Single User Cross Reality Workflow for Reservoir Engineering Work in Progress

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ABSTRACT

We propose a prototype for a single-user cross reality (CR) workflow for reservoir engineering. Cross reality is the technology that links systems at various points of the Reality-Virtuality Continuum (RVC), in which CR applications, by definition, should enable the transition between or simultaneous usage of different systems along the RVC [21]. The proposed prototype connects commercial and VR reservoir analytic tools through CR, allowing seamless transitions of reservoir models between desktop monitors and augmented reality (AR) space. The paper discusses related research on commercial and VR reservoir analytic software and cross-reality interaction methods. The design objectives and an overview of the prototype implementation are presented.

Index Terms: Human-centered computing—Visualization—Visualization techniques—; Human-centered computing—Interaction techniques; Human-centered computing—Mixed / augmented reality;

1 INTRODUCTION

The rapid growth of immersive technology leads to the rise of potential and usage for immersive visualization for human understanding of complex models and data sets, for example, in analyzing models for reservoir engineering. Reservoir engineering is a discipline essential to exploring and producing hydrocarbon resources. It involves gathering information, analyzing complex models and data sets associated with underground oil and gas reservoirs, and conducting simulation analysis workflows to find optimal ways to extract the maximum amount of fossil fuels while minimizing environmental impact [1]. Reservoir engineers often utilize computer simulations of subsurface processes to predict the result of different reservoir extraction scenarios [12]. To understand various subsurface properties and physical processes and how these could affect petroleum extraction approaches, it is necessary to visualize and analyze the reservoir models used and resulting from those simulations [22]. As seen in Figure 1, these reservoir models are typically large, composed of complex 3D grids of cells, each filled with information about different geological and reservoir properties. These models typically incorporate existing and planned wells to help assess how their presence will impact the surrounding geology and underground reservoir over time [1].

The analysis of reservoir models is an essential aspect of the reservoir engineering process. Tools that support clear visualization and effective interaction with the reservoir models are necessary for reservoir engineers' understanding of the data. Although commercial reservoir model analytics tools that operate on desktop devices have been long used by reservoir engineers, their dependence on a

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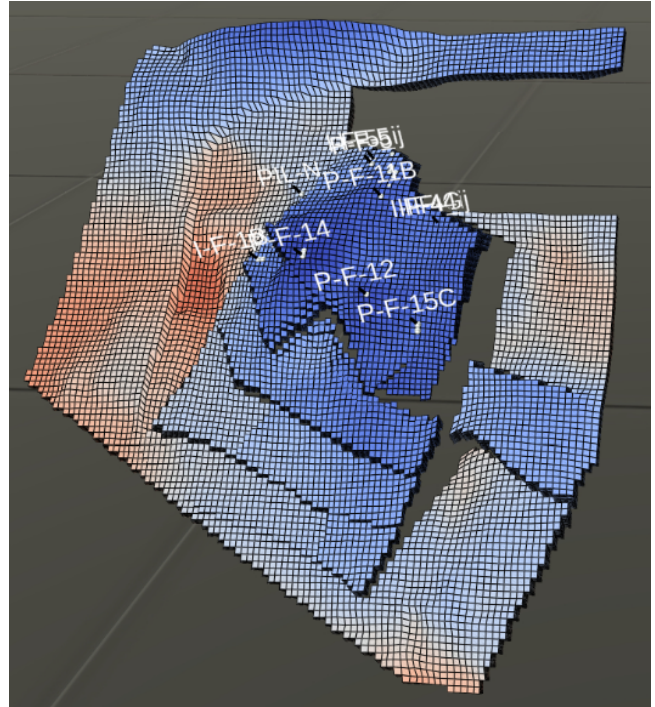
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Figure 1: An example of a reservoir model visualized in VR for analysis. Cell values are mapped to customizable color gradients. The color can be useful to see how data changes over time. Users can also view the location and trajectory of oil wells within the reservoir model.

physical 2D display constrained capability due to the limited screen space, and the use of mouse and keyboard for interactions [1]. Tools used in extended reality (XR) head-mounted devices (HMDs) with a virtual reality (VR) environment have been developed to resolve the constraints of commercial tools by providing larger working space [9–11], more natural and intuitive interaction [4, 5, 7], and improved spatial perception [6, 7, 14, 18]. Although VR tools benefit reservoir model analysis, motion sickness and mental fatigue caused by using XR HMDs for an extended period and the limited resolution of VR HMDs are issues within using VR tools [8, 16, 19]. Additionally, commercial tools have been developed and used for years by reservoir engineers, and VR tools do not yet support many analytic features supported by them.

In this paper, we propose a prototype of a single user cross-reality workflow for reservoir engineering. Cross-reality (CR) is the technology that connects systems at different points of the Reality-Virtuality Continuum (RVC), such as VR, augmented reality (AR), and standard monitor device (SMD) systems [13]. A CR application, by definition, supports the transition between or concurrent usage of more than one system on the RVC [21]. Our prototype will connect the commercial and VR reservoir analytic tools by transitioning the

reservoir model between the desktop monitor and AR space. By connecting the two tools with CR, we hope that the strengths and limitations of commercial and VR reservoir model analytic tools can be balanced to enable more efficient analysis and interaction with reservoir models.

2 RELATED WORK

2.1 Commercial Reservoir Analytic Software

Commercial reservoir analytic software, such as Petrel [17] and the CMG Suite [3] seen in Figure 2, is currently commonly used by reservoir engineers for analyzing reservoir data and models. According to Akhtar et al., [1], this commercial software typically adopts a 2D screen-based WIMP user interface (UI), which relies on physical 2D displays that limits their visualization and interaction capability. As the screen space is restrained to one or a few displays, the number of reservoir models that can be visualized simultaneously is limited during cross-comparison analysis tasks. The size of the models is also restricted by the size of the display, causing engineers not to be able to analyze the finer details, and surrounding cells' information gets lost when zoomed in. Additionally, since reservoir models are in 3D, visualizing them on 2D displays causes them to be flattened to a pseudo-3D perspective. The flattening removes the spatial information needed to perceive and interact with the models in their natural spatial dimensions.
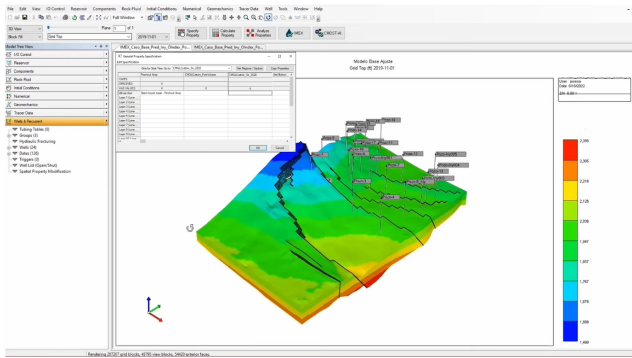

Figure 2: A view of CMG Suite's user interface. Note how popup windows can block the reservoir model. Image sourced from the Computer Modeling Group Ltd. [2, 3]

2.2 VR Reservoir Analytic Software

VR HMDs have been applied to reservoir engineering analysis tasks, such as creating and analyzing well trajectories and probing data from individual cells, by Ramos Mota et al. [15]. The evaluation results concluded that the three-dimensional perspective of immersive environments for analyzing reservoir models was generally regarded as superior to the traditional screen-based perspective. In our previous research, we conducted a user study on our VR reservoir analytics tool, as shown in Figure 3, with features including 3D reservoir model visualization, cell filtering and information probing, generating line Graphs for well and reservoir data, loading multiple models and graphs, and well paths visualization and planning [1]. The user study results show that participants perform better on multi-object comparison tasks, manipulating reservoir models, path planning, and plane cell clipping when using VR reservoir engineering analytic software. These improvements are due to the significant increase in VR working space, and VR interactions naturally imitate how people move and rotate objects in reality. However, participants commented that after an extended period of using the VR tool, they felt physical discomfort or exhaustion. Additionally, the breadth of features provided by the VR tools is not as broad as commercial

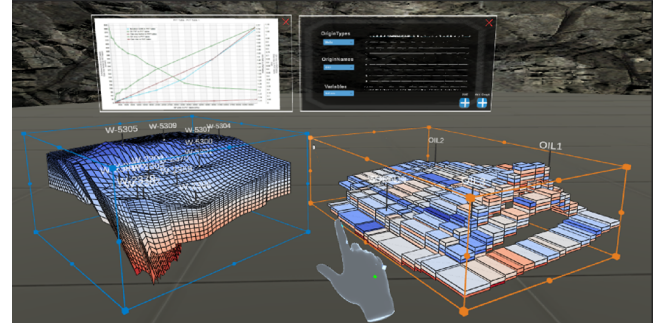tools, and the VR tool is not suited for precise tasks like text entry, placing wells, and raw data analysis.

Figure 3: A view of our VR reservoir analytics tool's user interface when used for reservoir comparison task.

2.3 Cross Reality Interaction

To gain benefits from both approaches, we are developing a CR prototype that integrates traditional and XR-based concepts. As mentioned in Section 1, the transition of reservoir models from desktop monitors to AR space is critical to this CR prototype. User's preference on interaction methods for moving virtual objects from one environment on one point of the RVC to another has been explored by Wang [20]. The user study's results conclude that hand gestures are overall the most preferred atomic interaction method. For the hand gestures, "Drag," "Release", "Tap," "Grab", and "Throw" are the most used hand gestures combination for moving virtual objects from SMD to AR space and vice versa. Other hand gestures are also used for other actions, such as "Swipe," which is used for transitioning all objects from AR space back to SMD. Meanwhile, controllers, including motion controllers, mouse, keyboard, and voice, are preferred as secondary interaction, especially for duplicating objects.
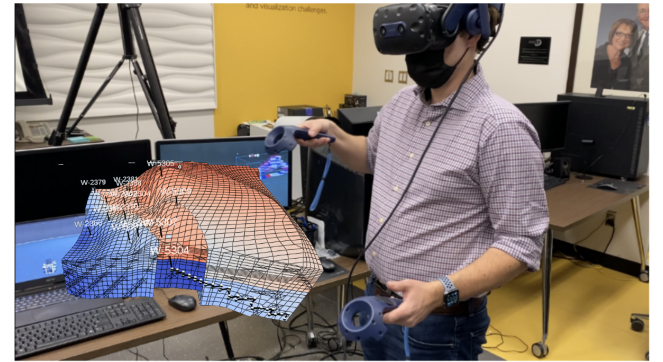

Figure 4: A concept photo of how the user interacts with the reservoir model in the XR space of the CR prototype. However, users will interact with the reservoir model being transitioned to XR space using hand gestures instead of the motion controller shown in the figure.

3 A SINGLE USER CR WORKFLOW FOR RESERVOIR ENGINEERING

3.1 Design Goal

Previous work has shown that commercial and VR reservoir analysis tools have their strengths and weaknesses, which can be balanced by combining both tools with the user's preferred interaction methods [1, 15, 20]. Therefore, we propose a proof of concept prototype for reservoir engineering's analysis workflow, where the devices and
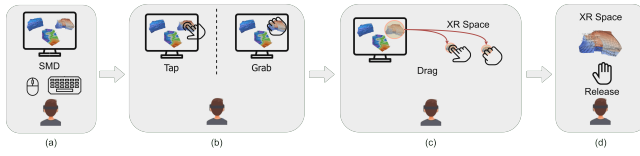
Figure 5: A view of the interactions required for SMD to XR space transition of a reservoir model. (a) Initial mouse and keyboard interaction on SMD, (b) "Tap" or "Grab" to initiate transition, (c) "Drag" to operate the transition, (d) "Release" to finish transition of the model and place it in XR space.
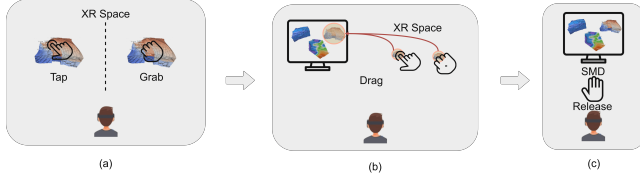

Figure 6: A view of the interactions required for XR space to SMD transition of a reservoir model. (a) "Tap" or "Grab" to initiate transition, (b) "Drag" to operate the transition, (c) "Release" to finish transition of the model and place it in SMD.
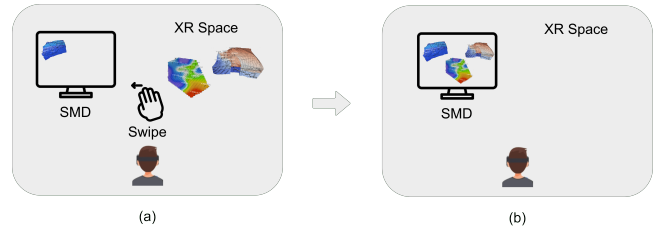

Figure 7: A view of the interactions required for the transition all reservoir models XR space to SMD. (a) "Swipe" to initiate transition, (d) All models in XR space is moved back to SMD after the interaction.
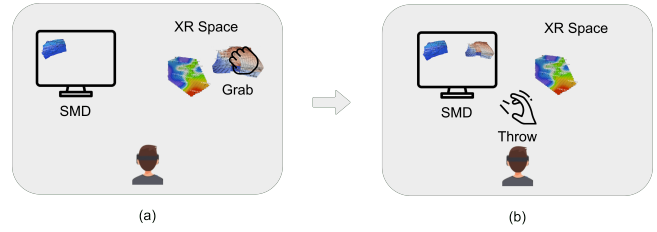

Figure 8: A view of another set of interactions required for XR space to SMD transition of a reservoir model. (a) "Grab" to initiate transition, (b) "Throw" to operate and finish the transition of a model from XR space to SMD.

environments of the commercial and VR tools are connected by CR transitions, allowing users to move the reservoir models and graphs to either the desktop monitor space or the XR space as they see fit. Following are some of our goals in the design for this prototype.

1. Seamless transition of objects between the monitor and XR space.

2. Enabling preferred interactions for the transitions.

3. Synchronized views of objects in different spaces.

3.2 Design Overview

The prototype will be composed of 2 applications, one on an SMD and one on an XR HMD, which are responsible for the monitor and XR space, respectively. Our VR reservoir analytic software mentioned in Section 2.2 will be used as the foundation of the application for the XR headset [1]. The interactions that trigger and allow a virtual object to move between the monitor and XR space will be implemented according to Section 2.3 [20]. The interactions are mainly hand gestures, including "Drag", "Tap", "Grab", and "Release" as the main interactions for the CR transition (see Figure 5 and Figure 6) , "Throw" and "Swipe" as supplementary interactions for the transition, specifically for moving one reservoir model and all models back to SMD respectively (see Figure 7 and Figure 8. Additionally, the input modalities of mouse and keyboard for SMD will be used to for precise adjustment to assist tasks in XR space.

3.3 Implementation

We will develop the prototype with Unity 3D and the Varjo XR3 headset. The headset is a video pass-through HMD that streams high-fidelity video to the display while simultaneously capturing high-definition video to display virtual visualization in real and virtual environments, allowing users to seamlessly transit objects between different spaces on the RVC. Varjo XR3 supports hand gesture interaction for the transition triggers and SteamVR for full-body motion tracking. As mentioned in the previous section, two applications will be developed. The application used on SMD will mainly interact with the mouse and keyboard, except for using hand gestures for transiting models from SMD to XR space. Tasks that require precision will be done on the SMA application, such as data

and text entry, raw data analysis, and interactions with 2D graphs. Meanwhile, the XR HMD's application will use hand gestures as its interaction method, allowing users to complete multi-model comparison, well path planning, plane cell clipping, and 3D reservoir model manipulation tasks. Since the user interface will be different for the SMD and XR application, for example, the menu for the SMD interface is in 2D while a 2.5D hand-mounted menu will be used for the XR interface. To reduce user distraction caused by the interface difference during the transition, approaches, such as using the same icons and layout for the menu, will ink the SMD and XR interface.
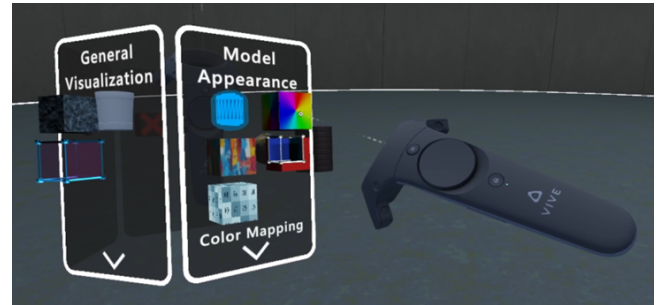

Figure 9: An example of a 2.5D hand-mounted menu. In the CR prototype, user will interact with the hand-mounted menu with "Tap" hand gesture.

4 FUTURE WORK AND CONCLUSION

In this paper, we presented the concept of a prototype for the single user CR workflow for reservoir engineering that combines features of commercial and VR reservoir analysis tools using CR. Our goal is to cancel out the limitations of both the commercial and VR tools by connecting them through interactions that allow seamless transitions of reservoir models between the different environments in the two tools lie on the RVC. The next step after implementing the prototype is to verify the positive impact and explore new challenges and

limitations of connecting commercial and VR tools through CR by conducting the following user studies:

1. User studies on interaction methods for specific reservoir analytic tasks.

2. Case studies on the efficiency of reservoir analytic tasks by comparing completion time and user experience of users completing tasks on SMD, purely immersive, and CR systems.

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