

PAPER • OPEN ACCESS

Study of Lighting and Material Iterations in Full Scale Model Using Virtual Reality and Interactive Architectural Representation

To cite this article: Gregorius A Gegana A *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **238** 012025

View the [article online](#) for updates and enhancements.

Study of Lighting and Material Iterations in Full Scale Model Using Virtual Reality and Interactive Architectural Representation

Gregorius A Gegana A¹, Jacky Thiodore¹, Ferry Gunawan¹

¹Department of Architecture, School of Design, Universitas Pelita Harapan, Jl. M. H. Thamrin Boulevard 1100 Lippo Village Tangerang 15811, Indonesia

gregorius.amunisianto@uph.edu

Abstract. Common architectural visualization is using 3D digital model represented in 2D media such as screen and papers. However, this method has two limitations. First, it does not have a full scale to provide a true perception space. Second, the 2D media to represent the 3D model is static. These limitations diminish the user's experience and understanding of space. Currently, architectural visualization is starting to utilize technological advances of virtual reality (VR) and interactive game engine. The full-scale projection in VR can minimize the perception gap between the client's and the designer's idea. It also has interactivity that enables users to explore the space and perform direct manipulation at some design aspects. This paper observes how VR and interactive technology is used to explore scale, lighting experience, and material iterations. The research was conducted for one semester in 2 courses. In these courses, students worked in groups to create, experience, test, and evaluate their design through 3D VR environment and interactive representation. Afterwards, the VR was tested to common users. We examined the enhancement that users get by experiencing design through VR compared to viewing the architectural visualization on picture and discuss how this could be improved and integrated to curriculum.

1. Introduction

The realm of architectural visualization is converting architecture idea such as shape, space and atmosphere from abstract into concrete world. It is used by architect to communicate his idea about space and get decision-making processes. This visualization would be able to show how the space would look like, having both virtual space on the one hand and reality [1].

Long history in Architectural visualization, we began with 2D visualization like collage, photo, rendering image, and later into 3D Visualization like Building Information Modeling (BIM). Currently, common architectural visualization is using 3D digital model represented in 2D media such as screen and papers. The visualization achieving a standard to offer a very realistic image from an architectural idea. However, this method has two limitations. First, it does not have a full scale to provide a true perception space. Second, the 2D media to represent the 3D model are static, thus it is losing the 3D experience itself.



In 21st Century with the emerging technology, design evaluation can be supported by computational design simulation which immediately confront the designer with the consequences of his design decisions [2]. Architectural visualization is changing from realistic images into realistic experience. The technology Virtual Reality (VR) offers a face to face interaction with virtual environment model. It is adding two dimensions to the space visualization: immersion and interaction [3]. Immersion is the subjective impression that one is participating in a comprehensive, realistic experience. Interaction in virtual reality can be done with natural gestures within the virtual world.

It is critical to see the virtual reality technology as a practical tool for architectural design and evaluation [4]. The immersive condition enables decision making without having to build full-scale mock ups. It also has interactivity that enables users to explore the space freely and perform direct manipulation at some aspects of virtual environment. In relation to architectural design, VR technology translates context, circulation, lighting, materials to an experience where there is a depth of engagement with the virtual environment [5].

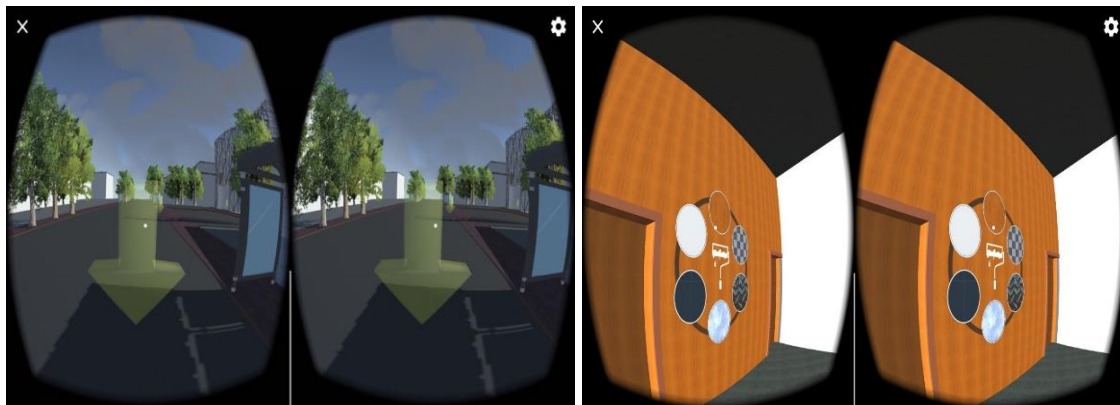


Figure 1. Stereo panoramic screenshot from architectural VR scene in Android platform by UPH students showing different types of interactivity: walkthrough (left) and material changing (right)

2. Objective and Methodology

There are at least 2 factors that affect one person in experiencing architectural immersive VR: 1) ability to adapt and interact in virtual worlds, and 2) sense's ability to measure the scale of space and objects in virtual world [6].

The main objective of this research is to observe how VR and interactive technology can be used to explore scale, lighting experience, and material iterations. Therefore, it can give more complete experience and understanding about architectural design compared to conventional image representation.

There are 2 main targets for this study: architectural students and common users. Students using this immersive environment to visualize their projects, enriched their spatial experiences, and enhanced their design outcomes [7]. Thus, the design can evolve: giving proper scale, better lighting ambience, and material iterations. For common users, they can visualize results and provide feedback instantly [8]. User can explore the space and perform direct manipulation of light and material in virtual environment to change the space atmosphere at will.

The whole research is divided into 2 parts: VR courses and public survey. Creating and experimenting VR environment was conducted in 2 courses: *Computer Based Design Simulation and Methodology* and *Architecture in the Digital Age* in one semester. At the end of semester, the students' works were presented and tested to public audiences: commoners and students from other faculties, to get the feedback about architectural VR experiences. Public were asked to fill in questionnaires, comparing static images and VR experiences in the terms of scale, lighting, and material experience.

3. Virtual Reality Courses

In the first half semester, each student worked individually to build the model and initial VR environment. In the mid-term, their works were selected based on design and digital modeling criteria. Afterwards, they had to develop comprehensive VR environment in group of 3-4 students for the second half semester. In the courses, we did collaboration with *Institut Teknologi Bandung* for workshop and final review.

To test and give various interactive/ immersive experience, we determined 3 target platforms for the project: Windows, Android, and Oculus Gear VR. Each platform has different level of interactivity and immersivity. Due to limitation of time, equipment, devices' specification, and expertise resources, we set the interactive and immersive levels for each platform as in Table 1.

Table 1. Interactive and immersive levels for each target platform

	<i>Windows</i>	<i>Android</i>	<i>Oculus Gear</i>
Output File	Stand-alone Windows executable file (.exe)	Stand-alone Android application (.apk) with VR cardboard SDK	Stand-alone Android application (.apk) with Oculus SDK
Devices	Windows PC	Android phone and generic VR headset (cardboard)	Gear VR supported Android phone and Gear VR headset
Control	Mouse and keyboard	N/A	Gear VR controller
Immersive	Screen Only	Full (VR headset)	Full (VR headset)
Interactive	Fully playable game Free movement	Gaze the predetermined icon to interact and move	Fully playable game Free movement
Dynamic experience	Day/ night time changing Visual Effects (VFX) Sound Effects (SFX)	Day/ night time changing	Day/ night time changing
Action type	Turn on/ off artificial light	Change surface's material	Move simple objects

3.1. VR Creation Workflow

The overall VR creation workflow is started from either generic 3D modeling or Building Information Modeling (BIM) software. Afterwards, the model is imported to open-source game engine software using fbx file format.

The first course, *Computer Based Design Simulation and Methodology*, is mandatory course for 3rd year students. The project for this course was to build VR environment from their 2nd year Architectural Design Studio II Project, i.e.: *Artist Residence and Gallery*.

The students of this class had been familiar with BIM from previous semester. Therefore, the modeling workflow was started from BIM application. Starting the model from BIM software has several advantages, such as structured and clear object and multi-material naming, which is important for objects selection and manipulation in the game engine application. The objects and lights also can be placed more precise and easier in BIM software. However, BIM software utilizes photometric light and non-standard material that cannot be read by the game engine. Therefore, the BIM model must be imported to 3D Studio Max to convert the light and material into standard light and material and exported to FBX file in the end. The overall workflow from BIM to VR can be seen on Figure 2.

The second course, *Architecture in the Digital Age*, is elective course for 2nd year students. The project for this course was to build VR environment from their previous semester Architectural Design Studio I Project, i.e.: *Inhabit Remote Ground*. Since the 2nd year students are just getting familiar with computer 3D, the workflow was started from generic 3D modeling software. The main disadvantage from this workflow is the object naming lacks clarity and needs to be set manually for each object.

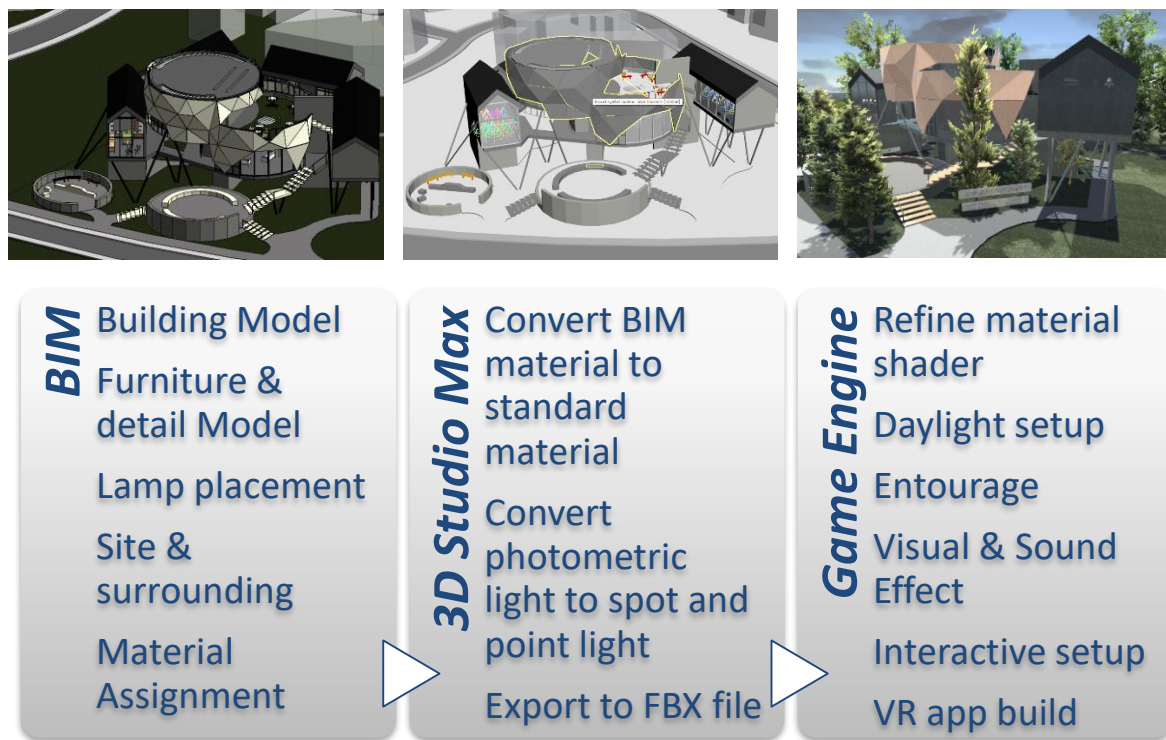


Figure 2. Workflow from BIM to VR

3.2. Key Findings: Model Development

The initial design was done manually without using computer or BIM. Thus, many of elements were not designed precisely since the students could not feel the users' feeling being in that space. During the first attempt, many doors and stairs were not accessible since they did not come up with proper dimension. Stairs and balconies without railing made the player fall and difficult to move.

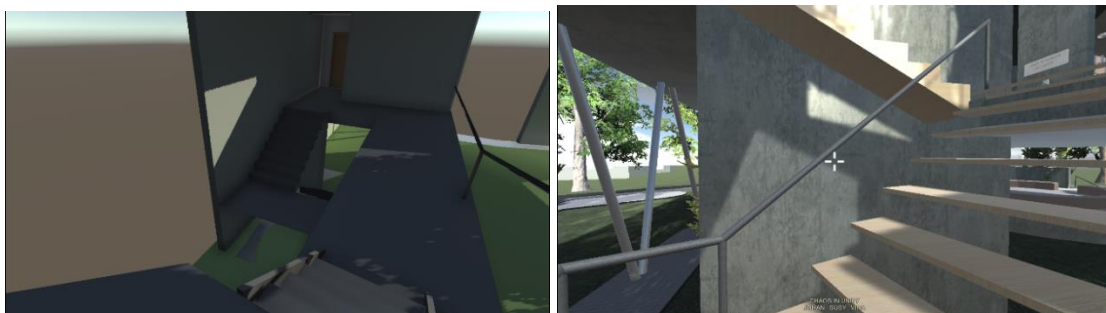


Figure 3. Development of ergonomic details from initial model to final app

The lack of ability to feel the design also resulted in poor material choices and light-shadow ambience. Many of the original design did not incorporate material finishes to the surface, resulting to dull feeling of the VR space. Daylight-shadow and artificial lighting were not initially thought well and resulting many dark areas.

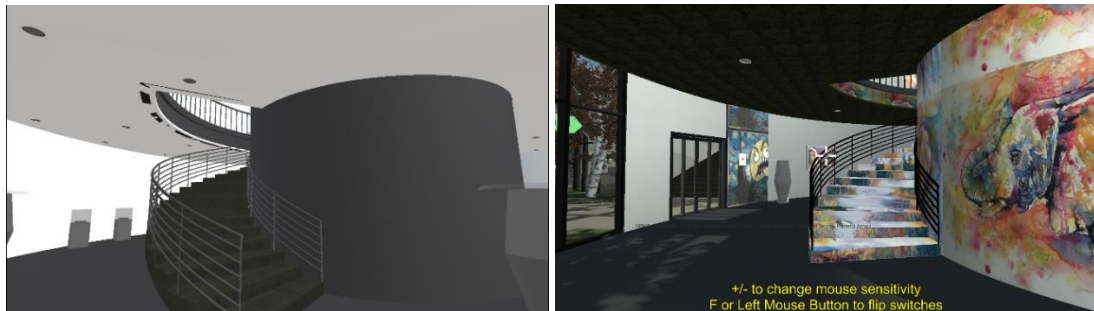


Figure 4. Development of material & lighting from initial model to final app

Space navigation is major issues in architectural VR and interactive representation. In virtual space we can move and explore the whole building space freely. Therefore, common users, who are not familiar with the building spaces yet, can get lost easily. To overcome this, one interesting solution was proposed, i.e. by using augmented label in the VR space. Although the solution is simple, it can give the spatial understanding and add atmosphere value that cannot be found in the real life.



Figure 5. Augmented label gives spatial navigation and new ambience

4. Public Review

As the final of the course, students had to present their work to the reviewers and public visitor from other faculties. For one day, the students opened a stall in campus neighborhood where passing by visitors, students and members from other faculties, could try the VR experience. Before trying the VR applications, visitors were shown of the static rendering images of the project. After experiencing the VR, they were asked to fill in questionnaires.



Figure 6. Exhibition and public testing (source: Publication Unit Architecture UPH)

The survey questions asking the comparison between still images and VR experience. The aspects questioned were based on initial research objective to observe how VR and interactive representation for exploring the scale, lighting, and material experience, as well as key findings we found during the class. There are 10 questions in total. The complete questionnaires can be seen on Table 2 below.

Table 2. Survey questions

Scale & navigation	Can you feel the scale of the space?
	Can you feel the height of the space?
	Can you determine the width of the room?
	Can you navigate from one room to another room?
Materials	Can you feel the atmosphere caused by materials?
	Can you change/ determine the material of the surface in the room
	Can you feel ambience changes because of material changes?
Light	Can you see the change of daylight inside and outside the building?
	Can you determine the time change caused by daylight changes?

4.1. Survey Result

There were 23 group projects presented in total. Due to time and space limitations, the public review was divided into 2 sessions: morning 9.00 am – 12.00 pm and afternoon 12.00 pm – 3.00 pm. The morning session had 12 projects while afternoon sessions had 11 projects presented.

There were 85 respondents in total. They responded the question based on scale 1-3 (lowest to highest). The choices are showing the level of their understanding after evaluating the entities of a project in both techniques. To measure performance of both still image and VR in communicating scale, material, and light experience, we summarized the total score obtained from all respondents for each questioned aspect.

Overall result shown in Table 3 confirms both techniques can communicate design idea that has been made by the architect. However, VR has higher points in all questions than rendered image.

Table 3. Survey points result

	Questions	Images points	VR points	VR > image
Scale & navigation	Can you feel the scale of the space?	240	248	8
	Can you feel the height of the space?	233	244	11
	Can you determine the width of the room?	234	244	10
	Can you navigate from one room to another room?	207	237	30
Materials	Can you feel the atmosphere caused by materials?	225	235	10
	Can you change/ determine the material of the surface in the room	221	240	19
	Can you feel ambience changes because of material changes?	223	239	16
Light	Can you see the change of daylight inside and outside the building?	229	242	13
	Can you determine the time change caused by daylight changes?	208	224	16

Both visualization techniques give the information about space's dimensions. The audience can evaluate that the room is wide or narrow, but they cannot confirm if it is fit to their body or not. This condition gives many of them answered '2' for rendered image, on the other hand they answered '3' for VR. The result in question 1-3 shows 8-11 points difference, that audience has deeper level of observation using VR.

The rendered image cannot inform a sequential space in the project because it is static. Most of the audiences answered '1' to question about navigation in a rendered image. But they mark '3' that they could navigate room to rooms and look around in the room with VR. The result has 30 points higher in VR rather than the rendered image. VR gives interactive quality, mainly the movement of the audience.

Another interactive aspect in VR shows in the daylighting and changing environment from day to night. This light changing casts different shadows to the room which increases dynamic qualities to the room. The ability to mimicking the phenomenon of reality into virtual environment gives different space experiences to the audience. Most of the audience answered in VR they can see or feel the time changing and different level of brightness outside the room.

Those projects that we visualized in VR empowers interactive and immersion as two important qualities that differ to image visualization. Those qualities are achieved by the capability of audience to change the materials for the interior wall. The audience can select and replace the color or texture in VR. In real time they can see the replacement, evaluate, and decide to get a suitable choice. In the questionnaire, most people could tell what kind of material used for the room in both visualization techniques. However, most of them answered it is hard to define the ambience of the room with rendered image only. With the virtual reality, they could see the application of different materials to the room. Nevertheless, this ability in VR did not make a person feel the difference of the room ambience instantly. This was possibly because the material interaction in the VR model was not applied to all surfaces in the room.

5. Conclusion

As the previous studies said, the use of VR does enrich students' spatial experiences and design outcomes. Some of the key findings during model development in class are scale and ergonomic, finishing materials, lighting ambience, and space navigation. One at a time, these issues were resolved through in-class peer-feedback and mid-term review, resulting better and complete experience.

For common users, both VR and rendered images can provide information about space dimensions, lighting, and materials. Rendered images offer fast glimpse of the project's atmosphere and easier to produce. VR, however, can give added value to the visualization of scale, light, and material by bringing the viewers immersive experience and enables interactivity to change the light and material at once and see the result in real time. Nevertheless, it is unknown about its effectiveness compared to the effort to create VR in design practice.

In addition to immersion and interactivity, VR visualization gives another important aspect: sequence of experience. It has sequence of the spaces where the audience can navigate from one room to another room. It also gives the sequence of time by daylight changing.

Creating VR visualization with intended interactivity level is difficult. There are only limited free-software for education and they require in-depth knowledge about video game making and programming. Another obstacle is limited hardware resources and capabilities to run VR in its full glory. Making VR for Android devices needs the optimization of the application to run it smoothly on limited device's specification. Thus, we must sacrifice graphic quality for performance.

3D visualization in industry nowadays is cross discipline between architecture, animation, and other designs, as well as computer sciences. The fact that creating architectural VR visualization requires knowledge beyond architecture itself forces us to work interdisciplinary in the course with other departments or universities. Further research should take multi-discipline collaboration.

References

- [1] P. Milgram and F. Kishino, "A Taxonomy Of Mixed Reality Visual Displays," *IEICE TRANSACTIONS On Information And Systems*, p. 1321–1329, 1994.
- [2] M. Coomans and R. Oxman, "Prototyping of Designs in Virtual Reality," in *The 3rd Conference on Design and Decision Support Systems in Architecture and Urban Planning*, Belgium, 1996.
- [3] P. Fuchs and G. Moreau, *Virtual Reality: Concepts and Technologies*, P. Guitton, Ed., London: CRC Press, Taylor & Francis, 2011.
- [4] G. Alvarado, "Virtual Reality in Architectural Education: Defining Possibilities," *ACADIA Quarterly*, vol. 18, no. 4, pp. 7-9, 1999.
- [5] G. Witmer, J. Singer and Michael, "Measuring Presence in Virtual Environments: A Presence Questionnaire," *Presence Teleoperators & Virtual Environments*.
- [6] F. A. Agirachman, "Pengujian Efektifitas Immersive Virtual Reality sebagai Metode Pemodelan Perancangan Arsitektur pada Tahap Konseptual," Institut teknologi Bandung, Bandung, 2017.
- [7] J. Milovanovic, . G. Moreau, D. Siret and . F. Miguet, "Virtual and Augmented Reality in Architectural Design and Education," in *17th International Conference, CAAD Futures 2017*, Istanbul, 2017.
- [8] C.-S. Chan, "Virtual Reality in Architectural Design," in *Computer Aided Architectural Design Research in Asia (CAADRIA 97) Workshops*, HsinChu, 1997.