Visualising Architectural Lighting Concept with 360° Panoramas

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This paper presents the establishment and refinement of a visualisation workflow based on initial learnings from introducing mobile Virtual Reality (VR) as representational medium for visualising and visually evaluating architectural lighting concepts using rendered 360° panoramas. Four student projects are described, each with a different aim and approach towards visualising architectural light in space: Two projects aiming at conveying reality with physically based lighting simulations and two projects with an artistic approach to conveying light impressions. The 360° panoramas were used at low resolution during the design process to qualify the projects, and the final panoramas were presented with great success as a supplement to visualisations, diagrams, technical drawings and physical models at Bachelor and Master exams. The benefits of using familiar simulation and render software together with low cost, accessible and portable VR HMD’s in the authors opinion far outweighs the reduced Field of View, lower frame-rate, lack of parallax and dynamic Point of View compared to realtime rendered high end VR.

Keywords: Architectural lighting, 360° panorama, Virtual Reality, Visualisation workflow

INTRODUCTION AND BACKGROUND

Architectural representation has many modes of display, mostly in 2D on paper or screens based on long used techniques like orthogonal drawings instituted during the Renaissance as well as perspective views for visualising the atmosphere of a place from a specific point of view (POV). For an immersive experience of space, the 360° panorama first invented by Robert Barker in 1787, on the other hand wraps the image around the spectator in a built scenography for the perfect illusion (Lescop, 2017).

Modern Virtual Reality refines this illusion and makes it accessible with Head Mounted Displays (HMD) useful for an immersive three-dimensional and 1:1 experience of architectural space (Shemesh, 2015). Earlier VR experiments focusing on the perception of space in architectural models also indicated possibilities of enhanced perception of light in space with VR, accurately conveying lighting conditions (Kreutzberg, 2016).

In recent studies of the influence of light on the atmosphere of a space (Stokkermans et al., 2017) and perception of daylight in VR, the results also indicate a high level of perceptual accuracy, showing no sig-
nificant differences between the real and virtual environments on the studied evaluations (Chamilothori et al., 2018). Real-time graphics engines for gaming, like Unity [1] and Unreal [2], can by now render physically based lighting simulations for use in VR, provided that the proper processing power and high quality VR hardware is utilized. Two factors are however making this setup inconvenient for student work. High quality VR hardware like Oculus Rift [3], HTC Vive [4] and Playstation VR [5] is available in consumer versions, but the full setup of computer, location trackers, head mounted display (HMD) and navigation controllers is not very portable, making this VR experience inconvenient outside the Computer Lab. A much cheaper and more accessible solution is mobile VR, using mobile phones in combination with a low cost VR viewer like GearVR [6] or Google Cardboard [7] (Dokonal, 2016).

Real-time rendering a physical-based lighting simulation for VR on a mobile phone, however, is not possible with current technology without heavy latency and risk of invoking motion sickness (Moss and Muth, 2011). Furthermore, the game engines are not yet part of the mainstream architectural visualisation pipeline, resulting in extra work learning to master new software. An alternative is pre-rendered 360° panoramic images with fixed POV (point of view).

Students already produce fully textured and lightened 3D models used for their project visualisations, and with minor extra effort, these models can be prepared for 360° panorama rendering.

**METHODS AND TECHNICAL SETUP**

**Visualisation workflow**

Studies leading to a perceptually accurate visualisation workflow for simulated images of lighting systems in context had also indicated the potential of displaying in VR (Murdoch et al., 2015).

Based on our default visualisation workflow (fig. 1) for image output the workflow was refined and adjusted for each project, in an iterative process formulating best practice.

The default visualisation workflow involve creating the geometric 3D model in a modelling software, importing the model into 3dsMax [8] adding physically based materials, lights and cameras. The V-Ray [9] renderer is set up to output an image in a certain size and a render quality defined by a specific light calculation method. The image output(s) are colour graded, composited and manipulated in Photoshop before final display on print or screen/projector.
Three different light simulation methods were tested and used, two of them physically based: Rendered V-RayIES Photometric Lights and V-Ray Photometric Lights in combination with volume Fog. A third method involved manually painted lights on panoramic photos in Photoshop.

Photometric lights can utilize an .ies file [10], which contains the distribution profile for the light. An .ies file contains complete specifications of a real world light bulb or tube including the shape of the light’s cone (fig. 2) and the steepness of the light’s falloff [11].

V-Ray Brute Force [14] and Light cache [15] were used in combination for improved rendering speed. The Brute force method for computing global illumination recomputes the GI values for every single shaded point separately and independently from other points and is very accurate. Light caching is a technique for approximating the global illumination in a scene. Tonemapping, the process of mapping a High Dynamic Range (HDR) image to 8 bit, was done directly in V-Ray before outputting to the jpg image format.

Two 360° panorama render outputs: Spherical maps (equirectangular) and cube maps (fig. 3) were tested in different sizes. The map type and size selected for each project were based on render time, quality, stereoscopy, editing in post-production and VR HMD & VR viewer app used.

GearVR (SM-R322) headset was used with a Samsung Galaxy S6 phone and BoboVR Z4 [16] and Google Cardboard headsets were used with an iPhone 5S. The headsets and phone screens have different specifications and qualities shown in the table (fig. 4), which also include specifications for Oculus CV1 for comparison of a High end headset.

The student projects described below were made over a period of two years, and are presented in chronological order to point out the lessons learned.

<table>
<thead>
<tr>
<th></th>
<th>Google Cardboard</th>
<th>GearVR (SM-R322)</th>
<th>BoboVR Z4</th>
<th>Oculus CV1</th>
<th>Samsung Galaxy S6</th>
<th>iPhone 5S</th>
</tr>
</thead>
<tbody>
<tr>
<td>FOV</td>
<td>80</td>
<td>95</td>
<td>120</td>
<td>110</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>IPD</td>
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<td>Fixed 63mm</td>
<td>Flexible</td>
<td>Flexible (58-72 mm)</td>
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<td>-</td>
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<tr>
<td>Lens To Eye</td>
<td>18 mm</td>
<td>Adjustable</td>
<td>Adjustable</td>
<td>Adjustable</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Screen</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Dual low-persistence Samsung AMOLED</td>
<td>Super AMOLED</td>
<td>LED-backlit IPS LCD</td>
</tr>
<tr>
<td>Resolution</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1200 x 1080 (per eye)</td>
<td>2560 x 1440 pixels</td>
<td>1136 x 640 pixels</td>
</tr>
<tr>
<td>Brightness</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>542 – 784 cd/m²</td>
<td>500 cd/m²</td>
<td></td>
</tr>
<tr>
<td>Refresh rate</td>
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<td>-</td>
<td>-</td>
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<td>60hz</td>
<td>60hz</td>
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<tr>
<td>Sensors</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Accelerometer, Gyroscope, Proximity Sensor, Magnetometer</td>
<td>Accelerometer, Gyroscope</td>
<td>Accelerometer, Gyroscope</td>
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<tr>
<td>Tracker</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>6 DOF Constellation camera, optical 360-degree IR LED tracking</td>
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</tr>
</tbody>
</table>
and the progress of refining the 360° visualisation pipeline for physically based light simulation as well as the adaptation of the pipeline to artistic light simulation.

**Project 1.**
Master’s project (Architectural Lighting): Lighting concepts for Samsøe & Samsøe Flag store.

The introduction of cube 6x1 rendering in V-Ray 2.5 for 3dsMax in 2015 and a wish to demonstrate light distribution in a 3D model to examiners, led to the first experiments with rendered 360 panoramas for lighting simulation in VR. The 3D model was highly detailed with applied materials reflecting real-world physical properties as well as a lighting setup with manufacturer provided Luminaires and V-RayIES Photometric Lights.

The virtual camera used was set to Type: Cube 6x1 with an Output size of Width: 9216px and Height: 1536px. An added VRayStereoscopic Helper object allowed the definition of two virtual cameras based on the currently selected render camera. The eye distance was set to 63mm (Dodgson, 2004) in the VRayStereoscopic settings and the final output resolution doubled to 18432px x 1536px. Render time was approximately 5½ hours - too long for iterative render experiments (fig. 5 & 6).

The IES Photometric lights were emphasised by adjusting contrast in the rendered image in postproduction, and displayed well in VR, which was the main purpose of implementing VR in the presentation. The distribution of light in space was not as precise as expected though, although the overall perception of the rather small room was surprisingly well displayed in VR. Preparation of Render Elements for individual adjustment of light distribution and intensity in postproduction would have solved some of the problems.

The placement of POV was not ideal mainly be-
cause of the store podiums close by. They broke the immersion when looking down. Later experiments showed that a radius of approximately 2 meters free space from the POV would solve this issue. The initial idea of POV in the center of a room is not necessarily the best location for VR. Placed in a corner the viewer has an overview without having to turn around.

At the exam presentation one examiner was below average height, and commented on the seemingly wrong scale in the VR model. Eye height was set to an average of 165 cm - with which he did not comply. Eye height is indeed an important factor in perceiving scale correctly in VR (Leyrer et al.). One disadvantage of the pre-rendered 360° panoramas for VR is this fixed eye height decided on at render time. A solution could be to render several versions at different eye heights for presentation purpose.

Project 2.

Master’s thesis (Architectural Lighting): “Restaurant with open kitchen”, a photo real interior setting with a combination of daylight and artificial light based on IES Photometric files.

Building on lessons learned at the previous project, early test renders in low resolution and mono were made to help adjust the light setup proposed.

Different positions and rotations of the lumieres were tested and the effect observed in 1:1 from several POV’s. Test renders also helped decide on the best POV for the high quality rendering to be used at the final presentation. Render elements, component parts of the rendering, were used to edit and enhance the final cube map renderings in post-production (fig. 7). Direct- and reflected lighting render elements helped balance the light and the ambient occlusion render element added a subtle shadow to adjacent surfaces.

Manual retouching was not possible or at least very difficult because the retouching had to be uniform in both stereo renderings and at all seams.

The GearVR with the cube maps was offered to the examiners at the end of the examination session. All three examiners were very positive towards the representation of light in pre-rendered VR. Although the other representational material in the project was already very comprehensive and sufficient, the addition of VR presented the spatial lighting qualities in a full body experience not achievable with 2D visualisations.
**Project 3.**

Bachelor thesis (Spatial Design / Visual Communication): “Mind Upload - a Ritual”, a futuristic conceptualized staging of a spiritual ceremony with light beam effect and volumetric fog.

The Design Fiction method was used to conceptualize a future scenario by staging of a rite of passage. In the ritual, one of the last people on earth passes into the infinite life in the virtual dimension. A 4 min. voiceover was made for the kneeling experience in seemingly limitless space.

The concept indicated only a faint suggestion of volumes and voids shrouded in fog. Textures in the 3D model were restricted to plain white with a few abstract patterns. Volume lighting was used to symbolize a “beam me up” effect as well as distance fog to make the scene appear infinite.

Many monocular spherical renderings in low resolution (1080x540px) were made to adjust the composition of the scene as well as the lighting effects before the final stereo cube map was rendered (fig. 8 & 9).

The virtual camera was placed at 110 cm above ground to mimic a POV for a kneeling person. The final rendered stereoscopic cube map (18432 x 1536 pixels) was displayed on a Samsung Galaxy S6 mobile phone in a GearVR headset combined with head phones for play back of voice over sound file.

At the examination, experiencing the VR space from a kneeling point of view was very convincing according to the examiners. A point of view not easily conveyed by other media.

4 minutes of kneeling, is a long time though and may be uncomfortable or even next to impossible for many, even when kneeling on a soft pillow. Rotating the head far enough to see all parts of the space when following the audio instructions was also commented as difficult because of the kneeling position.

**Project 4.**


An alternative approach to visualising spatial light in VR was used for the exterior night scene in the Master’ project “New Lighting Concept for Lergravsparken”. 360° photos were taken with a Ricoh ThetaS [17] camera on site at dusk. White markers were placed in the “real world” as guides and the lights were added by painting in Photoshop according to the markers. The spherical mono images have distinct polar distortion - a conversion to cube map with Pano2VR [18] was tested before editing and adding the lights and other elements to have a better sense of perspective when painting (fig 10).

After editing, the cubemap was converted back to an equirectangular spherical map (fig.11) to be viewed with the ThetaS App [19] on a BoboVR Z4 HMD with an iPhone5S.

The exterior night scene worked extremely well in VR. Darkness seems more comfortable to view on a screen close to the eyes than very bright screens. The long distance view worked likewise well with
the mono spherical image, real stereoscopy has the greatest impact at close distances (Howard and Rogers, 2012).

CONCLUSION

Some spatial phenomena like light distribution are more easily explained with the bodily experience in VR than with traditional architectural 2D representations, and pre-rendered three-dimensional panoramas with fixed Point of View displayed in VR on a mobile is often sufficient. Students can take advantage of the already fully textured and lit 3D models used for visualisation renderings, and supplement with 360 panorama renderings for VR. Certain requirements to the 3D model must be taken into account for the illusion to work, like proper distance from POV to elevated geometry as well as POV in correct eye-height.

Render elements can provide a variety of adjustments in post-production thereby reducing the number of test renderings.

Stereoscopic cube maps offer high resolution and little distortion which make it easier to add elements in postproduction, but they are time-consuming to render and thus most useful for final presentations. Latlong spherical images have more distortion and lower resolution but render fast and are very useful for design iteration.

Of the tested HMD’s the GearVR provided the best overall viewing quality and comfort, but is limited to certain Samsung mobile phones, whereas the BoboVR Z4 was a comfortable around HMD supporting both Android and iOS mobile phones. Google Cardboard was the least precise and most uncomfortable HMD, but is cheap and versatile in also supporting both Android and iOS mobile phones.

The benefits of using familiar simulation and render software together with accessible, low cost and portable VR HMD’s in the authors opinion far outweighs the reduced Field of View, lower frame-rate, lack of parallax and dynamic Point of View compared to high end VR like Oculus CV1.

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