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Let Every Seat Be Perfect! A Case Study on Combining BIM and VR for Room Planning

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Abstract

When communicating indoor room design, professional designers normally rely on software like Revit to export walk-through videos for their clients. However, a lack of in-situ experience restricts the ultimate users from evaluating the design and hence provides limited feedback, which may lead to a rework after actual construction. In this case study, we explore empowering end-users by exposing rich design details through a Virtual Reality (VR) application based on building an information model. Qualitative feedback in our user study shows promising results. We further discuss the benefits of the approach and opportunities for future research.

Index Terms: Human-centered computing—Interaction paradigms—Virtual Reality

1 Introduction

The need for reworking in construction projects has long been a severe problem that leads to enormous waste in both time and resources [3]. In order to gain early feedback and mitigate the risk of having to rework, designers should communicate with clients during the design phase. Then, utilizing building information modeling (BIM) software like Revit, they would generate renderings, a walk-through video, or a 3D model of the current design for users to assess, and refine the design accordingly. Though BIM provides detailed building information (e.g., the position of the furniture) and supports simulation (e.g., solar study), designers, in practice, do not expose their clients to rich information under BIM because it remains challenging for inexperienced users to navigate BIM applications like Revit. We assume that a lack of in-situ experience in a given demo prevents users from providing valuable feedback.

Inspired by previous studies [1, 2], we aim to integrate the advantages of both BIM and VR in developing a design application. As such, it not only offers the in-situ experience but also provides the construction details of the buildings and the simulation. With such an application, we can easily gather the users' in-situ experience and feedback before construction. Based on the feedback, designers can improve their designs from the users' perspectives, thus improving the efficiency and quality of construction. Ultimately, combining BIM and VR has great potential for improving existing work processes by drawing users closer to the designers.

2 Method

We have built the preliminary VR application using Unity XR Management and XR Interaction Toolkit. Figure 1 shows four screenshots of the VR application. Figures 1(a)-(b) illustrate the layout of a real room in a local university and Figures 1(c)-(d) show the view while sitting in VR. In the application, users can freely navigate the virtual room by teleportation. Moreover, users can pick a seat, and

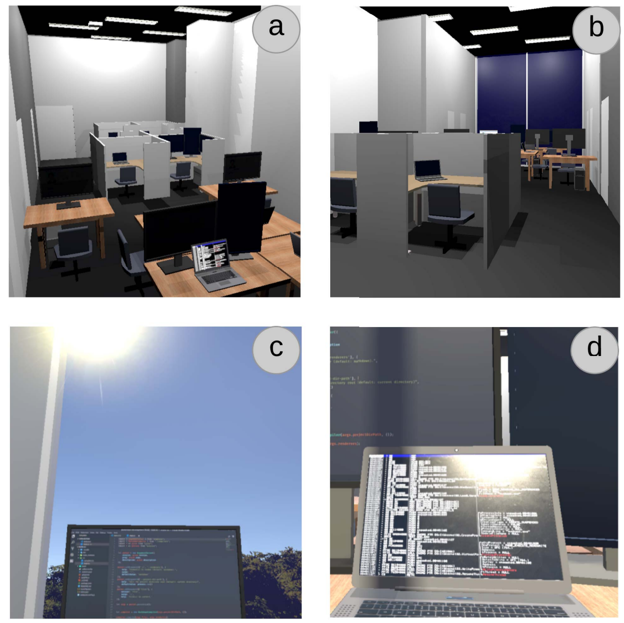

Figure 1: This figure presents four screenshots in the VR application: (a) full scene of the room, (b) scene viewing from the door, (c) dazzling sunlight, and (d) strong reflection on the laptop screen.

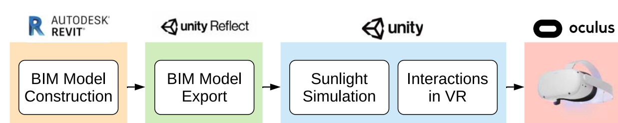

Figure 2: Our workflow consists of four components: constructing the BIM model, exporting the BIM model, simulating sunlight and implementing interactions in VR.

fix their viewpoints above the seat to mimic the experience of sitting on the seat, as shown in Figures 1(c)-(d).

The overall workflow is shown in Figure 2. The BIM model is first created using Revit. To enable accurate and realistic simulations in VR, we need information beyond the 3D models provided by the BIM model. As such, instead of exporting only 3D models from Revit, we use Unity Reflect to import both the 3D model and all metadata. Finally, we deploy the light (indoor light and sunlight) simulation to VR for an immersive experience.

For the indoor light simulation, we directly adopt the lighting condition from Revit with the help of Unity Reflect. For the sunlight simulation, since we want direct control over Unity, we adopt an algorithm[1] to calculate the direction of the sunlight using the time and location, similar to the solar study in Revit.

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[1] https://gist.github.com/paulhayes/54a7aa2ee3cccad4d37bb65977eb19e2

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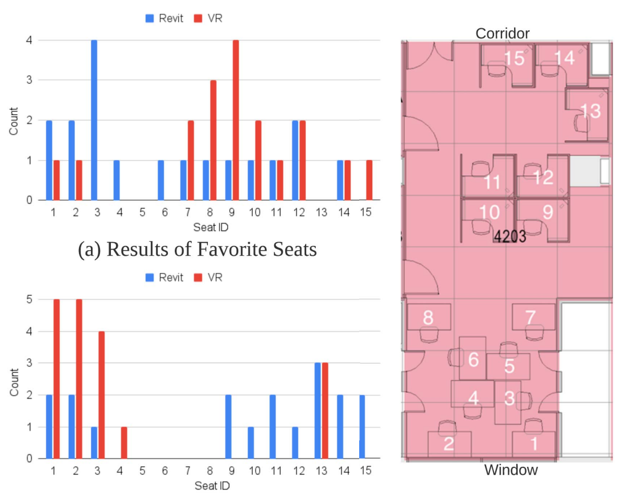
3 Evaluation

To evaluate the usefulness and effectiveness of our application, we conducted a user study with 6 postgraduate students (2 females, $Age_{mean} = 25$). We deployed the application on Oculus Quest 2.

Protocol. In the user study, the participants' task was to explore the room for 10 minutes and then select the top-three most favorite and the top-three most problematic seats according to the lighting conditions without ranking them. We asked the users to conduct the task using a widely applied existing solution (i.e., Revit) and our VR application. By comparing users' selections when using different applications, we aimed to verify whether the VR application can provide users with a more situated experience and thus give useful feedback for room designers. After finishing the task with two applications, we interviewed the participants to learn their reasons for selecting seats and their opinions on Revit and our VR application.

Results. The results of participants' top-three most favorite and problematic seats are shown in Figures 3(a)-(b). We noticed that the results are inconsistent, especially regarding the seats near the window (i.e., seats 1-4 in Figures 3(c)). When using Revit, the seats near the window are generally preferred since most of the participants appreciated the natural light. However, after trying the VR application, they changed their opinions. Regarding such changes, a participant commented that *"In VR, I find that the sunlight in seat 1 and seat 2 is too dazzling"*. To better understand their diverging selections, we further inspected and identified the mentioned seats on the VR application. As Figures 1 (c)-(d) shows, the seats near the window had potential lighting issues such as strong reflection and dazzling sunshine. These issues are hard to be identified in Revit, but relatively easy in VR since users can have an in-situ experience by sitting on the seats. This shows the advantage of our VR application.



(a) Results of Favorite Seats

(b) Results of Problematic Seats

(c) Floor Plan with Seat IDs

Figure 3: (a) and (b) show the results of the top-three most favorite and problematic seats selection. (c) is the floor plan of the room.

User Feedback. According to feedback in the retrospective interview, bringing users under the VR environment offers some unique benefits over visualizing the simulation data directly on common 3D design software. First, **the realistic experience anchors abstract simulation results with prior knowledge.** Participants applauded for the realistic experience under VR when deciding the best or worst seats during the user study. It helped them understand the data better since people know what is regarded to be "too dazzling" by nature. However, they might not interpret the numerical value of light intensity well, even when rendered in BIM software. Second, **natural interactions smooth the exploration process.** Compared with rigid desktop interactions like zooming, panning, or even pressing on keyboards. Participants appreciated the natural interactions under VR environments. For instance, to change their perspective, they only need to turn their heads. Furthermore, through a click on the controller, they were able to sit on a seat of interest, which maintained the exact height of the head-mounted device. All these intuitive operations reduced the mental demands when exploring the room, and therefore supported the user to focus more on actual analysis tasks. Lastly, **the immersive environment stimulates user interest and encourages them to stay longer.** Some participants mentioned that they were fascinated by the swaying trees and shimmering sunlit leaves outside the window. The immersive experience engaged them during the exploration. Thus, they generally spent more time investigating the lighting conditions in each seat.

4 Opportunities & Future Work

Based on user feedback, we reflect on opportunities for future research. First of all, it remains interesting to *enable direct manipulation for "what-if" analysis.* In the user study, users presented their desires to directly manipulate basic settings directly under VR, like controlling the light while modifying the desk position. Another interesting extension is to *support collaborative analysis*, which benefits a more flexible analysis by putting target users together or bringing both designers and users. Finally, the idea to *design according to individual's experience under VR* could be extended to many other scenarios, especially those facing diverse end-users. Take seat arrangements for instance. When planning seats for a movie theatre, it remains challenging in the first place to consider the sore necks of the people sitting in the front rows without having had a situated experience. The same applies to a concert seating plan where the sound effects play a significant part, and a car seating design where the hood might occlude the view.

5 Conclusion

We investigated situated analysis for indoor design under a VR environment and explored the representative problem of seat arrangements. Built on an existing building information model (BIM), our VR application allows end-users to roam around in a room, inspect the design, and provide feedback to designers based on their experiences before actual construction. An initial user study focusing on lighting conditions demonstrated that VR helps align human's prior knowledge with abstract numerical values, where people could intuitively identify issues like strong sun reflection on a screen according to the design plan. In addition, the immersive experience stimulated a passion for exploration and encouraged people to think from real-life scenarios. Future work could incorporate more interactions allowing designers to conduct what-if analyses by modifying the design plan directly on the VR environment.

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