High quality Virtual Reality for Architectural Exhibitions

Anette Kreutzberg
1 The Royal Danish Academy of Fine Arts, School of Architecture
1 anette.kreutzberg@kadk.dk

This paper will summarise the findings from creating and implementing a visually high quality Virtual Reality (VR) experiment as part of an international architecture exhibition. It was the aim to represent the architectural spatial qualities as well as the atmosphere created from combining natural and artificial lighting in a prominent not yet built project. The outcome is twofold: Findings concerning the integration of VR in an exhibition space and findings concerning the experience of the virtual space itself. In the exhibition, an important aspect was the unmanned exhibition space, requiring the VR experience to be self-explanatory. Observations of different visitor reactions to the unmanned VR experience compared with visitor reactions at guided tours with personal instructions are evaluated. Data on perception of realism, spatial quality and light in the VR model were collected with qualitative and quantitative methods at two different occasions and setups after the exhibition, both showing a high degree of immersion and experience of reality.

Keywords: Virtual Reality, Oculus Rift, GearVR, Exhibition display

INTRODUCTION AND BACKGROUND
As a part of the exhibition series World Architecture at the Danish Architecture Centre [10] (DAC) in Copenhagen, the exhibition 'World Architecture - Snøhetta' [13] opened to the public in June 2015. The exhibition, created by Snøhetta [12] and Danish Architecture Centre, ran until September 27th 2015 and had 13,000 visitors. Experimental use of virtual reality was implemented in the exhibition to demonstrate state of the art communicative methods and tools as well as expand the range of media used to present architecture in exhibitions.

The experimental VR model let the audience experience the vast space of the Central Hall in King Abdulaziz Centre for World Culture [11] in a 1:1 scale as if they were actually present in the building complex situated in Saudi Arabia, well before the building was inaugurated.

Architectural representation and experiencing architectural space
It is not enough to see architecture; you must experience it (Rasmussen 1959). There is a discrepancy in the way we sense architecture and its representation. For an architect it is important to be able to precisely express oneself and make sure that visions and intentions are fully understood. Architectural representations are primarily drawings or images, previously handmade and nowadays mostly computer generated from 3D models, but it is still 2D representations presented either on paper or on screen. Although often supplemented by scale models to touch, the 2D
representation remain the primary and purely visually focused method of representing architecture.

Adding interaction or motion to screen images can help conveying space (Kreutzberg 2011) but there is still a difference in envisioning the real space within a frame of an image or animation and experiencing the space with your body in the real world. Experiencing architectural space is a multi-sensory experience involving more than mere vision (Pallasmaa 2005).

VR has the potential of bridging the gap between 2D visualization of space and the bodily experience of space in the real world by placing the viewer in the virtual world, making the viewer part of the virtual world and therefore experiencing the virtual world with bodily senses.

**Virtual space**

Previous studies have found VR displayed on Oculus Rift DK2 [9] Head Mounted Display (HMD) to be a promising media platform for visualizing and demonstrating complex spatial 3D models, especially for non-experts untrained in reading technical drawings (Kreutzberg, 2015).

VR is still an emerging medium, where hardware and software are improved and refined constantly, many of which are still only available in developer versions. Strict limitations of the models concerning poly count, texture size, lights and screen effects apply, to run a stable and comfortable VR application.

Some issues are acknowledged and important to address especially concerning simulator sickness in VR (Moss, 2011). It is of major importance to prevent feelings of disorientation and nausea, and to protect users from motor-visual functioning issues after use, especially at a public exhibition. Creating a stable execution with sufficient frame rate and limited draw calls is the challenge.

The experience of realism in architectural VR models relates to the use of real world model size, detailed surface properties, shadows and reflected light. They are all important for experiencing and understanding the architectural space but especially for sensing the intended atmosphere, light is important. Real-time rendering of reflected light and soft shadows are very computational demanding and require extensive optimization of the VR model for use with contemporary available HMD’s.

**METHODS**

Phenomenological studies were made several times during the exhibition period, observing the behaviour of the visitors in the area with the VR HMD at a distance. Differences in behaviour of groups, singles and groups on guided tours were observed.

**Survey at cultural event**

After the exhibition period a cross-sectional anonymous survey (Creswell 2014) was conducted at Kulturnatten [2] collecting data [6] from visitors (N=72) at a cultural event displaying the KACWC VR model. Questions relevant for this paper were focused on the experience of realism, image quality, degree of vision and comfort as well as including a comparison of viewing the VR model in Oculus DK2 and as stereoscopic 360 °rendered image in GearVR [8].

**Qualitative empirical study**

To get a more thorough understanding of the experience in the KACWC virtual space, data was collected on sensory, bodily and atmospheric experiences through video-recorded Walk-and-talk interviews with nine participants, inspired by Sensory Ethnography methods (Pink 2009).

The interviews were arranged after the exhibition and the cultural event, and were conducted in a meeting room at an architect’s office. The interviewer followed along on a computer screen and made conversation about the sensuous experience while it was happening. The interviews lasted between 8:20 minutes and 13:35 minutes each. (Hermann 2016.)

After the interviews, the participants summarised and discussed their individual experiences in two focus group discussions.
**Exhibition design - practical setup**

The exhibition Snøhetta: World Architecture was organised in three rooms each representing the exhibition subtitle: People Process Projects. The VR experiment was placed in the first room representing the people and their work environment. An Oculus Rift DK2 HMD was mounted on an acrylic box discretely placed on the wall, representing the very long office working table. The connected laptop was hidden behind the wall and not visible to the audience. A small instruction label was placed in the box. See figure 1.

![Figure 1](image1)
The HMD.

The HMD was modified to be used hand held without having straps tied to the head for two reasons. Firstly, a hand held experience restricts the movement of the upper body avoiding vigorously turning and secondly, it places the hands "out of sight".

Some visitors had previous experience with the Oculus DK2 or had seen it demonstrated online, and they unfortunately wanted to use the heads traps, and tried to tear the straps down that were secured on the side of the HMD.

Proper visual instruction as to how to hold the HMD with both hands instead should have been more visible. The comfort of not having the HMD strapped to the face was obvious though, and people wearing glasses could actually use the HMD with their own glasses.

**VR model**

The VR model was created by converting a Rhino [3] solid model to several mesh models in 3dsMax [4] and importing these mesh models into Unity [5] for texturing, lighting and programming of interaction and finally output the complete model to an executable file.

Converting a huge conventional 3D Rhino architectural solid model representing 100,000m² to a low poly mesh model suitable for VR is not an easy task. All unwanted details were deleted prior to the mesh conversion and still the final optimised mesh model had more than 2 million triangular polygons. It was not possible to optimise all the geometry automatically without at the same time changing the appearance of the original architecture. Several parts of the model were therefore completely remodelled to optimise and at the same time to lay out the topology for clean UV mapping of texture maps and light maps. All mesh optimizing and UV mapping were done in 3dsMax. See figure 2.

![Figure 2](image2)
Central Hall in King Abdulaziz Centre for World Culture, Screen View.
Lighting was created in Unity with Precomputed Real-time Global Illumination with Forward Rendering in combination with Baked Global Illumination. It allows for the use of hardware techniques like ‘multisample anti-aliasing’ (MSAA) which can have a great impact on image quality.

The different light sources were adjusted in intensity, direction and colour in an attempt to best represent the combination of daylight and artificial light in the architectural model. The Unity Profiler was used throughout the process as a tool to analyse and ensure stability in performance of the final built.

RESULTS AND REFLECTION

Using VR in an exhibition space without personal instruction turned out to be a larger challenge than first anticipated. First of all the VR headset was not spotted by quite a lot of visitors - it blended in with the wall displays too well! Secondly if spotted - quite some bewilderment arose as to what was displayed and what to do. Most visitors found out to look around but not all tried to turn their body 180 degrees.

Initially it was intended to allow for movement and exploration in the VR model, but concerns about simulator sickness and the practical setup in the unmanned exhibition turned the experience into an exploration from a fixed viewpoint.

Halfway through the 3-month exhibition period, an update was made to the model creating a loop with fade-to-black between two different positions instead of displaying just one permanent viewpoint. The loop was combined with plan views indicating the active point of view. See figures 3, 4 and 5.

Looping between two positions did not work as intuitive as expected - fade to black was set to 4 seconds for a comfortable feel - but it was often interpreted as a fault - that the installation broke when the screen turned black - and visitors took of the headset before they could realize it was a transition into the next position.

Many visitors completely lost track of the orientation in real space in the exhibition, and were quite disoriented when taking off the HMD again.

Generally, women seemed more focused on exploring the architecture, sensing the light and general atmosphere accepting the immersion of being somewhere else while looking through the VR glasses, whereas many men moved their heads and bodies vigorously to test the latency and precision of the technology behind the player.

There was a difference in the way people acted if they were in a group, with a lot of audio to align to the real world, and the single visitor without any comforting companions. The latter tended to be gentler in the movements and were examining the headset afterwards - and reading the instructions on the wall carefully before they tried the experience.

Most people tried to take a step or two while being immersed in the VR environment - and it took some tries to realize that locomotion was not possible.

On guided tours, the visitors were introduced to the VR setup, and they could understand the loop feature and were generally very impressed. Explanations as to what the model actually showed was also explained by the guide.

It was a popular task in groups to film or photograph each other wearing the HMD.

Cultural event

At the cultural event posters with renderings, drawings and text gave visitors an opportunity to learn more about the architectural project displayed in VR. Visitors were guided in their VR experience and spent approximately 5 minutes in total testing the different HMD’s. The survey results (N=72) were very pos-
itive with 31% of survey respondents experiencing the realism to be "Fantastic" and another 43% respondents experiencing the realism to be "Good". Degree of vision and comfort were experienced as "Fantastic" by 53% and 44% of survey respondents respectively. See figure 6.

Visitors used Oculus DK2 to view the looping VR model from the exhibition and had the opportunity to compare it with a pre-rendered stereoscopic 360° image of the same VR model (in this example rendered from within Unity 3d game engine in a rather blurry resolution!) displayed in GearVR on a Samsung Galaxy S6 [7] mobile. The comparison was interesting because the high quality VR model used static points of views, and did not utilised the possibility of movement. The same static point of view in a pre-rendered stereoscopic 360° rendering can be rendered directly from the render software without the need of time consuming optimising for real-time rendering in a game engine.

**Figure 6**
Experience of the room with Oculus Rift DK2.
Difference in experience of realism and image quality was noticed though including the smaller view frustum in Gear VR (100°) compared to Oculus DK2 (120°). See figure 7.

With the use of high quality renders, the GearVR does have great potential - it is cheap, portable, and you can store many 360-renderings on the mobile.

**Walk-and-talk**

The walk-and-talk interviews were conducted during two days in November 2015.

Sixteen questions in three categories were included in the interview guide, asking for comments ranging from purely descriptive to emotional and intuitive reflections.

Participants were architects (4) and users of architecture (5) and the two groups had very different approaches to VR. The architects reflected mostly on the representation of architectural space whereas the architect-users reflected on the virtual space and not the representation of space.

**Mass and volume.** All participants described the different components of the space, especially the contrast between organic volumes emerging from regular straight ceilings and walls. Most participants also commented on the large number of columns scattered in the hall.

**Materials.** The participants perceived most of the materials correct. They identified wood, metal, polished stone, glass and concrete, only the rammed earth (walls) was generally confused with other materials like cork, wood or brick. One exception was a participant confusing the polished stone floor with a carpet.

**Light.** Many participants described in detail different light settings, contrasts and emphasized the natural or artificial appearance.

One architect commented on the different light setups in the two positions in the VR model:

(Pos. B) "I can see they have been working with artificial lighting in the ceiling. I am not particularly mad about it, if I may say so. I think that the skylight at the end of the room is impressive though, but it feels like some daylight is missing, compared to the other place I was before.

(Pos. A) Here there are the same ceiling lights as in the other place, but here it is much lighter in a pleasant way. It is because I can see that the light comes from above. There is a place by the stairs where some light is, it could be daylight."

In the final focus group discussion her conclusion was: "I think what worked best in VR was the representation of the light. [...] You got a great feel for the character of light in VR, and you could experience the various light settings, daylight, reflected light and various types of artificial lighting. It is difficult to represent light in an image. Here I really think it [VR] has potential." (AN, Interview C)
Haptic impulses. All participants expressed an urge to explore the virtual space, especially "to look past the edge and down". The visual experience made them forget the fact, that it was a stationary representation, and they tried to walk towards the points of interest. See figure 8.

Implicit sensory perception. "I have a feeling that if I touched the pillar in front of me, I would feel stone. Cold against the hand. I clearly recall the surface from places I have been before." (SM, Interview B3)

The bodily dimension. "I'm surprised at how wild this is. I can look up, and I can turn around. Which is a full 360 degrees! I can look down." (JD, Interview B5)

Eye height. The eye height in the VR model was fixed and set to 165cm. Individual calibration of eye height is possible with Oculus DK2, but since it was the exhibition VR model that was being tested, the fixed eye height was preserved. All participants were in the height range of 165cm.-180cm.

"The simple and tangible, such as standing up, means a lot. That you experience the space standing, instead of sitting at a conference table and looking down at a drawing or looking at a screen. [...] You achieve a completely different physicality by standing up and turning your body. It gives a physical feeling, which you cannot obtain in other ways. Other than by being in a room in the real world." (JJ, Interview C)

Atmosphere. For fully calling forth an atmosphere in VR, light and materiality seem not to be sufficient; the model must contain furniture, people and other artifacts to have a real feel of life to it.

CONCLUSION

Reconstructing and optimising the very large Rhino 3D model for use in VR was very time-consuming, but resulted in a stable execution including real-time rendered light. The model was on display in the Snøhetta: World Architecture exhibition for 3 months.

The integration of VR in the exhibition was too
discreet in the unmanned area; many visitors did not discover the HMD at all. For those that did, they seemed to have an exciting experience, although many did not understand what was on display - neither the content nor the technology.

The automatic loop between two fixed views introduced halfway through the exhibition period was not as intuitive as expected. Sufficient instructions on what to expect and why, especially concerning duration and (limited) interaction, proved to be very important for a positive VR experience.

The perception of spatial and lighting qualities in the VR model worked very well and was examined thoroughly at walk-and-talk interviews after the exhibition period. The comment from a user: "It is almost too real," explains the urge to walk around and explore the VR environment although interaction was restricted to fixed viewpoints. Since virtual reality is a medium that attempts to replicate one’s experience in the physical world, users are likely to have an expectation that they will be able to interact with that virtual world in the same ways they do outside of it.

User responds indicate that for perception of atmosphere in VR, light and materiality are not sufficient alone; the model must also contain a certain amount of furniture, people and other artifacts.

Further studies should extend the experiments with representation of natural and artificial light in VR and should include experiments with 360° stereoscopic renderings for faster iterative work.

ACKNOWLEDGEMENT
The Danish Arts Foundation [1] funded the development of the VR model.

REFERENCES
Creswell, JW 2014, Research design: Qualitative, quantitative, and mixed methods approaches, Sage Publications
Hermann, D 2016, Kroppen og sanserne i Virtual reality, Master's Thesis, University of Copenhagen
Kreutzberg, A 2011 'Game Engines as Dynamic Tools in the Design Phase', First International Congress of Retevitruvio 2011, Bari, Italy, pp. 1585-1593
Pallasmaa, J 2005, 2008 edn., The Eyes of the Skin, Wiley-Academy
Pink, S 2009, Doing sensory ethnography, Sage Publications