# Designing a Lighting Installation Through Virtual Reality Technology - The Brighter Brunnshög Case Study

Boa Kim[1], Emmanouil Xylakis[2], Andrei-Ducu Predescu[2], Georgios Triantafyllidis[2(✉)], Ellen Kathrine Hansen[2], and Michael Mullins[2]

[1] Department of Sculpture, College of Fine Arts, Seoul National University, 1 Gwanak-ro, Gwanak-gu, Seoul 151-742, South Korea
avo07@snu.ac.kr

[2] Department of Architecture, Design & Media Technology, Aalborg University Copenhagen, A. C. Meyers Vænge 15, 2450 Copenhagen SV, Denmark
xylakis@gmail.com, {adp,gt,ekh,mullins}@create.aau.dk

**Abstract.** This paper investigates how VR technology can support the process of designing light installations. Specifically, how visual immersion through digital means can create spatial awareness of an area, without the need of physical presence, thus facilitating the fluency of the design process. The motivation for this study lies in exploring new methods and techniques which can support the process of designing with light. This study attempts to set up an initial design methodology built upon a traditional approach, and expanded based on its three aspects; real-time rendering, flexibility and spatial experience. The project brighter Brunnshög is used as a case study illustrating how a method such as this can be integrated.

**Keywords:** Virtual Reality · Lighting design · Methodology
Lighting design experiment

## 1 Introduction

This paper sees the possibility of VR as a product of lighting design and attempts to establish a design model within VR by outlining the immersive condition of designing in VR. With advancements in computing power and the recent release and affordability of Head Mounted Displays (HMD), Virtual Reality (VR) has resurfaced and shown great potential as a tool for industry and education likewise. Specifically, one aspect of VR is of great importance and that is the ability to create spatial experiences via stereoscopy. Being visually immersed in spaces without the requirement of being physically present, can assist the process of design and improve the designer's workflow.

Up until now important steps have already been done in integrating VR tools but mainly in the areas of communication and sharing. The focus of the present study is though how the design process itself can take advantage of VR.


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The project used as the case has the requirements that relate to interaction and lighting design so the methodology proposed here relates not only to designing a spatial experience but also meaningful ways of interaction with it. The design process model proposed by Hansen and Mullins [1] guides the overall development and is used to explain how a technology such as this can be beneficial.

### 1.1 Case Project Brighter Brunnshög

It is generally a known fact that people oppose urban development. This effect is known to as the Endowment Effect which refers to the tendency by residents in urban development projects of weighting and emphasizing losses more than gains, i.e. even though residents can get advantages from the urban development, they are critical of losing their routine, heritage and culture due to the construction [2].

Interactive public art installations are suggested to minimize this resistance, and the sense of loss, and which lead to a sense of ownership over development by creating an interactive platform which represents their routines, activities and heritage. This study hypothesizes that by transferring/recreating the experience of a public art piece into a virtual world, it will be possible to recreate its stimulating effect, and as such minimize resistance to development projects in the same way and with the same effect as real works of art.

Brighter Brunnshög, is the first stage of an urban development project in Lund, Sweden, and aims to integrate residents into the development of the area, and spread the word of this new science city and its research centers. This project is conducted under the Lighting Metropolis [3] umbrella, in cooperation with Lund Kommune and Lighting Design in Aalborg University, and funded by Kraftringen.

This VR project is considered as an interactive lighting design product itself, not only as a prototype or testbed for further construction. To enlarge the field of VR into media for lighting design, new design approaches and methodologies are needed based on an understanding of the VR environment, and its comparison with the physical environment.

### 1.2 Lighting Metropolis Initiative

The case in this investigation, Brighter Brunnshög, is part of the project Lighting Metropolis.

Lighting Metropolis is the first decisive step in realizing a vision for Greater Copenhagen as the world's leading Living Lab for smart urban lighting. The aim is to strengthen the significant role lighting can play in supporting safety, accessibility, identity, health, and education for people in cities.

A second Lighting Metropolis target is to facilitate and support the Greater Copenhagen region by tapping into the significant growth potential of these areas as they expand globally and exponentially [3].

### 1.3 Motivation

The motivation for this study lies in exploring new methods and techniques for supporting the design development of light in the virtual environment. With the release of "VR editors" [4] (transfer of software environment into the HMD interface), new approaches in design, mainly for the gaming industry, were realized. Using this emerging technology, this study tries to explore its potential and initialize an approach that could potentially change the way that we are designing spaces in VR.

### 1.4 Related Study

It has been highlighted that VR interfaces with the human perceptual system to a more intense degree, providing a more effective opportunity for computer to human communication. Further, new design interfaces for VR have been suggested which enable designers to work based on their instincts [5]. These attempts, however, focused on developing a tool/system for design, rather than how VR can affect a designer's perception.

To achieve an immersive experience in VR requires gathering various scientific domains to create a robust visual and interactive support for educational setting [6]. This multi-disciplinary framework of VR has been addressed with respects to its pros and cons, and its complexity and flexibility, and requires designers to work in tight collaboration with other experts [7]. Ever since collaboration between multi domains became normal, there have been a lot of theoretical and practical studies of how to integrate the different fields into one. Problem based learning (PBL) [8] and lighting experimental design model highlighted the importance of translating, transforming and testing the data and knowledge from different fields into one project [1].

As such VR offers users spatial experiences with time and lighting, the importance of using VR for presentation in architectural fields has been outlined. Especially for lighting, a multi-dimensional design element which is always connected to time and space [1], its spatial condition can be considered as an ideal design platform in architectural projects.

Aspects of participatory design that constantly get fed into a dynamic system would create the sense "of a living form that is constantly evolving/adapting to the social environment it is embedded in" [9].

Finally, with the decision of using a digital experience as a platform for the above, an extended research on the different types of VR techniques will help in understanding how such technology could host an art installation, that could support its qualities and how it differs from an actual real life installation.

## 2 Methodology (Design Process Model)

The design process within VR is based on *architectural experiment design model* [1], based on current demands for a transdisciplinary approach with multiple collaborative fields. In this study, the architectural experiment design model is named the *model of lighting design experiment (LDE) as it has been developed for designing with light in* *architecture* [1]. The design approach is based on one directional procedure where the feedback between creation, adjustment and re-creation is either non-existent, more cumbersome or slower and less dynamic in nature. By contrast, the constant feedback in VR requires the designers within the virtual workplace to have the ability to instantly and simultaneously process results and feed these back into the design itself. The virtual environment which approximates the real world enables the designers to work with their spatial perception. Based on these conditions; fast and constant communication between software, real time workflow, and spatial experience, this study explore how LDE can be optimized in VR.

This VR environment requires designers to take on the responsibility of learning due to the complex relationship between the input and output during the design development. As it provides opportunities for self-directed learning and self-assessment [6], *problem based learning* (PBL) [6] is used as a guideline in VR for optimizing the LDE design process into the multi-dimensional learning and developing design process.

### 2.1 The Model of Lighting Design Experiment

Since the concept of the project penetrates different domains, the design process is driven by *the model of lighting design experiment (LDE),* the latter of which is a theoretical proposal of how to design with light as a multi-dimensional design element by integrating scientific, technical and creative approaches to light in 5 domains [1]. Drawing from the work briefly outlined in the preceding section, the theoretical framework has been developed on how research traditions can be integrated in trans-disciplinary practice, illustrated in the model for architectural experiments (Fig. 1) [1].

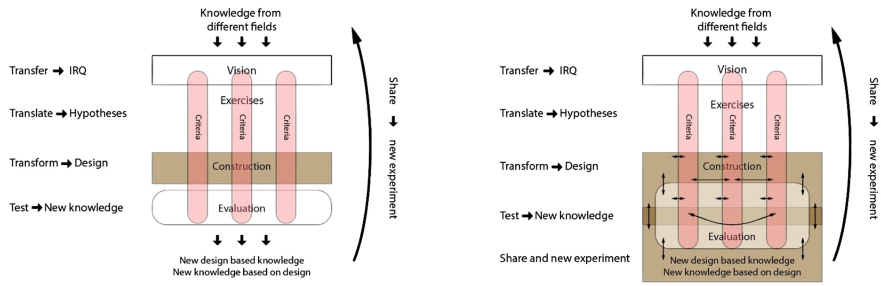


**Fig. 1.** LDE (left) and LDE in VR (right)

The feedback loops in its structure result in a stepwise process of adjustments and/or improvements. As such each step synthesizes and integrates the data from different fields into the single project. These loops result in an irreversible trend whereby alterations are not undone. The design model structure consists of five steps: (1) Transfer-Image and ask, (2) Translate - Explore and propose, (3) Transform - Link and construct (4) Test and explain - evaluation (5) Share and learn, and run in this sequence in a loop like fashion, where step 5 is followed by step 1 again [1].

The model attempts to resolve the question of how the knowledge of different disciplines can be thoroughly integrated into the design process, create innovative solutions and generate new explicit knowledge [1]. This works not only as a tool for integrating the knowledge from different domains but also as a guideline for the procedure for designers to achieve their goals the most effective way.

## 2.2 The Model of Lighting Design Experiment in VR

Designing with light in a virtual environment differs from designing in a physical environment in terms of the radically different environments. VR is formulated by the combination of the programming language, data values and graphical assets, and is not a space where tangible objects are created. In other words, designing in VR means basically creating the entire virtual environment including lights, and calculating the relationship of all the graphical components in the scene with high speed processing languages. This critical difference implies the necessity of new design methodologies.

LDE for traditional light installations are developed based on the irreversible factors of the physical world in terms of the scale and the time. If the design can be developed where by time and space can be ultimately controlled, how can the designers operate this flexibility?

The three main factors in VR are defined in terms of real time rendering, flexibility and spatial experience. These factors critically affect the traditional design approach, and can be used to validate the design phases with light in VR and its multi-dimensional elements [1].

### 2.2.1 Real Time Rendering and Constant Feedback in Design Process of Light

With the latest advancements in virtual environments VR now closely approximates real-world conditions [7]. This highly advanced visual output and the technology of HMD enables designers to use their spatial sense for lighting. The application of LDE in VR, therefore, implies its adaptation, as many aspects within VR fundamentally change the nature of design and workflow.

In VR, the flexibility between VR engaged software and protocols has been the subject of study which has indicated its relevance. The research on VR application has established several VR conditions such as flexible integration and configuration of heterogeneous VR and external software, ease-of-use, lowering the learning curve and empowering end-users [7, 10].

As VR relies on the flexibility and freedom which is easily adjustable depending on the programs engaged, these elements have been developed to be well-compatible with each other, and allow for constant feedback due to instant communication [7]. They can be adjusted and integrated within “a host graphics engine”, and as such can be expanded greatly. This system directly influences the way LDE can be applied. More specifically, steps 3 to 5 in LDE; transform - test and explain - share and learn, are engaged more complexly, and the boundary between steps fade somewhat. Further, feedback between the steps is continuous and results in a model where the order of elements is less restricted and more interchangeable.

As indicated by Hadiness [7] “VR is highly controllable and makes procedures repeatable with respect to the design of the environment and the way of interacting with it.” Figure 1 (right) outlines the multidimensional communication between the different elements of the model. This model highlights the complex and strong ties of steps 3 to 5. The design, test and evaluation keep repeating during the design progress.

Imported models interact much faster in the game engines as these enable rendering of the visual asset and allow interactions with virtual environments in real time and in a highly realistic manner. In addition, body position, pointing direction, and exploration movements can be measured with high precision in real time [7] (Fig. 2).

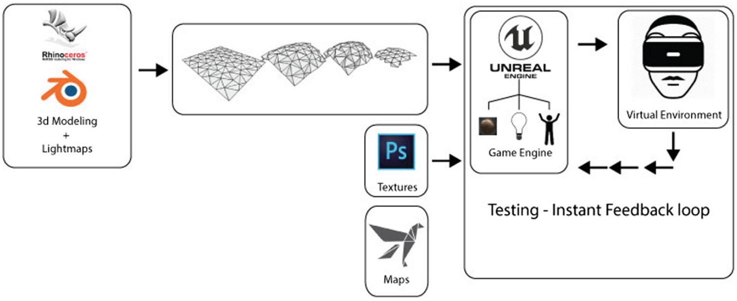


**Fig. 2.** Continuous feedback between the steps in VR development.

### 2.2.2 Spatial Experience in the Design Process of Light

The spatial aspects of VR have been highlighted and considered the strongest point of the vision of VR in different industries and as such the human experience is based on spatial environment. Regarding the spatial factor of VR, Hardness outlined that firstly “manipulations of the environment, of viewpoints or metrics of the virtual space (e.g., physical inconsistencies or non-Euclidean metrics), and of interactions with the virtual reality are possible in real time.” Secondly, “different sensory modalities related to spatial perception can be tested selectively and can be brought into competition with one another in order to estimate their relative contributions for a given task.” Lastly, “virtual reality enables the measurement of spatial behavior in large-scale environments also under real walking conditions (e.g., treadmill or walking sphere).” For these reasons VR has been proposed as a more cost effective and safer replacement of physical projects which might be inappropriate or impossible to be realized due to inaccessibility, cost, security issues [7].

Besides the aforementioned impact on user experience, the spatial conditions in VR equally affect the method of the design process itself. More specifically, it enables designers to experience the light while they are simulating the light and creating the scene. In this process, the field of perception moves constantly between 2D flat screens and the virtual workplace.

This temporal and spatial approximation of the real world is relatively precise, and enables designers to propose lighting scenarios based on real situations, and find the best solutions. However, VR requires the designers to react almost instantaneously to its constant feedback during the design, and at the same time the designers are expected to exploit this flexibility and freedom with absolute control through blueprints and scripts etc. In addition, this real-time and fast feedback requires the lighting designers to either obtain more broad and precise knowledge about other fields integrated in the project or, as Haan [11] commented, need to collaborate closely with domain experts. In other words, when creating a scene in VR, each element has to be introduced and adjusted simultaneously, the latter of which implies knowledge of e.g. botany, architecture, construction, besides understanding such aspects as reflectance of materials and trees when dealing with the lighting. Moreover, these different methodologies enable lighting designers to join the project from its early stage of development.

# 3 Development

## 3.1 Setup and Tools

Choice of tools relied on factors such as ease of integrating external interfaces, availability of tutorials and size of community around them, ability to fulfill requirements connected to real world. As the main platform for development, the engine Unreal Engine 4(UE4) was chosen and the HMD interface, HTC VIVE.

Data from user interactions is being collected dynamically and in real time with the use of arduino and sensors within the engine.

## 3.2 Analysis and Initial Designs

The project initially seeks to answer the question: "How can public art reduce the sense of loss during urban development projects?". The three design criteria of awareness, mutuality and flexibility were formulated according to client needs, focus interviews etc. aimed at answering the question from different perspectives. These three criteria are transferred into lighting (awareness), structure (flexibility), and interaction (mutuality) in VR, as the initial criteria were originally formulated without considering the distinction of the virtual environment.

*Lighting (awareness):* Lighting in this case study is the main media which enables users to recognize themselves as a part of the development project, and become aware of their area and environment by lighting up the virtual area. Lighting scenarios aiming to solve the problem from different perspectives were designed and simulated in the engine for testing. Figures 3, 4 and 5 illustrate the more distinct cases. The idea behind the design is to put the participant in the position of the designer/artist and light would represent his palette. Virtual "LED screens" placed at the inner side of the tunnel allows for content to be displayed and manipulated according to user's input (Fig. 5). Characteristics such as hue, intensity, motion and patterns are being altered thus resulting by the end of each session a finished installation according to his/her decisions.

*Structure (flexibility):* The modular structure of the tunnel initially aimed to transform its physical structure to be able to adapt different spaces during the development. The physical body of the installation can correspond to VR itself as the media delivering the

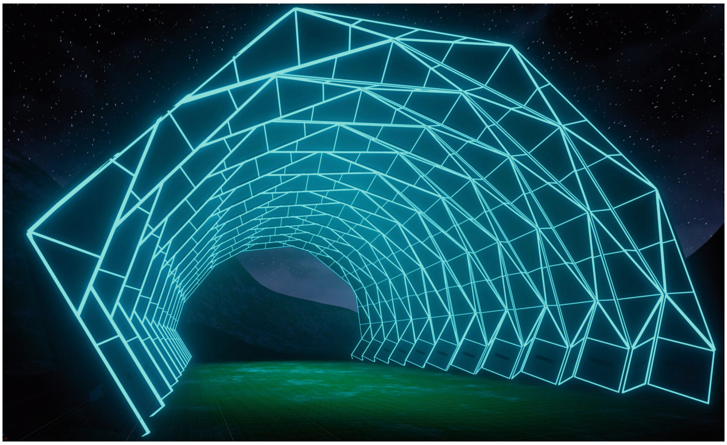

**Fig. 3.** Initial lighting design and experiment with linear led light

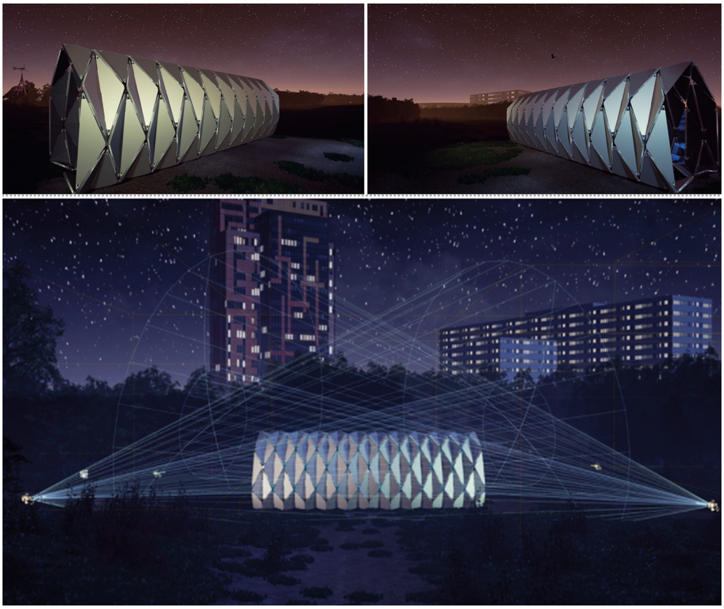

**Fig. 4.** Tunnel lighting simulation and setting

design. VR as a media is chosen for its ultimate flexibility which can simulate any time and place. In addition, VR is a platform which connects different graphical, and programing languages, i.e. it allows the designers to work with ultimate freedom.

To create the desired environment in Brighter Brunnshög the designers had to go through different combination of these values, test them, return to the basic model and constantly optimize the results. This process is conducted using multidimensional

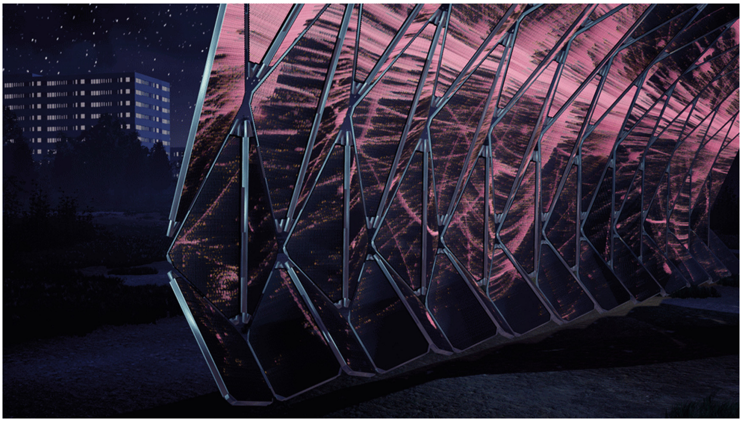

**Fig. 5.** Lighting pattern and LED screen simulation

feedback during the development as the settings are continuously affected by small changes. The strength of VR is that these can be tested immediately, as they are developed and proposed.

*Interaction (mutuality):* Interaction in the virtual environment aims to provide the setting for a mutual relationship between the users and the area. More specifically, it enables not only the users to learn about the area and its vision, but also the Kommune, companies, and public/private organizations can learn from the users. Further interaction between the installation and the users is that in which the users can design the light in the tunnel. VR realizes this idea by transferring that control to the user via different types of sensors. For the more direct interactive elements motion controllers and infrared sensors are being used parallel with ambient interaction sound and radar sensors, which were tested inside the engine.

## 3.3 Transform and Prototyping

Physical mockups in the step above helped establishing the physicality of the installation and enabled idea generation and details around its form. Taking that further into a VR Environment would help gain an understanding of the installation within its space and experiment with features such as lighting, tunnel motions material shaders and interactions.

With the room-scale VR technique, a physical space (room) was chosen according to the physical dimensions of an active area of the tunnel. This step is important in simulating the experience of walking inside the tunnel and create a sense of scale.

Sensors' input is mapped to actor's parameters such as light intensities, tunnel motions, etc. This helped in understanding an area of interest across gathered data from each type of sensor. Diagram below illustrates the process (Fig. 6).

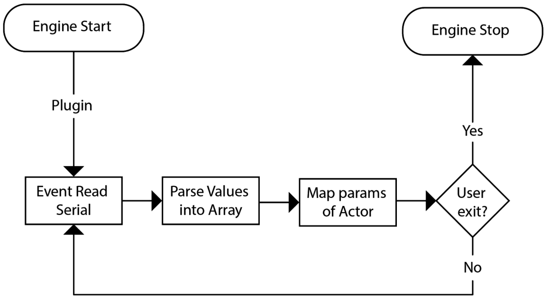


**Fig. 6.** Process of data collecting from sensors

### 3.4 Test and Share

Lastly, other than integrating sensor functionality for prototyping/experiments, UE4 is being used as the communication platform for the Installation. By generating the environment around the installation with the use of height maps and procedurally create the foliage, we were able to recreate a big part of the area of Brunnshög and with the use of the HMD visually immerse users into the area. That serves the purpose of communicating the installation's presence in the area.

Secondly a qualitative approach in evaluating the experience would yield valuable results as to how well the virtual experience communicated the design idea of the installation.

## 4 Discussion

This study aims to initialize an approach to lighting design with the use of virtual reality technology as part of the design process. An approach to design by utilizing digital design tools such as VR, comes with the responsibility of understanding their roles and limits [12]. A stronger interdisciplinary approach in media technology, lighting phenomenology, physics and architecture is required by designers that make use of these tools. While this methodology comes with advantages in communication, evaluation/testing and cost efficiency, meanwhile demands dedicated hardware and special interfaces (HMDs, powerful workstations).

## 5 Conclusion and Future Work

It is clear that VR offers users the immersive experience based on its spatial aspects which is very close to the experience in the physical environment. This is the one of the strong reasons of VR for designing with light, a multidimensional element in space. Despite this similarity between VR and the physical world, these two worlds rely on different systemic environments, i.e., VR is created by graphic programs and programming which are very flexible and give the designer ultimate control. These three aspects of VR means designing with light in VR can be different from designing in the physical environment. The Brighter Brunnshög case study explored how the design model can be adjusted in VR, and its potential as a media for lighting design. Evaluating this approach is seen as our next step by a qualitatively answering questions like: how did the design process improve by integrating it, which phases during the process could get the most out of these tools and how embodiment was achieved. A successful evaluation of this methodology would assist in optimizing this embodiment as well as the development of dedicated software to accompany it. We are still at the dawn of understanding how to best make use of these tools and truly realize their potential in order to help us design our lighting, our buildings, our living.

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Video: https://www.kraftringen.se/Om-Kraftringen/Projekt/Brunnshog/brighter-brunnshog/virtuella-brunnshog/.

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