Towards Advancing Reservoir Model Analysis with Virtual Reality

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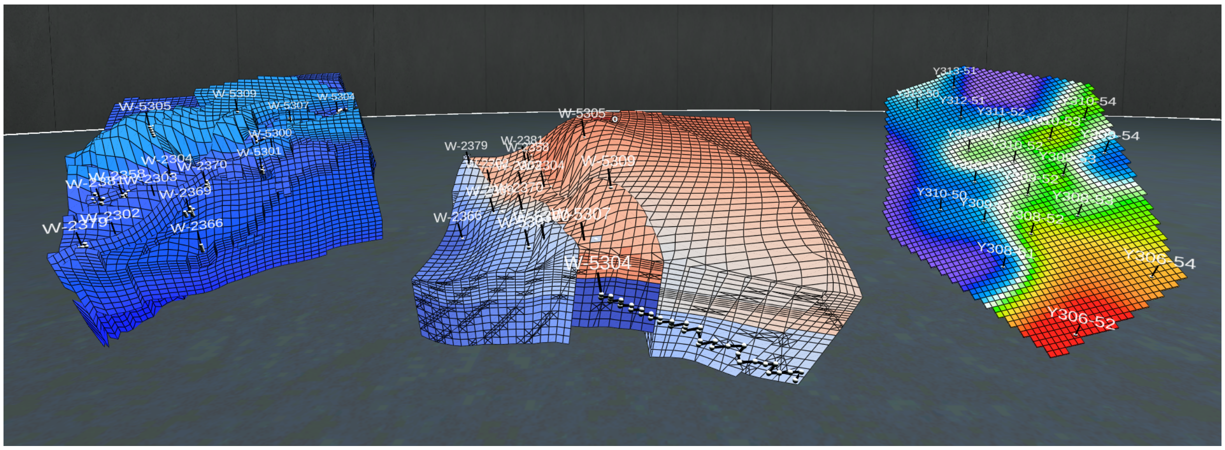

Figure 1: Three reservoir models visualized in virtual reality for analysis. The center model shows cells with colors mapped to cell values for the porosity property via a default red-blue color mapping. The effect of a plane clipper cutting through this model's front can also be seen revealing a well path and its perforations inside, seen as a black line with white spheres. The leftmost model is the same model, except it's been rotated to be seen from a different perspective. A blue color mapping and property filter has been applied too, the latter removing the top-most cells to reveal the tops of some wells. On the right, a different model is custom color mapped to highlight cell trends and areas of interest.

Abstract

Traditional software tools for visualizing and analyzing reservoir model data utilize 2D displays, and thus can only offer capabilities subject to the restrictions of these technologies. We describe ways to advance reservoir model analysis workflows beyond conventional methods by leveraging the strengths of virtual reality technologies to improve how one understands, analyzes, and interacts with reservoir models. Specifically, we discuss a reservoir model analytics tool exploring how virtual reality can be used to improve the spatial perception and navigation of data, support more intuitive and natural data interactions, enable larger workspaces, and promote more effective collaboration over reservoir models.

Keywords: Immersive, Analytics, Virtual Reality, Reservoir, Engineering, Human-Computer Interaction, Information, Workflow, Visualization, VR.

Index Terms: Human-centered computing—Visualization—Visualization Application Domains—Information visualization; Human-centered computing—Visualization—Visualization Application Domains—Visual Analytics; Human-centered computing—Human computer interaction (HCI)—Interaction Paradigms—Virtual reality; Applied computing—Physical sciences and engineering—Engineering;

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1 Introduction

Immersive visualization technologies have much potential to enhance human understanding of underground oil and gas reservoirs and improve reservoir engineering workflows which analyze models of them. Reservoir engineering is a discipline integral to the exploration and production of hydrocarbon resources. Specifically, reservoir engineers are concerned with finding optimal and innovative ways to extract hydrocarbons from underground reservoirs by maximizing the discovery and extraction of fossil fuels while reducing environmental impact. To do so, they often utilize computer simulations of subsurface processes to predict outcomes of different reservoir extraction scenarios and ensure projects are both economically viable and environmentally sound [3]. Both the reservoir models used by these simulations and the simulation results must then be visualized and analyzed to obtain a clear understanding of various subsurface properties and physical processes, and how these may potentially impact different approaches of petroleum extraction [30]. This is often performed not just by a single reservoir engineer, but by many collaborating together alongside other geological and petroleum professionals. These reservoir models are typically large, complex three-dimensional grids of cells, where each cell contains its own data of various geological and reservoir properties, such as pressure, porosity, permeability, and oil saturation, and how these may change over time. Pre-existing and planned wells are also typically included in these models to help determine how their presence impacts the underground reservoir and the surrounding geology over time.

The analysis of reservoir models is a vital aspect of the reservoir engineering process, and as such, it is important to have tools that both clearly visualize these models and support effective interaction with them during the analysis process to maximize a user's ability to gain insight from the data. Conventional tools, such as Petrel [27] or the CMG Suite [21] seen in Figure 2, typically employ a

2D screen-based WIMP user interface (UI). Although a common approach, their capabilities are limited by their reliance on physical 2D screens. For example, the restricted screen real-estate of one or a few screens imposes a limit on how many reservoir models one can have effectively visualized in front of themselves at the same time during cross-comparison analysis tasks. Additionally, this also restricts how large one can make these models when trying to analyze their finer details since one cannot increase their size past that of the screen, and important contextual information from surrounding cells can be lost when zooming in. Also, reservoir models are three-dimensional in nature. When visualizing them on 2D displays they are flattened to pseudo-3D perspectives, removing important spatial information from being perceived and interacted with in its natural spatial dimensions. Collaboration over models is also less effective, since when remotely collaborating across devices collaborators must rely merely on verbal and video communication. Alternatively when collaborating in person, all are restricted to using a single workspace or viewpoint at a time.

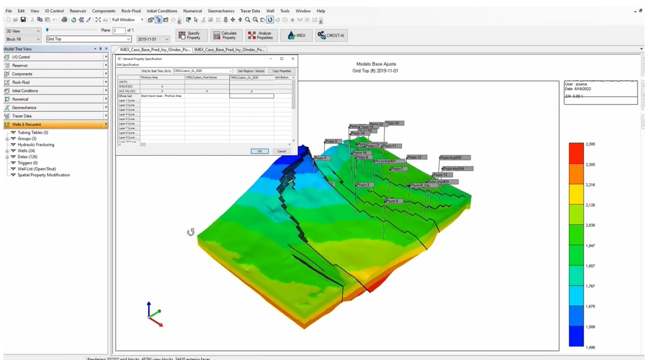

Figure 2: A view of CMG Suite's user interface. Note how popup windows can end up occluding the reservoir model. Image sourced from the Computer Modeling Group Ltd. [4,21]

Virtual reality (VR) head-mounted displays (HMDs) on the other hand suffer no such limitations and have been demonstrated to be advantageous across many scientific fields [5,6,10,14]. One reason for this is that the virtual display real estate available in VR is far beyond what is available with screens [18]. Thus in immersive VR workspaces, not only would a user have the display real estate to place a large number of reservoir models and other virtual objects around themselves in any size and direction, but since stereoscopic VR HMDs display virtual surroundings in what a user perceives to be true 3D, one can also visualize and interact with these natively 3D models in true 3D for potentially improved spatial perception and better depth cues [12,13,24,28]. VR HMDs also offer large, customizable workspaces in which users may better spread out and organize their data, allowing one to build virtual workstations for data analysis tasks [19,20,22]. Natural forms of data interaction [8,11,15] and interpersonal communication while remotely collaborating [2] are also better supported in VR compared to screen-based methods. To explore how such potential benefits of VR technologies may be best used to assist reservoir engineering workflows, we present a VR reservoir model analysis tool being developed as part of ongoing research and discuss how it is used to analyze and interact with reservoir models.

2 Related Work

Although prior work has demonstrated that immersive technologies show promise for improving reservoir engineering and geological data analytics tasks, how best to apply these technologies to enhance such workflows remains an open research question. Using virtual reality to visualize and interact with 3D geological datasets has been explored by works such as Santos et al. [26] and Lawton et al. [16], the former remarking expert feedback indicated the sense of immersion helped to identify data features and 3D structural patterns. For supporting reservoir engineering analysis specifically, immersive CAVE technologies have been explored [7,9,17,25]. More recently Ramos Mota et al. [25] have applied VR HMDs to reservoir engineering analysis tasks such as probing data from individual cells or creating and analyzing well trajectories. Formal evaluation revealed promising results, finding that the three-dimensional perspective of immersive environments for working with reservoir models was generally considered to be superior to that of conventional screen-based methods. In addition, comparing VR HMDs and CAVE approaches, VR HMDs were found to be more useful for single-person tasks by most, but concerns were expressed regarding the limitations of VR headsets regarding collaboration, field-of-view, visual fidelity, and long-term comfort. Now that VR HMD technologies have progressed to better address some of these limitations, our research aims to expand upon such prior research by further exploring how leveraging HMD strengths may be used to improve reservoir model analytics workflows as well as investigate how immersive collaborative analytics between multiple users can be effectively achieved within shared virtual workspaces.

3 Key Features of the Immersive Reservoir Model Analytics Tool

3.1 Reservoir Model Visualization

Our immersive application creates 3D visualizations of reservoir models from reservoir simulation output file types commonly used in industry. As seen in Figure 1, primarily these visualizations consist of thousands or millions of cells which make up a reservoir model's volume. To visualize the data stored in each cell, a color mapping algorithm is used which colors each cell according to its stored value for the chosen property. Users can change what property they wish to map the cell color to, allowing for the visual analysis of how different geological and reservoir characteristics like pressure, porosity, and oil saturation change over the course of an entire model. This is useful for quickly getting an idea of how two cells or cell groups in any section of a model compare to one another for a given property. Some properties change over time and so, as seen in Figure 3, our tool also allows for one to select different timesteps for the time-varying properties and see how the cell colors change as one progresses through time. This is especially useful for allowing reservoir engineers to see how drilled wells may impact the subsurface conditions of a reservoir and its surrounding geology over time. By default, our tool uses an industry-standard color mapping of a specific red-to-blue color gradient as seen in Figure 3 and Figure 4, however fully customizable color mappings like that in Figure 1 can also be created which enable one to create unique views of a reservoir model to place visual emphasis on desired subsets of its cells which one wishes to highlight and better analyze.

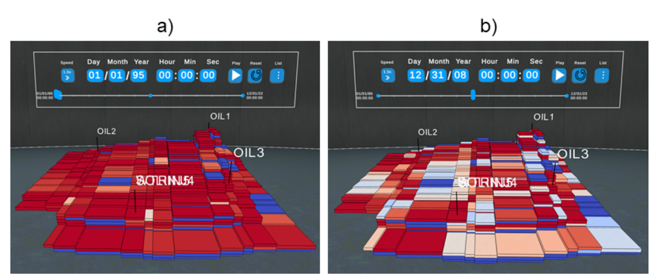

Figure 3: An example of a reservoir model's selected property, in this case oil saturation, changing over different timesteps. The UI to switch between different timesteps can be seen above the model.

Alongside a reservoir model's cells, its wells are also visualized within the model. Well paths through the ground are shown as black lines, and the perforations where holes connect a well to the reservoir are shown as white spheres to better stand out from the colored cells. The names of each well are also present above its surface origin for quick and easy identification during analysis. The leftmost and central models in Figure 1 feature exposed well paths, their perforations, their connections, and their names.

3.2 Cell Filtering

Cell filters allow users to visually remove large amounts of cells in a reservoir model from view to place better emphasis on other cells of interest or gain better views of them. They are also useful for gaining access to cells and wells on the interior of reservoir models which are otherwise occluded by other cells. This allows for analysis to not just be performed on the exterior of the reservoir models, but is critical for allowing reservoir engineers to gain access to a model's interior where important and useful information is located. Our tool provides three different types of cell filters for users to utilize: property filters, clippers, and cutters.

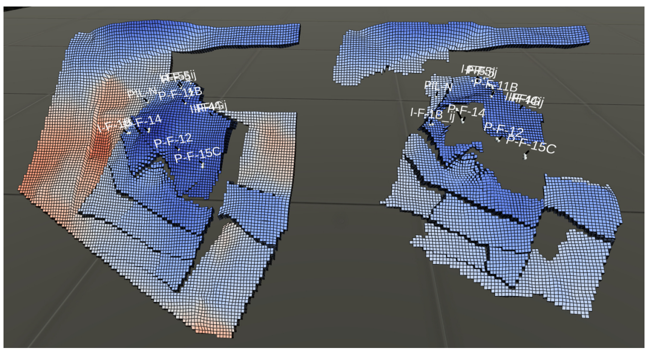

Figure 4: Visualization of a reservoir model before (left) and after (right) a property filter for pressure has been applied.

Property filtering, as demonstrated in Figure 4, enables users to quickly remove all cells in a model from view whose individual cell values do not fall within a value range chosen by the user for a selected property. This type of filtering is particularly useful for rapid, model-wide removal of cells that are not important to the analysis task at hand and allows one to place sole focus on the cells with property values important for a specific analysis task. It is notable that the property chosen for filtering does not need to be the same as the one used for mapping color to the cells, which allows for multi-variable analysis tasks to be performed. In fact, the effects of multiple property filters can be combined at the same time to find highly specific subsets of important cells within a reservoir model.

Clippers are a type of volume-based spatial filter which removes all cells from view which lie inside of the volume of a filter's 3D shape. As shown in Figure 5, our tool provides users with clippers in three different shapes: cubes, spheres, and planes. Using one's hand-held controllers, all three of these clippers can be grabbed, scaled, and placed by the user anywhere within a visualization they wish, giving users the ability to rapidly remove large portions of the model with ease and expose views of the interior. Plane clippers are especially useful for removing all cells on one side of its plane from view, granting users the ability to gain views of important cross-sections of a visualization. This capability is especially important to expose well paths and the cells they travel through to assist reservoir engineers in planning or analyzing well paths, an example of which can be seen in Figure 6.

Cutters are a plane-based type of spatial filter that, unlike plane clippers, removes all cells from view that do not intersect with the cutter's plane. These are a means to generate cross-section slices through a reservoir model, the effect of which is displayed in Figure 5. Typically, cutters are the most useful to reservoir engineers for isolating and analyzing views of how reservoir characteristics change between two locations inside the reservoir model, such as two different wells. Multiple cutters can even be used like this in tandem and can also be used to support other common analysis techniques like generating cross-sectional slices along each of the model's axes to show how cells around a central point of interest inside the reservoir, such as a well perforation, changes along each axis.

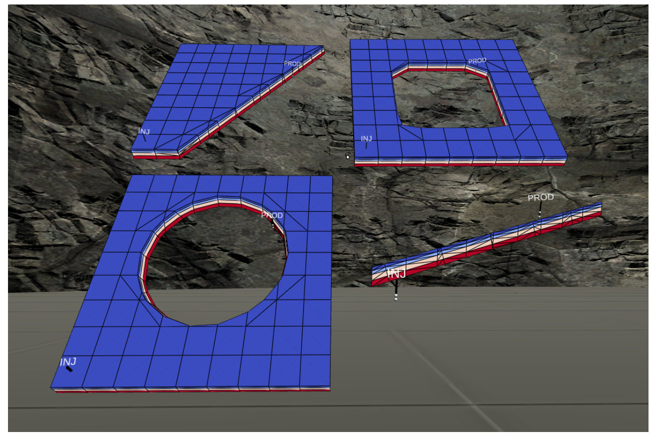

Figure 5: The effects of the different kinds of clipper and cutter filters when applied to the same simple reservoir model. Specifically, the image shows the effects of a plane clipper (top-left), a cube clipper (top-right), a sphere clipper (bottom-left), and a plane cutter (bottom-right).

3.3 Cell Information Probing

The ability to select a specific cell and display detailed information specific to that cell is important to a variety of reservoir analytics tasks, especially when one wishes to see exact numerical values instead of values conveyed via more abstract visual methods such as color. Our tool allows the user to point at and select any cell in a model and information related to this cell can be viewed via text on a virtual panel close to the user. For instance, when selecting a cell one can view a list of the cell's exact numerical values for the different model properties at once. By being able to readily access and view this information, engineers can gather precise information about specific cells to inform decision making and assist in understanding the finer details of the model's nature. For instance, by selecting the cell which a well perforates, one can assess how this cell is affected by the well's presence in better detail.

3.4 Line Graphs For Well & Reservoir Data

By selecting individual wells, users can spawn traditional 2D line graphs around themselves displaying how various well characteristics change over time. Simulation curves predicting future well performance and field test results also can be visualized using these graphs, allowing for well data analysis using traditional 2D techniques alongside the reservoir models. By leveraging the unique strengths of both data visualization approaches in tandem with each other, one can see how both the well's characteristics and production performance changes over time together with the spatial path of a well through the reservoir model and the cells it impacts. This is used to provide superior context of the information when analyzing wells than if only the graphs or wells in the model were being analyzed on their own. In turn, this is aimed to aid reservoir engineers in better determining if and how a well could be better placed or otherwise optimized further. For similar reasons, data relating to how an entire reservoir changes over time is also able to be visualized alongside the models using 2D line graphs for improved analysis of the reservoir's evolving state and how all wells in the model affect its properties over time. Examples of both types of these line graphs can be seen in Figure 6 alongside a reservoir model.

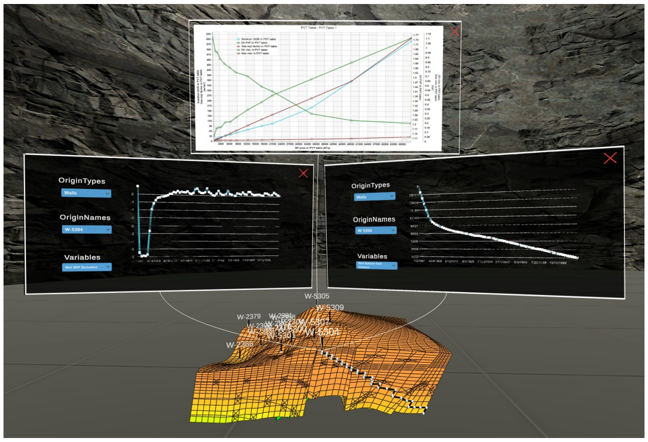

Figure 6: A reservoir model with associated 2D graphs showing reservoir data (white panel) and well data (black panels) linked via lines to their associated well. Note that the path of the well associated with these graphs has been exposed using a plane clipper to filter out the cells which lay between the user and the desired well.

3.5 Multiple Models & Graphs

As shown in both Figure 1 and Figure 7, users can load multiple visualizations of the same model or of entirely different models at the same time in the environment. The selected property, time, color-mapping, and cell filters for each model can be uniquely customized to highlight certain model characteristics. Being able to have copies of the same model visualized in different ways near each other allows for improved cross-comparison between different model aspects over the alternative; trying to compare model characteristics by switching just one model between different states. For instance, having many variations of the same model each set to display different properties or times allows for comparison of these different properties and times between these models. Alternatively, one could utilize multiple models each with different custom color mappings or combinations of filters to see unique details about the same dataset in each and cross-compare for faster identification of specific model aspects. To assist in this cross-comparison, multiple models can be selected at the same time and be set to have their properties, times, color mappings, or filters synchronized between them to facilitate quicker manipulation and analysis of groups of visualizations. The orientation, scale, or translation of model groups can also be synchronized so that one is able to see all models in a group from the exact same perspective or move groups around one's workspace with ease. To better facilitate such cross-comparison tasks, models can be organized into 3D layouts which standardize the orientation and scale of every model in the layout and organizes them into planar or cylindrical grid-like patterns to minimize occlusion and provide more structure for multi-model analysis tasks. Similarly, multiple line graphs can also be created in one's workspace as in Figure 6, allowing for the cross-comparison of different wells or various aspects of the same well against each other. Supporting these cross-comparison tasks contributes to effective and efficient reservoir engineering workflows by assisting reservoir engineers so they may gain accurate, high-quality insight faster and make better decisions about a dataset than if they were limited to using just one or a few models to do so.

3.6 Virtual Collaboration

Our application allows multiple reservoir engineers to work together on model analysis tasks inside shared virtual workspaces. Over decades, researchers have found that making decisions together is often more effective than working on a problem individually [2]. In addition, studies have found that collaboration on tasks that rely on visualizations to solve real-world problems often produces more accurate results [23, 29]. Since collaboration between reservoir experts is an important part of model analysis workflows, it is vital that our application supports this in addition to single-user analysis. While collaborating, model visualizations can be set by users to be either publicly viewed or private to one user. This determines whether other collaborators can see and interact with them. This also enables collaborators to have their own private workspaces within these shared workspaces without cluttering the workspace for others, while also allowing for other model visualizations to be collaborated over by all. Reservoir models can also be switched between these modes to share private workspace elements with others or remove models no longer necessary to be shared from the view of others. All manipulations and customization of public models are synced in real-time across collaborators, enabling multiple reservoir engineers to work on analytical workflows together by viewing and interacting with the same model in virtual reality. Users are represented to one another as basic virtual avatars like those seen in Figure 10. The avatar's position, movement, and orientation of their head and hands convey where other collaborators are located within the shared workspace as well as where they are looking or currently interacting with using their hands or controllers. This aids communication amongst collaborators by providing non-verbal context clues and gestures to others.

3.7 User Interface

A virtual hand-mounted main menu on the non-dominant hand provides compact and readily available access to all implemented features as it moves with the user regardless of where they are in their workspace and all functionality is always within arm's reach. Wrapped around one's wrist like a bracelet, this menu can be either minimized or moved out of view with little effort to allow for unobstructed views of the models in one's workspace. This menu also can be used to toggle on and off floating world-space panels or other user interfaces like those in Figures 3 and 6 which provide access to more detailed interfaces for specific features and customizing aspects of the visualizations like selecting the property and time range, customizing color mappings, or setting cell filters. These can be placed near their corresponding visualization to remain accessible for rapidly switching visualization characteristics and can either be used to modify one model or many models simultaneously. Among other benefits, spawning these feature interfaces in the world enables one to set up customizable workspaces tailored for specific analysis tasks and be able to readily modify visualizations while avoiding any unnecessary switching back and forth as would be the case if they were all located in the hand-mounted menu.

4 Benefits of VR for Reservoir Model Analysis

As discussed in section 1, when compared with conventional planar displays, virtual reality technologies have been demonstrated to enable larger working spaces, support more intuitive and natural interaction, improve spatial perception, and supply methods for more effective collaboration. How reservoir engineering workflows can specifically benefit from such improvements is an open question, however, which this research explores. As such, in this section we discuss preliminary findings based on our informed opinions, self-evaluation of the prototype, and anecdotal feedback from reservoir engineers in industry who have used the prototype as well. More formal evaluation is needed to provide evidence-backed conclusions and is planned to be performed in the future once the prototype has been further developed.

4.1 Increased Working Space

In comparison to conventional model analysis tools, the working space available to reservoir engineers in virtual reality is notably increased. No longer are those analyzing reservoirs restricted to viewing only one or a few models on their screen at a time, but now many tens of models or more can be present around oneself in spacious virtual workspaces and analyzed in tandem or cross-compared with one another. A small example of this with twelve models is demonstrated in Figure 7. Although graphics hardware constraints technically limit how many models can be rendered at once and how much space is actually navigable by users in VR, this still provides a large amount of usable 3D space for workspaces that are better able to adapt to multi-model analysis tasks. With the space available, one also has the option to scale up models larger than previously achievable using conventional planar displays, even up to the size of entire rooms if desired, to potentially help analysts see finer model details more easily. This could be particularly useful for viewing cells or wells in a high level of detail without needing to zoom in which reduces the chance that other important contextual information is removed from view.

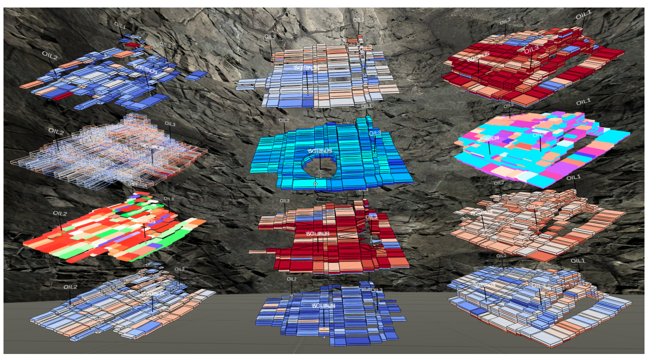

Figure 7: An example of twelve variations of the same reservoir model set up in front of a user at once. Notice that while being simultaneously in view, models can be customized differently to each highlight particular aspects or views of the same model to assist in analysis tasks.

On top of this, many 2D graph panels and various feature interfaces can be laid out around models to create highly customizable workspaces to facilitate the analysis task at hand. Since virtual workspace elements do not rely on hardware, they can all be freely moved, oriented, and scaled however one wishes to form workspace layouts not achievable with non-immersive technologies. It is even possible for multiple different workspaces each containing many models, graphs, and feature interfaces tailored to specific analysis tasks to be present in one's virtual environment at once. To switch between these different workspaces users can freely move between them in VR, no longer being restricted to one type of workspace or analysis task at a time.

4.2 Natural, Intuitive Interaction

Hands-on interactions, afforded by virtual reality controllers or hand-tracking, can be argued to be more intuitive than mouse and keyboard interactions when interacting with three-dimensional objects. Thus, supporting hands-on methods to interact with reservoir models is aimed to make engineering workflows more efficient. Our tool supports a variety of 3D spatial interactions that are required to understand and work with reservoir models. In our VR workspaces, models can be intuitively grabbed and moved using one hand and roughly scaled or rotated with both hands. For finer rotation and scaling, the wireframe boxes outlining the boundary of models can be interacted with as demonstrated in Figure 8. To select wells or cells, one can point one's hand toward a desired visualization element to select it. One can even move one's hands into a model and touch the wells or cells of interest if they are close enough, offering an intuitive way to interact with the data of a model as if they were actually touching it. Informal feedback from domain experts on this combination of natural interactions and hands-on model manipulation has shown promise, indicating that working with reservoir models like this is easier, more enjoyable, and more intuitive than conventional approaches.

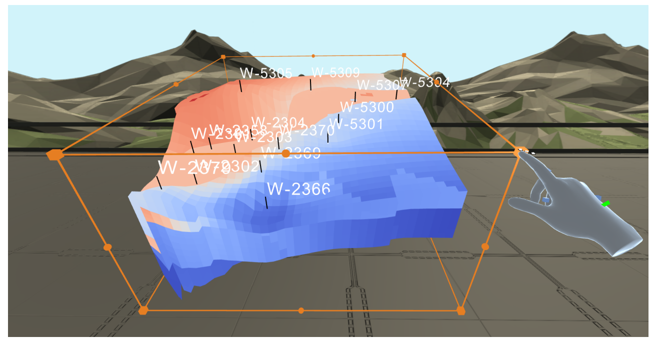

Figure 8: An example of a user interacting with a reservoir model's boundary wireframe UI for fine rotation and scaling.

Industry professionals also identified these types of hands-on interactions as being especially better than conventional approaches for manipulating clippers and cutters within reservoir models. Using clipping shapes in a non-immersive platform can be tedious and frustrating at times as it can be hard to place the spatial filter exactly where one needs with a mouse and keyboard. This is especially the case when attempting to place a plane cutter between two wells to see how the cell properties change between them. Virtual reality, on the other hand, can take advantage of how people can naturally move and rotate their own hands in 3D space to place objects with exactly the right orientation and position. In turn, this allows analysts to manually place or orient cutters and clippers quicker and more accurately within virtual reality, providing reservoir engineers with a more enjoyable and effective analysis experience.

4.3 Improved Spatial Perception & Navigation

Our application intends to leverage immersion to better convey the natively 3D structure of reservoir models to analysts by taking advantage of the improved sense of depth stereoscopic VR HMDs offer in comparison to planar 2D displays. For instance, even actions as subtle as moving one's head around in virtual reality have been proven to improve understanding of spatial relationships between objects [1]. Understanding well paths throughout the model is especially hoped to be beneficial as one not only has improved depth cues, but can also navigate around and into reservoir models to see well paths and other model details from almost any perspective they chose. Our tool provides two methods for users to navigate through their workspace: physical locomotion and teleportation. By physically walking while in virtual reality, users can navigate through reservoir models and their workspace as if navigating around in the real world. For instance, users can walk or lean toward visualizations to view detailed information from a closer perspective. Taking this a step further, one can even walk inside reservoir models and explore cells and wells from the inside as demonstrated in Figure 9. Alternatively, one could instead walk away to get an overview of many models at once as seen in Figure 7. Secondly, the entire virtual workspace can be navigated via a teleportation functionality which allows users to move freely around the virtual workspace without being concerned about the size of their physical workspace. With this teleportation feature, users can access visualizations and spaces that are further away with little effort and even navigate when sitting down or standing still. This enables one to fully utilize the vast working space available in virtual reality without having to compromise due to physical space limitations.

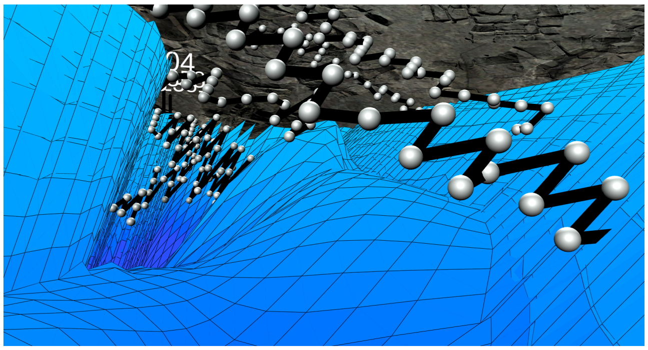

Figure 9: The viewpoint of a user who has moved into the interior of a reservoir model to get a closer look at its well paths from inside.

4.4 Enhanced Collaboration

Immersive virtual environments allow people in different physical locations to work together in the same virtual workspace and studies have found that this kind of distributed synchronous collaboration in VR can perform similarly to in-person, co-located collaboration [2]. Compared with traditional synchronous remote collaboration over reservoir models where users communicate using voice and video, VR collaboration enhances the experience using avatars that convey the position and orientation of the user within their shared workspace to others. Natural gestures are also supported so that, when collaborating over a specific model, instead of describing a feature of interest verbally they can instead physically point at the feature using their hand and this pointing gesture would be communicated by the hand of their avatar to others. This ability to support gestural communication methods has the potential to improve communication amongst remote collaborators to in turn increase the effectiveness and efficiency of their collaboration.

In addition, collaboration in VR has another important benefit over traditional co-located collaboration: the ability to provide any perspective of the virtual environment to any user. When collaborating over models on physical screens, to share roughly the same perspective as someone else one typically has to place themselves beside another user or look over their shoulder to do so. This can be awkward and inconvenient, especially since doing so often causes one to remove themselves from their own workspace to see the perspective of another which can lead to work inefficiencies. This can be overcome with VR since when collaborating over virtual objects, constraints present in the real world do not need to apply, and instead one can present the same object to multiple users differently. For example, in VR an object can be uniquely positioned or rotated in each user's point of view so that, regardless of how they are positioned relative to others, all can share the same view of the object without being beside or near each other. To demonstrate this, consider the case where two users are faced directly across a reservoir model from each other and collaborating over it. In such a case, the model could be rotated to face both users the same way in their own viewpoints. As such, both users would be able to see the model's front and collaborate over it despite perceiving one another to be standing on opposite sides of the model. When representing models this way, supporting gaze and pointing indicators could be used to identify to others where a user is pointing or looking in their viewpoint to avoid any confusion. Using virtual reality to support collaboration over reservoir models in such ways not achievable in the real world is another aspect of the tool domain experts have expressed promising feedback on, expressing its potential to move past prior limitations with multi-user model analysis tasks and lead to easier, more effective remote collaboration.

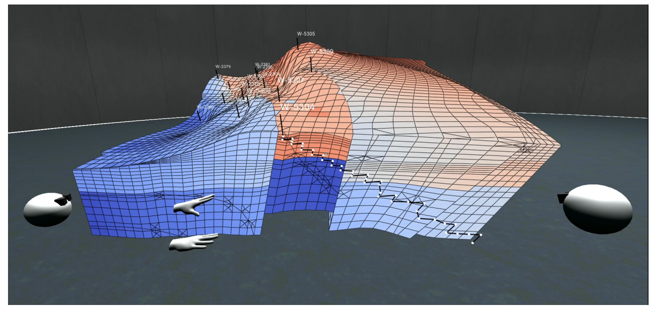

Figure 10: An example of two users as basic white avatars performing collaborative reservoir model analysis in a shared virtual workspace.

5 Conclusion & Future Work

Reservoir engineering is a challenging and highly deductive field, requiring extensive professional judgment and precise data analysis. Virtual reality technologies have much potential to advance how reservoir engineers analyze and interact with reservoir models, and our reservoir model analytics tool exploring this was discussed. Our tool allows users to view one or many reservoir models simultaneously and customize them with cell filters and unique color mappings of cell data. Either individually or collaboratively, in VR environments multiple models, 2D graphs, and feature interfaces can be laid out to form virtual workspaces tailored to the analysis task at hand. Based on informal self-evaluation and anecdotal feedback from industry professionals, our tool is expected to visualize reservoir models with an improved sense of depth beneficial to analysis tasks, enable more customizable and scalable workspaces, and supply ways to more naturally interact and collaborate over models when compared to conventional tools using non-immersive displays.

Despite these initial impressions, there is still work to be done before our immersive reservoir analysis tool can be formally evaluated to confirm these insights. Before this takes place, we are first iterating upon the current design to improve its features and further explore the breadth of capabilities virtual reality can uniquely offer reservoir engineers. Feedback from domain experts has indicated that it would be beneficial to investigate aspects such as gestural interaction methods, novel 3D data visualization techniques for well data, more dynamic multi-model layouts to better support cross-comparison tasks, and study how hands-on interaction can be used to improve creating 3D well paths within a model during their planning. Once implemented, we then intend to run user studies to capture feedback from subject matter experts on various aspects of our tool to formally assess the benefits and challenges of performing reservoir model analysis in virtual reality.

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