletop. Ishii et al. [4] proposed a sculpting interface for modeling geological surfaces; Couture et al. [2] incorporated a tangible user interface to a system targeted for geophysicists and the analysis of seismic data. Recently, an application called Petrotrek was released for the Microsoft Surface [6], designed to monitor oil production plants. To our knowledge, our prototype is the first to map a practical reservoir engineering visualization system to a tabletop environment.

THE RESERVOIR ENGINEER AND 3D VISUALIZATION

Oil/gas reservoir exploration and production involve complex tasks, with multi-phase workflows and dependent on a multitude of variables from four main groups of inter-related disciplines: geophysics, geology, reservoir and production engineering [1]. For a new exploration project, field measurements are made using diverse techniques. Seismic data are gathered and interpreted by geophysicists, while geologists incorporate contextual knowledge necessary to validate and understand the environment from which the readings are collected. The output, a 'static' geological model, is handed down to the reservoir engineer, whose work consists of extending the static model to create a 'flow' model which may be used to determine the best possible drilling and production strategy. The outcomes of the reservoir engineer analysis are later used by the production engineer, who has the responsibility of producing an economically viable production plan. This process requires considerable interplay between the reservoir engineer and the production engineer, as the abstract analysis takes shape in concrete physical actions. In case of a mature field (when production is already established), the reservoir engineer also monitors oil/gas production and matches it with the model-predicted behaviour, in a process called History Matching [1]. Overall the reservoir engineer is constantly engaged in a critical, meticulous and highly collaborative technical process which strongly relies on visualization of the reservoir.

Seismic data serves as a starting basis for the 3D shape of the geologic model (often represented as a corner-point grid [1]) in which each cell will represent a physical partition of the reservoir, as part of a layered volumetric entity. Each of the cells on the model is associated to *property values* (e.g. permeability levels of that fraction of the earth) which can also *undergo variations over time* (e.g. the oil saturation levels after 10 years of production). The decisions on where to drill wells and how to produce must take into account all these property variations and correlations. For that, the reservoir engineer uses specific computational tools that allow the manipulation and visualization of this model under a number of perspectives. Following, the work of reservoir engineers is taking place mostly in their office, interacting with simulation and visualization tools. The computational tools used by them can be classified following these categories: (1) *Pre-processing tools:* Used to build and configure resource extraction scenarios to a static reservoir model using the data provided by the geologist; (2) *Simulators:* It's a heavy and time-consuming computational component, responsible for forecasting reservoir behaviour by numerically simulating fluid flow according to the engineer's configuration. It outputs a complete flow model, with newly computed property values; (3) *Post-processing tools:* An environment for viewing and analyzing the immense amount of data generated by the simulators. It includes both the creation of graphs (2D plots) and 3D visualization (our focus on this paper).

The development of 3D visualization tools represented a real breakthrough in reservoir engineering [8, 9]. Allowing real time manipulation, it greatly facilitates understanding and analysis of the model, as well as communicating ideas to other team members [8]. Initially interpreted from raw piles of computer printouts, from the late 80's simulation output began to find its way into 3D visualization. Although hardware limitations severely impacted interactivity and model size, technological advances eventually allowed the visualization of more and more complex structures. When desktop computers were powerful enough to run Visualization software, reservoir engineers began having their own workstations.

This last evolution is two-edged, however, as Thomson and Poupon [8] reflect on the transfer to the desktop environment: *'(reservoir engineers) were spending more and more time in front of their monitor, and less and less time directly interacting with their colleagues. The days of leaning over a large work table covered with seismic lines, maps and well logs are long gone... even though these work sessions were developing true multi-disciplinary approach and promoting different perspectives'*. We find the revitalization of these highly cooperative environments a matter worth investigating, for collaboration is essential in the petroleum domain. Its complexity makes the interchange of ideas between different areas of expertise an essential practice in the field, as well as validation of one's work through peer-review sessions.

OBSERVATION SESSIONS

Seeking greater insight into the work and the environment of reservoir engineers, we observed for a week the activities of the customer support office of a company that commercializes tools for the domain. Four trainees composed this group, all being engineering students seeking a specialization in the petroleum industry. Their work consisted in solving issues users encounter when operating any of the company's tools. Two of them had recently joined the team, while the remaining had one year of experience in the function. The latter group performed the trickiest support requests, and also served as mentors for the new interns on their free time.

We chose a customer support environment instead of regular reservoir engineer office mainly due to time restrictions: an actual oil project may last for years, requiring a long term commitment to observation. Contrastingly, a customer support office would receive isolated reservoir engineering tasks in great number and range, even in our limited timeframe.

We adopted an open and subjective observation approach. Notes were taken, reporting and time stamping observed events. Dialogues were transcribed when possible. In the intervals between tasks, interns were inquired about the work they were performing and how the tools helped them achieve their goal, in a way to interfere as little as possible on their

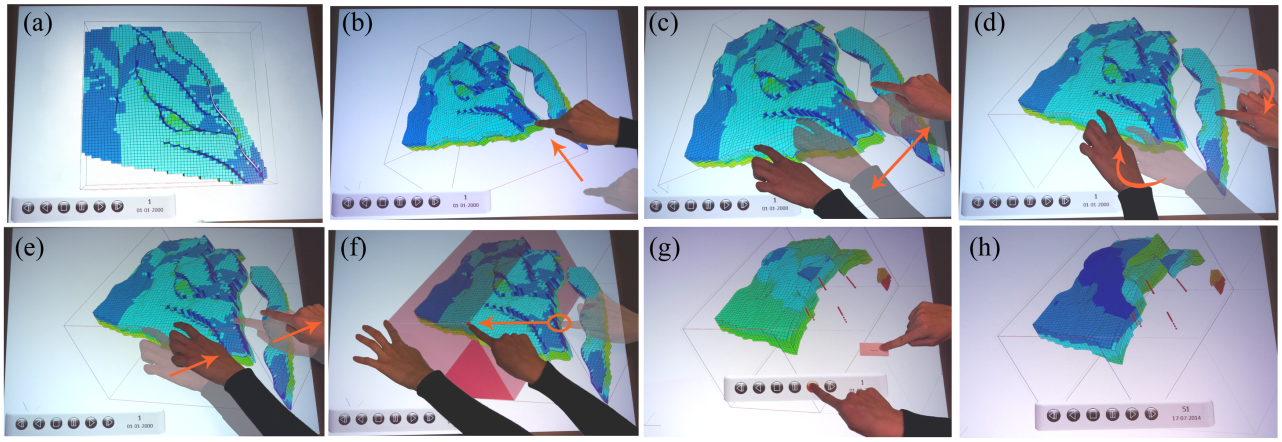

Figure 2: A step-by-step usage of our tabletop prototype with the 3D reservoir model in Figure 1 (Property color scale was removed for better depiction). Ghost imaging and orange arrows and marks show previous position in gesture execution. (a) A reservoir model, at time-step 1; (b) one touch orbiting, (c) zooming, (d) rotating, (e) panning, and (f) performing a cross-sectional cut of the model to expose its internal 3D layer structure; (g) the resulting view after the cut. A different simulation property is selected with a property card, and time step navigation is initiated; (h) visualization of the simulated property values for step 51.

job. In the following paragraphs, we will briefly discuss some of the most relevant aspects we concluded from this experience:

On Interactivity While we did not conduct a rigorous and extensive study to evaluate all available tools in the environment, we were convinced of the need for more interactive tools in the domain. The number of features in today's tools can be overwhelming for both novice and expert users.

On Tool Usage Expertise There is a deep coupling between reservoir engineering proficiency and familiarity with related programs. The work of this professional depends heavily not only on actual field knowledge, but also on usage skills of specific (and complex) computational tools. Due to this challenging nature, usage often requires long and extensive training. Also, it is very likely that even a seasoned professional will fail and stumble when interacting with unfamiliar tools.

On Cooperation We observed numerous cases of collaboration and interaction in the study. It was naturally recurrent among the trainees, due to the learning environment established for the new interns; they would often ask questions to their seniors on how to access a specific function in the programs. However, it was also frequent for graduated reservoir engineers to come help the veteran trainees on particularly complicated support cases. We also observed the opposite happening, when reservoir engineers came to consult the interns relating to tool usage. We believe this reflects not only the mentor-mentee relationship of the internship, but also the inherently intricate nature of their job.

THE PROTOTYPE

With the interactive and collaborative needs of the reservoir engineer in place, we decided to experiment with an interactive visualization system on tabletop. One of the fundamental benefits of tabletop interaction is its facilitation of collaborative work [7]. Combining reservoir visualization with tabletop interfaces could potentially ease data exploration and help facilitate discussions between individuals [8]. Tabletops would also enhance the repertoire of interaction capabilities of reservoir model manipulation, through touch and tangible devices. We selected a few important operations available in Petroleum Visualization systems and implemented a prototype on the Microsoft Surface (MS), using C#, XNA and the MS SDK. A general view of the interface and its components is provided in Figure 1. Reservoir datasets were generated using CMG's family of simulators (IMEX, GEM and STARS), which are directly imported in our program.

Manipulation of the reservoir model is done through touch, with 2D gestures – such as pinching and spreading – detected by the MS SDK, which we interpret and map to fundamental 3D transformations for manipulating models, i.e. [3]. *Orbiting* (Figure 2b) is performed with one touch; the (x,y) delta translations of a touch are mapped to spherical camera rotations. *Zooming*, *rotation*, and *panning* (Figures 2c, d, e) are achieved with two or more touches, and can be performed simultaneously. Zooming is mapped to relative distance variations between touches; rotation is performed when touches rotate around a single pivot point; and panning, when touches are equally displaced.

We provide property cards (Figures 1 and 2g) to visualize different reservoir properties. Each card contains the title of a property, associated to an unique MS byte tag at the back. By placing a card on the screen, the whole model displays its corresponding property values (Figure 2g). This format was conceived to provide more user flexibility for selecting properties as well as allowing a quick shift between them, and thus facilitating correlation.

The color scale (Figure 1) is a movable and resizable component that displays color codes associated to the value range of the selected property; the time step navigator (Figure 1, 2g-h) is a movable-only component similar to a media player, allowing visualization of data changes through time. Component manipulation is achieved with the same gestures described for model panning (translation), zooming (scaling) and rotation; one-touch interaction performs a translation.

We also offer a mechanism to display internal parts of the reservoir (such as property values and well paths) by specifying a 'cutting' section through a manipulable bounding box (Figure 2f). The simultaneous selection of two adjacent corners of this box defines the cutting axis, which can be adjusted through "corner dragging" to restrict the selection volume. Visual cues are provided during this operation, showing where the cut will be performed. When the touches are released, the visualization is adjusted to display only the cells inside the defined sub-partition (Figure 2g).

Additionally, we provide a tool for the user to select other models for visualization. A tagged tangible object brings out a circular menu with a set of available datasets (Figure 1).

DESIGN CRITIQUE AND DISCUSSION

In a domain-specific application such as the one presented here, considering feedback from actual users is crucial. Therefore, we hosted two design critique sessions, with around 15 expert practitioners from the oil industry. We presented and demoed our prototype, we invited the participants to interact with it and then we asked for their informal feedback. Our goal was to expose the users to the concept of digital tabletops and discuss its potential on their work environment, as well as brainstorming ideas for future development. Both groups were very satisfied and excited with the concept, and also offered many suggestions for improvement. Below, we present some relevant discussion themes, from feedback gathered through these sessions.

Team Engagement We received very positive feedback concerning the collaborative potential of the tabletop environment. Some of the comments were related to team focus and engagement, as well as favouring interaction amongst complementary disciplines (i.e. *"Everyone has ideas, but it is hard to convey and converge them in a group"*). Also, it was stated that a more inviting work environment is not only pleasing, but it also stimulates and fosters collaboration; users want a *"place where people will enjoy going to"*, but also having an *interactive* collaborative work environment, more than just a room to look at end results in 3D (i.e. Visualization rooms).

Remote Collaboration As company offices and teams are commonly spread around the world, they brought to our attention the importance of providing means for remote collaboration, such as local and distributed manipulation of the reservoir model, plus voice/video conferencing.

Tangible User Interface For the prototype, we prepared a set of 36 property cards. The participants liked the idea, but commented that they found cumbersome to flip all the cards to find a single property. Participants proposed selecting 5 or 6 more relevant properties and associating each of them to a special tangible object, with a differentiable and intuitive shape for quick recognition. Another suggestion was to let the user decide which properties are relevant, by allowing an interactive association of properties to a set of wild cards.

Enhancing the Visualization Participants provided interesting ideas for interactive visualization resources that would nicely fit in a tabletop environment, including: (1) intuitive ways for spatially manipulating geological layers of the reservoir model; (2) synchronized exploratory visualization between layered 2D view and 3D views of the reservoir; (3) selecting regions of interest to allow further inspection, and present more detailed property information about them.

Ergonomics One of the participants commented it was uncomfortable to sit around the table for a long period of time. Considering the prolonged interaction that such a tool might require, this was considered a very relevant remark. While the chosen platform – the Microsoft Surface – is more casual and less aimed for continuous extended use, height adjustments of the table and surrounding chairs could help reduce the fatigue even with the current setup.

Training Due to the collaborative factor and the ease of operation, training was also highlighted as an interesting use of our interface. Additionally, participants suggested its exploration as a mean to better communicate ideas and technical aspects between individuals with varied levels of expertise.

CONCLUSION

We presented insight into practical and collaborative aspects of the tasks of a reservoir engineer, from initial explorations in the field. We also designed and implementation a tabletop prototype for reservoir visualization, and its preliminary evaluation. We plan to extend the capabilities of our prototype and proceed with a more complete evaluation of its performance in valid domain-specific visualization tasks, hoping for a greater impact on the reservoir engineering community.

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