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Sketching Artificial Lighting Design with Scale Models and VR

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Key words: artificial light, lighting design, scale model, 360° panorama, VR

Abstract

This paper presents work in progress experimenting with rendered and photographed 360° panoramas viewed in virtual reality (VR) as a supplement to traditional representation methods for evaluating perceived qualities of light. Presented are initial findings in combining analogue and digital methods and tools for sketching artificial light with a focus on visually perceived light quality.

The project investigates the perception of accuracy in the quality of artificial light in a 1:10 scale model by direct observation and in VR by exploring photographed 360° panoramas from inside the scale model as well as 360° rendered panoramas from a digital twin model with photometric lighting.

The scale model is based on a full-scale test room equipped with varying light fixtures for reference of perceived accuracy.

The aim is to introduce fast and iterative work flows for architecture and design students encouraging integration of artificial lighting design from the very beginning of the design phase.

The preliminary recommended work flow based on results from the experiments provide an acceptable accuracy in directly perceived light quality in the analogue scale model as well as when viewing 360° photographed panoramas of the model in an HMD. The workflow is based on easily accessible tools and equipment for designing artificial lighting in scale models and supplemented with 360° photography, supporting the design process for architecture and design students.

Introduction

Experienced lighting architects know how light distributes from various light fixtures and how it interacts with daylight, a knowledge gained from vast experience. Undergraduate students and architects at the beginning of their career cannot equally rely on experience so trial and error are therefore a common and important method of problem solving in the design process.

How can undergraduate spatial design students be encouraged to integrate artificial lighting design as part of their initial project sketching, when they lack the experience and knowledge of contemporary artificial light properties?

How can they represent and refine a conceptual idea of artificial light in space using tools and methods they master even as novices?

These are the key questions considered in this paper and findings from a comparative lighting study form the basis of a suggested workflow for successfully integrating artificial lighting design in spatial design sketching by students.

Background

An important part of teaching lighting at KADK has for many years been the attention to human perception of light. The perception situation consists of an interaction between an object or context, a light source and a subject perceiving. The position and view direction of the subject compared to the light source and the object has major impact on the perception of glare, luminance, color and contrast (1).

The diagrammatic representation of the three elements of the perception situation is extended to adapt to our project, introducing the impact of filtering the perception through cameras and screens and the consequences thereby for accuracy in color perception (Figure 1).

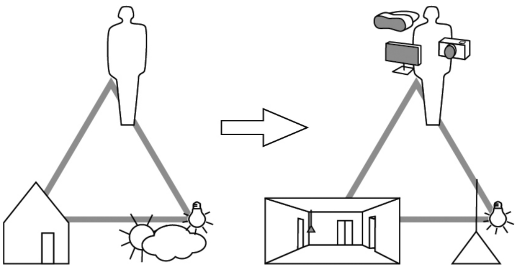

Figure 1. Elements of the perception situation extended with screen filtering.

Daylight color, intensity and direction are dynamic and controlled by time, date, place and context as well as weather. The light source (sun and sky) is outside and the size, number and placement of window and door openings regulate the amount of daylight inside. The quality or pureness of daylight inside is affected by glass type, indoor surface colors and obstacles in window openings like curtains, blinds and plants. The benefits of studying daylight behavior with physical scale models is well established and scale models are widely used as design tools from the early conceptual design phase, in order to inform and communicate spatial experience and atmosphere.

Artificial light on the other hand consists of many types; Incandescent, halogen, neon and LED (Light Emitting Diode) to name a few. They have varying properties and qualities like color temperatures (Kelvin dg), total quantity of visible light emitted (Lumen lm), Color Rendering Index (CRI) and many others. Artificial light may be regulated or controlled by for instance dimming, diffusing or applying lamp shades. By expanding the use of scale models to design with artificial light we hope to achieve similar benefits in the design phase as established with daylight.

Difficulties in examining the interior of a scale model can be overcome by photographing 360° panoramas inside the model for view in VR. When photographing 360° panoramas the camera Point of View (POV) can act as the eye height in VR, determining the perceived scale of the scene to be 1:1 no matter the original or real-world scale, as long as the established eye height in VR matches the user's real-world eye height (2). The ability to capture light distribution with photographic precision combined with a 360° panoramic VR display enhances and expands the use of illuminated scale models for daylight as well as artificial light studies (3).

Methodology

The perception of accuracy in artificial light distribution and color temperature was explored in a comparative study of lighting scenarios using analogue as well as digital representation methods experienced by direct observation and through 360° rendered and photographed panoramas viewed in VR. Lighting scenarios and representation and perception methods are discussed beneath as well as the practical and technical setup.

Lighting scenarios

Four different lighting scenarios were established in a full-scale studio, serving as reference for comparison of perceived accuracy in light distribution, intensity, glare and color. Tree settings used LED bulb light fixtures (Philips CorePro, 7W 806lm 2700K) for retrofit replacement of incandescent bulbs mounted with two different lamp shades and the fourth setting used a rack of three wall-washers (ERCO Pantrac Lens wall-washer, LED 12W 1260lm 3000K) (Figure 2).

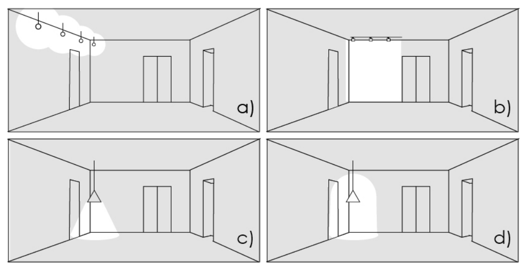

Figure 2. Light scenarios: a) Bare incandescent bulbs. b) Wall-washer. c) Metal pendant. d) Pleated plastic pendant.

Representation and perception methods

1:1 mock-up, reference studio

The studio dimensions are W5.5 x L8.0 x H2.7 meters, and the window façade has an area of 14.85 m^2. The studio has a grey linoleum floor; walls and ceiling are coated with white paint. Doors and skirtings are painted a semi glossy grey. The windows have glossy painted, white metal frames.

In the 1:1 reference studio the window façade is covered with white boards to avoid any daylight interference. A black curtain is hiding the white boards to mimic darkness at nighttime. The curtain unintendedly prevented reflections from the luminaires otherwise visible in the window glass. A plywood armchair is placed in one corner for reference of scale and for reference of color other than whites and greys.

Light fixtures a, c and d are mounted from a ceiling trac 60 cm from the wall. a) 60 cm from ceiling, 200 cm apart. c) & d) 125 cm from lower edge to floor, 85 cm from the back wall. b) Three wall-washer units mounted on a transverse trac 93 cm from back wall, 93 cm apart. The 1:1 reference studio was directly experienced from the center of the room, facing the back wall. Each lighting scenario was 360° photographed with a Theta Z1 camera for reference and comparison to the 1:10 scale model.

1:10 scale model

The scale model used in this study is a demonstration model made for use in daylight studies. It is an exact 1:10 scaled version of the reference studio, all surfaces covered with matching paint and materials. The 1:10 scaled armchair was made in balsa-wood. For this study a simple white cardboard ceiling replaced the original ceiling with skylights. The metal pendant was from an older lighting kit, the pleated pendant was made in paper for this study. Several UBH LEDs (Ultra-High Brightness Light Emitting Diode) of varying color temperatures and brightness were tested for the 1:10 scale model. A comparison with each 1:1 light scenario resulted in a qualitative closest match choice of a 5mm UHB LEDs (50mA 30000mcd (1.6lm) 3000K) to represent the bulb light fixtures. The wall-wash units were established by slicing and folding down a slit in the cardboard ceiling to direct light from a T5 LED luminaire (4W 340lm 4200K) to the wall (Figure 3).

The 1:10 scale model was directly experienced from the doors or windows. To experience the room from the center, each lighting scenario was 360° photographed with a Theta Z1 camera extended in height to a Point of View of 165 mm to simulate an eye height of 165 cm for reference and comparison to the 1:1 room. The 360° panoramas were viewed in OculusGo HMD or directly on the smartphone display with clip-on lenses filtering the perception with screens.

Digital twin (3D model)

The digital twin model was imported from Rhino to 3dsMax 2020, and was assigned V-Ray PBR (Physically based rendering) materials (4) and V-Ray photometric lights based on IES files provided by the lighting manufacturers (5) (6).

1:1 model	Luminous flux	Tcp	CRI	Order product name
Philips CorePro LED bulbs a)c)d)	694lm	2700K	90	CorePro LEDbulb ND 8-60W A60 E27 827
ERCO Pantrac Lens wallwasher b)	806lm	3000K	92	77766.000

1:10 model	Luminous flux	Tcp	CRI	Order product name
5mm UHB LED a)c)d)	1,6lm*	3000K	91**	OSM54K5111A
LED T5 b)	340lm	4200K	83**	LST5442
* Converted from mcd				
**Meassured with Sekonic Spectromaster C-7000				

Figure 3. Full scale light sources and their 1:10 representations.

360° panorama image outputs were rendered with a Spherical Panorama camera type in V-Ray with ray-traced lighting calculation. Brute force was set as primary engine for Global illumination and Light cache as secondary engine. The render output size was set to 6720 x 3360 pixels to match the Theta Z1 panoramic photos described below. The 360° rendered panoramas were viewed in OculusGo HMD filtering the perception with a screen.

Photographing 360° panoramas

A Theta Z1 360 camera (7) was used for capturing 360° panoramas inside the scale model and in the 1:1 studio for reference. The camera supports manual as well as auto settings with f-stop 2.1, 3.5 and 5.6 and an ISO sensitivity range from 80 to 6400 for still images. The maximum image size of 6720 x 3360 pixels for still images was used for all captures. The camera offers an HDR rendering (High Dynamic Range) shooting function with a semi-automatic setting allowing for manual White Balance by Color Temperature (2500 to 10000 Kelvin) and manual Exposure compensation (-2.0 to +2.0 EV, 1/3 EV steps). This shooting mode was chosen because of the one-click HDR shooting function saving time compared to standard bracketing captures that need to be combined and tone mapped in post. A Wi-Fi connected smart phone controls all camera settings.

Viewing 360° panoramas

360°panoramas can display on screens with embedded navigational interaction when viewed in a dedicated app. The native Theta app (IOS & Android) (8) provides instant feedback with a live view from a Wi-Fi-connected smart phone or tablet with gyroscope. As soon as the panorama is captured multiple views are available. VR view (single lens), VR view (twin lens) and standard screen. VR view (single lens) displays a portion of the panorama perceived to be in scale 1:1 in the direction the device is pointing. Rotating and reorienting the device displays other parts of the panorama. VR view (twin lens) also displays a portion of the panorama in the direction the device is pointing, but on a split screen. Mounting clip-on lenses on the smart phone instantly enables viewers to experience a 1:1 bodily perception of the captured space and its illumination. Standard screen display rotates the view with touch gestures. On a computer screen mouse or arrows rotate the panorama view. A higher quality HMD (OculusGo) was used for the comparative study. Both photographed and rendered 360° panoramas viewed in HMD were experienced and compared to directly perceiving the 1:1 reference room in this study.

Results and Discussion

Representation and perception methods

1:1 mock-up

The 1:1 mock-up is perceived as completely accurate, it is the real thing – no abstraction needed.

Unfortunately, limited accessibility to light fixtures and room configuration in general might limit the usability of this kind of representation for including artificial lighting in spatial design sketching. Photographing the space with the 360° camera for reference proved to be very challenging. The lack of color consistency when capturing images of LED lighting was very obvious. An average color adjustment for each of the two types of LED light represented in the lighting scenarios was found by trial and error adjusting the Tint value in Photoshop's Camera Raw filter (Figure 4).

1:10 scale model:

Scale models of high detail as well as rough models of cardboard boxes are suitable for sketching artificial lighting. Observed directly, the full-size light situation can easily be abstracted.

Examination of the scale model can be extended with 360° photographed panoramas viewed in an HMD where the perception of the human scale and the scale of light is experienced in 1: 1. The best experience and immersion with 360° panoramic photos is achieved by transferring the images to an HMD with good and adjustable lenses with a wide viewing angle and a high-resolution quality screen. The images are either uploaded directly to a local media library or viewed online through a web browser.

For a quick iterative process of continuously adjusting the location of the light sources, display on the smartphone with e.g. clip-on lenses is excellent. There is no extra transfer time as the Theta Z1 camera is remotely controlled via Remote Capture with the Theta App on the smartphone so that the image is transferred instantly. For presentation to others of photos of LED lighting, a color adjustment is often necessary and should be performed to best represent the light color.

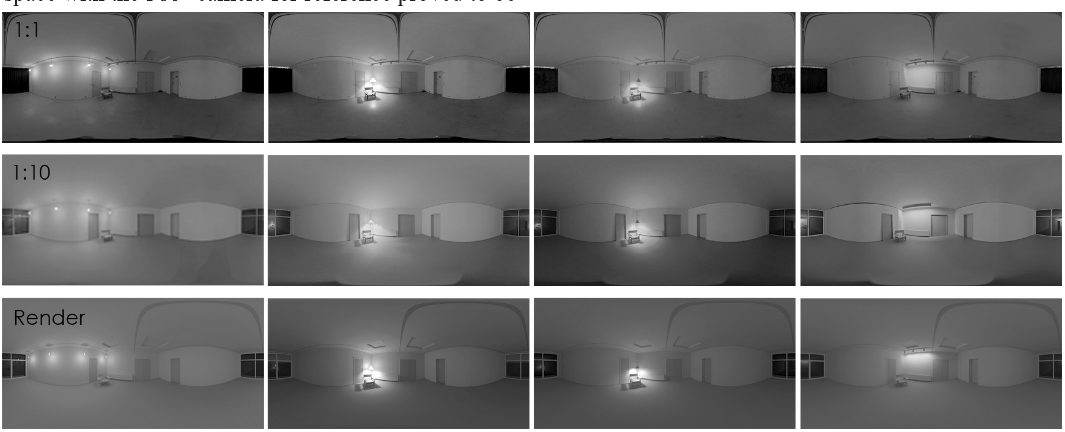

Figure 4 Comparison of accuracy in 360° panoramas (photographs and renderings).

It is advisable to create a varied diode kit in advance and store it for multiple uses. The diodes should be checked and measures to account for possible mismatch of intended color temperature, intensity and distribution.

Digital Twin (3D model)

The 3D model used for sketching light should be drafted with precise measures and physically based materials. Incorrect material properties can yield wrong representations of light – although the render output may look "realistic". Advanced digital light and render skills are usually required, which novice design students may not have.

Outputs of 2D perspective images can be further manipulated and light painted digitally in Photoshop or analog on print.

360° rendered panoramas have the same perception benefits as the photographed panoramas described above but lack the quick output generation. It takes a long time to render 360° panoramas at sufficiently high resolution for viewing in an HMD. Additional render variations e.g. separating direct and indirect lighting is possible through Render Elements as well as false color luminance/illuminance rendering.

Photographic representation

It can be a challenge to maintain color consistency when photographing LED lighting, since LED light sources have a spiky Spectral Power distribution with a predominance of green tones as opposed to daylight which has a broad spectrum and with a uniform layout (Figure 5). As a result, photographs of LED lighting tend to have a green color cast that must be neutralized in post-production, even with correct color temperature set in the camera White Balance settings.

Attention should also be payed to setting a sufficiently slow shutter speed to avoid brightness inconsistency occurred from the LEDs refresh rate.

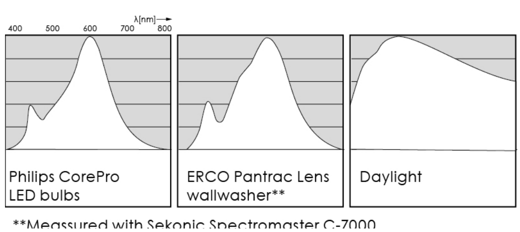

Figure 5 Comparing Spectral Power distribution

HDR (High Dynamic Range) images contain details in both shade and highlight and thus can represent the adaptive abilities of the human eye where details in both shade and highlight are clarified over time. HDR images can be generated by combining and tone mapping images with different Exposure Values. The Theta Z1 360 camera has an Auto HDR recording function used for this study.

360° representation with HMD

The 360° panorama image viewed in an HMD can position the viewer at the correct eye level pointing in any direction and thus glare can be directly examined, although the intensity of the glare is limited to the brightness of the screen. This is quite impossible otherwise except in the 1:1 mock-up.

Perceiving a space at correct eye-height as if present in scale 1:1, no matter the scale of the captured scene, is probably the most significant benefit of viewing 360° panoramas in an HMD. The immersion can be powerful even when experiencing a scene with a high abstraction level.

Evaluating light sketching methods

High-end digital light simulation software was not included in the comparative study as was not analog light sketching with pen and paper or tablet. They are included though in the evaluation of light sketching methods below, because they both represent the outer extremes concerning accuracy and time consumption.

When perceived output accuracy and relative time consumption are combined the analog 1:1 model seems to be the best choice. However, it is not always possible to establish a 1:1 mockup because of limited accessibility to light fixtures and room configuration. Digital tools, especially simulation tools also have high output accuracy but are advanced and very time consuming and complex to master and are therefore not really suitable for the suggested iterative method in the initial design phase. Analog light sketching is fast but not very accurate, and requires a certain level of expertise to be useful. In comparison between the different representation methods, the analog scale model in combination with 360° photographed panoramas has in our opinion the best combination of perceived accuracy and relative time consumption.

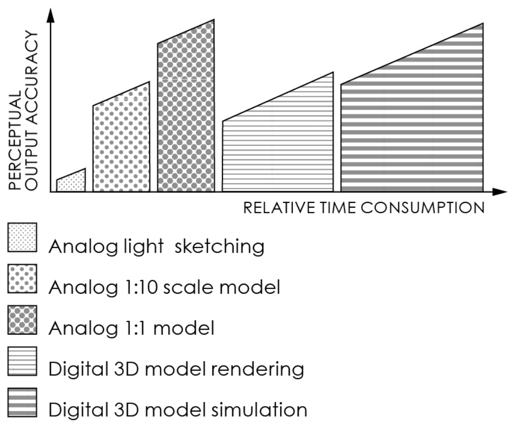

Figure 6. Comparing light sketching methods.

Conclusion

Artificial light can be represented and sketched in many ways, analog and digital. For the inexperienced design student simple and intuitive tools are sought for, especially tools and methods suitable for the trial and error work-flow often used in the initial sketching phase.

In this study analog and digital representations of artificial lighting design have been compared and evaluated according to perception of light accuracy in distribution, intensity, color and glare, but also the complexity and time consumption in creating the representations have been evaluated. The analog scale model in combination with 360° photographed panoramas showed the best combination of perceived accuracy and relative time consumption.

The outcome forms the basis of a best-practice guide for design students with instructions on how to equip scale models with artificial light and further enhance the perception of light and scale in the model with 360° photographed panoramas viewed in an HMD.

Perception is subjective and difficult to quantify. In this comparative light study the findings are the results of the authors' perceptions only, due to Corona restrictions in access to the 1:1 reference room and 1:10 scale model. We hope to conduct the initially planned survey at a later time.

Further studies

Further studies could include dimming, colored light, mixed lighting, lamp design as well as the camera specific aspects of capturing LED light.

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