Simulation of Daylight in the Architecture of Louis I. Kahn: A Study of the Un-built Hurva Synagogue

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Abstract. *One of the most powerful aspects of Louis I. Kahn's architectural space is his handling of natural light. Kahn believed that architecture began with the 'making of a room' and that 'a room is not a room without natural light.' Throughout his career, he explored bringing light into interiors in the most imaginative ways. Kahn used endless possibilities, from small devices to complex dome structures, to create a poetic and spiritual light inside buildings.*
The purpose of this paper is to present the theories and practices of natural light in architecture by Louis Kahn, who has deftly used it as a creative medium in his design of buildings. Starting from development of theories, this research focuses on how he implemented his theories into practice. As a case study, the Hurva Synagogue project is selected to analyze its unique lighting solutions. Many of Kahn's previous concepts can be traced to the Hurva, making it an ideal project for lighting study.
Since Hurva Synagogue is an un-built project, recent techniques of computer graphics is used to understand how daylight illuminates the interior in different times of the day and year in both still images and in 3D animations.
Keywords: *Louis I Kahn, Daylight Simulation, 3D Model, Animation.*

Introduction

The relationship between natural light and architectural form is intimate. The form, scale, orientation of the building and the character of interior spaces can be influenced by daylight as a design variable. Architects and painters have long realized its potential. Baroque architects used hidden windows to create a sense of mystical light penetrating into religious buildings. Impressionists discovered the atmospheric light and turned from stark contrasts to subtle shifts of tone within a narrow range of the color palette. Oriental designers filtered the light to create soft interior spaces and Islamic architects veiled daylight with complex grilles to cast patterns of light on walls and floors. Since early days of civilization architects began to consciously control natural light effects in their designs by taking advantage of the daily and annual movements of the sun. The Egyptian Temple at Abu Simbel was designed in such a way that only twice in a year light reaches inside the sanctuary for just a few moments. In the Roman Pantheon, the oculus in its dome controls the direction of light so that the light strikes directly one altar in the morning

and moves gradually across the floor to shine on the other altar in the afternoon. These environments are animated by the interaction of space and light whether in the ancient world or today.

We do not see light, but the effects of light. Reflected light on walls, floors, ceiling and furniture sends information about color, surface, material, highlights and shadows to our brain. Brightness of the objects helps us to understand the distances and depth of the space. Glare may cause discomfort. Even shadows assist us to understand the time of the day.

From the beginning of the history of buildings, architects considered natural light as one of the most important element of design. The role of light has long fascinated many architects who are interested in using daylighting to create a space which is not static but animated according to light's intensity and direction over time. In the Late Modern Period, Louis I. Kahn was one of those architects who had used natural light in his architecture deftly as a creative medium in his design of buildings.

This paper is designed to address the issues on Kahn's theories and their applications into practice. However, Kahn left a number of projects un-built and computer visualization is the only effective way to understand the lighting solutions in those buildings.

To verify whether a daylighting design is fulfilling Kahn's expectations, we tested daylighting options using computer visualization and calculation tools in which light's role in a building can be accurately rendered at any time of the day, and any day of the year.

As a case study, the Hurva Synagogue was chosen to analyze its great lighting solutions. Kahn integrated all great solutions in this building and designed the building as a masterpiece in modern architecture. Since the building is an unbuilt project, recent trends in computer graphics are used to comprehend how daylight illuminates the interior in different times of the day and year in both still images and animations.

Understanding Lighting in Kahn's Architecture

Louis I. Kahn spent significant time of his life to find the best solutions for lighting problems in his architectural buildings. He says that architecture is making a room and a room is not a room without natural light. He explained the importance of natural light: "A space can never reach its place in architecture without natural light. Artificial light is the light of night expressed in positioned chandeliers not to be compared with the unpredictable play of natural light." (Wurman, 1973)

The various methods of light control and different elements for light modulation can be observed in Louis I. Kahn's design work from beginning to end. At the beginning he started to use devices mostly on the façade to prevent the glare. Those devices were changed in each design according to their needs. Sometimes they became sunshade elements at the façade, textile strips as a curtain, or sliding panels which adjust the amount of sunlight inside the room (Figure 1). However, he was still using applied devices to deal with sunlight rather than the structure itself. The use of structure for lighting later became his main theory that he developed throughout his

Figure 1
The simulation of vertical sliding panels in the Pincus Building Psychiatric Hospital, Digital Model

practice. According to Kahn, structure is the giver of light and the columns represents the rhythm of light and no light.

After 1958, Louis I. Kahn started to work on the commissions which influenced his ideas about light's metaphysical effect on architecture. Kahn started to give more attention to finding appropriate quantity of light inside a building, as well as emphasizing the quality of light. As a consequence, he began to consider the relationship between structure and light. Layering or double-shell walls are the first steps in experiencing structure as a giver of light. Keyhole windows in the U.S. Consulate, Luanda (unbuilt project) or screen walls which he calls 'light shields' featuring circular, triangular or rectangular openings in the Salt Institute are some of the examples of the double-shell walls (Figure 2). These walls are self-standing devices to control the amount of light going inside the building and prevent the glare that would have been caused by the contrast between outside and the dimness within. These interstices enable not only light modulation, but also provide ventilation and framed views towards the outside.

Figure 2
U.S Consulate in Luanda, Digital Model

In the late work of Louis I. Kahn, it becomes apparent that skylights play an increasingly important role and he developed more sophisticated solutions for light control and modulation. Ranging from simple openings in a pyramidal roof, all the way to a complex dome structure, Kahn developed an astonishing spectrum of architectural solutions for skylight illumination.

Kahn often spoke of the Greek column in terms of light. He had the idea that the column could be hollowed out and its periphery became the filter for light entering the column. These columns act as diffusion chamfers. Daylight shines through their openings, ricochets around the inside of the columns, and filters subtly through openings into the room.

Open air courts were another essential element after he realized that he can create colors by using the changeable play of sunlight. He used sunlight and different materials to find a special hue and intensity of light in the courts.

Using nature to prevent the buildings from glare was used first and last in the Common Library, Berkeley, California. In this project, rather than using sunshade elements, Louis I. Kahn preferred to use a 'green filter' planted in front of the windows.

As one of Louis I. Kahn's most powerful design considerations, the handling of natural light was a big success in his architecture. He brought light into his interiors in the most imaginative ways. For each project he considered new applications according to the project's needs, location, and design theme.

Case Study

In 1967, Louis I. Kahn received a commission to design a synagogue in Jerusalem to replace the old destroyed Temple of Solomon. This was a big opportunity for Kahn to express his ideas on architecture and to incorporate the elements of ruin in his building. It was an opportunity for him to build within the archeological boundaries of the ancient world that had so moved him in his earlier travels. The power and dignity of ancient architecture, in which monumentalism was tempered by a sense of balance and form was intended to elicit feelings of awe that were fitting to a building's function, had a profound effect on him. In its eschewal of ornamentation and its incorporation of squares, circles, and other simple

geometric shapes brought to realization in lustrous concrete, the work Kahn created over the next two decades had a power that many have characterized as spiritual or mystical.

Form

The first proposal of the synagogue was designed between 1967and 1968. The inspiration from the Temple of Solomon can be seen in his scheme. The outer building of Hurva consists of sixteen massive pylons, four in each side, recalling some ancient ruins (Figure 3).

The plan was a perfect biaxial symmetry, however unpredictably, the entrances were on the narrow corners instead of on axis.

Four columns at the corners support the inner sanctuary. The first floor is designed to be a place for a bema, ark and candle service and the second floor is designed for seating (Figure 4).

The most outstanding element in the final proposal is the series of four cylindrical openings on the axis piercing the ceiling planes shown in one of Kahn's pencil sketches. Also a square opening at the center of the ceiling brings light to the interior sanctuary, similar to the Pantheon.

In the final proposal, Kahn used a very sophisticated way for the modulation of light in the synagogue, including ruin forms as an outer shell to protect the inner sanctuary from heat and sunlight, openings in the ceiling as a skylight to bring natural light and its unpredictable play inside the synagogue.

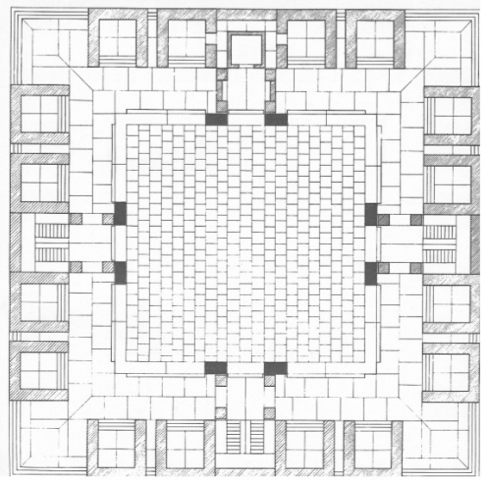

Figure 3
First Floor Plan of the Hurva Synagogue

Material

"Material cast shadows, shadows belong to light" (Johnson, 1975)

By the early 1960s, Kahn developed a vocabulary of materials, which he used over and over during his last years. Concrete was the main material he used in most of his designs, which he felt soaked up the light like a sponge. He used concrete for both structure and finish in almost all his buildings after

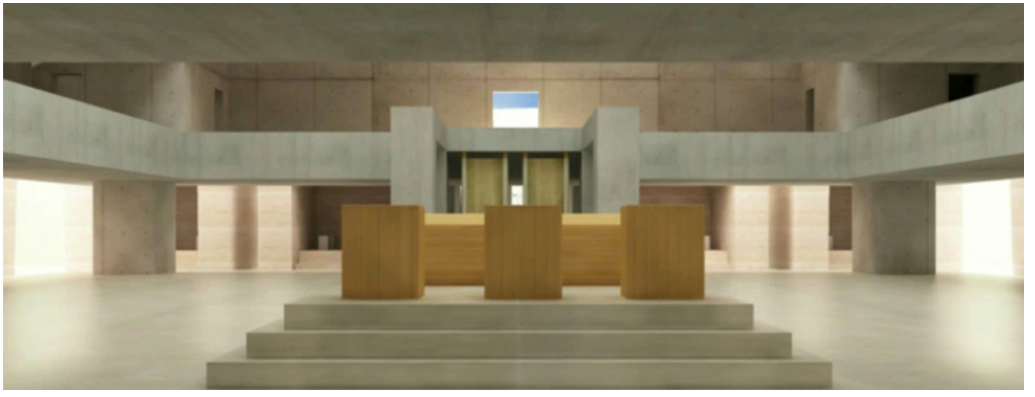

Figure 4
The Sanctuary of Hurva Synagogue, Digital Model

1959. Kahn's concrete was a fine and beautiful cast material with depth and subtle finish. He and his assistants worked many years to find a perfect mix of formwork, admixtures and sand to achieve a perfect color, depth and texture. Kahn's concrete absorbs light as it reflects and creates chiaroscuro effects.

Travertine was the second material Kahn liked to work with. He used travertine for the plaza of the Salk Institute, foyer and stairs at the Exeter Library; floors, walls and details in the Kimbell Art Museum. In the Hurva Synagogue, he would have preferred travertine but, due to financial restrictions, he chose to use Jerusalem stone for the pylons.

By using concrete inside and Jerusalem stone for the outside shell, Kahn saw the building in two colors: gold for the outside and silver for the inside.

Since glare is the common issue in Kahn's designs, he always preferred to use materials that diffuse the light evenly in the space, so that light inside the building creates the softest possible illumination.

Light

The special control of light in conjunction with the spatial qualities of the material, from the structure make the Hurva Synagogue one of the most stunning and unique design conceived by Kahn.

In his all life, Kahn searched endless possibilities of devices to find the perfect solution in light modulation. He started from small devices installed either to the façade or roof to double shell walls, to skylight and hollow columns. In his final design, which was the Hurva Synagogue, we can see a good synthesis of all the possibilities he had searched for, until the time he died. In this very sophisticated building, it is obvious that he combined the idea of layering the outer shell (ruins) with a great skylight solution. Unlike his other projects he used the hollow columns again as a service area rather than a source of light.

Skylight in the Hurva Synagogue

In the final proposal, Louis I. Kahn decided to use skylights as a main light source in the project. Both in the first and second proposal; light came from the top, but these light sources were narrow slits in the ceiling. However, in the third final design, four cylindrical and one big square skylight openings are designed to be the light source (Figure 5). It was noticeable that he was inspired from the light of the Pantheon. In the Pantheon, it is an oculus to the sky.

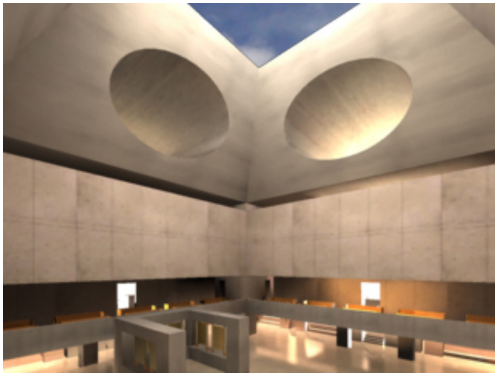

Figure 5
Skylight in the Hurva Synagogue, Digital Model

A precedent for cylindrical openings can be found in an unbuilt version of the central hall of the Exeter Library in 1967.
For Kahn, not only the quantity but also the quality of light inside the room was significant. According to him, artificial light is static and does not have variety that depends on the time of the day.

Hollow Column in the Hurva Synagogue

The idea of a hollow column was one of Louis I. Kahn's most sophisticated theories. However, his theory and practice not necessarily are on the same line. In the Hurva Synagogue he used hollow columns similar to those designs from his early practice days; a serving space. The first use of the hollow column as a mechanical shaft was in the Trenton Bath House. After that, he developed the idea and made these columns larger until they are a room. However, in the Hurva Synagogue, he again attempted to use hollow columns in the second floor as a circulation area between balconies.

In the sanctuary, the hollow columns are located in each corner between the balconies to create a

circulation area between them with door size openings on two axes (Figure 6). Unlike his theory, he did not design any opening to bring natural light inside these hollow columns. Only small openings provide the natural light that makes the interior seem mysterious.

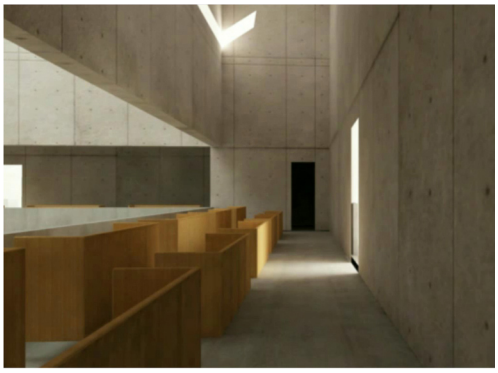

Figure 6
Hollow Columns in the Hurva Synagogue, Digital Model

Ruins in the Hurva Synagogue

When Kahn was asked to design a new synagogue on the site of the old structure, he decided to let the ruins remain and build the new temple beside them. Kahn used the concept of ruin in connection with light as early as 1959 in the US Consulate in Luanda surrounding a building with a ruin. These ruins became self-standing panels in the Salk Institute meeting halls. In 1964, after he first used ruins in his buildings, he asked himself what ruin means in the life of a building. It was the freedom from the servitude of performing the practical function for which it was designed, freedom to fully express its spirit or form essence. (Tyng, 1984)

Kahn's conception of the Hurva Synagogue came out of his new theory about meaning of ruins. The building is a 'ruin' all the way through to its core because its glare-shielding element is part of its fabric (Figure 7).

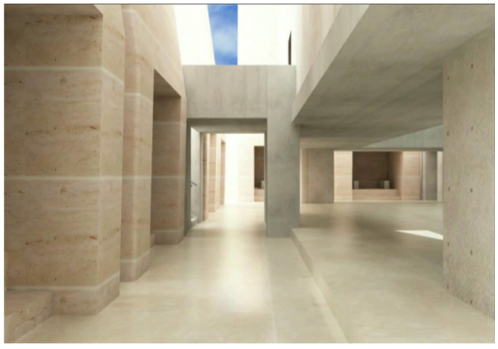

Figure 7
The Pylons (Ruins) in the Hurva Synagogue, Digital Model

Simulation of Lighting in 3D Environments

In real life, daylight encompasses all natural light that is available during the day and originates from the radiation of the sun in the visible spectrum. Sunlight is the part of daylight that is radiated directly from the sun to the area of interest, or reflected or diffused from surfaces.

In the world of Computer Graphics, a time series animation (time of day animation / time of year animation) or Simulation of Lighting in 3D environment, shows the changes in lighting (especially sun impact) over the day, or the changes over the year, or at a fixed time of day. This feature can be a very significant one when creating daylighting simulations for architectural buildings that are not built.

Light is essential for human existence. It dictates our activities, influences our frame of mind and affects the way we perceive all things. Light is extremely fundamental when it comes to architecture. The role of light in architecture has been long realized by many architects.

When it comes to unbuilt projects in architecture, computer based visualization helps us to understand how natural light interacts with its form and spaces with accurate lighting data. Of course there may be other options to simulate the light in architectural projects. One of them can be creating a cardboard model and using a spot light to simulate the sun. However, since the cardboard model's scale is usually small, flexibility to show all interior

spaces become very difficult. Also, the material of a cardboard model may not be exactly same as the real environment which would cause changes in diffusion of the light. On the other hand, in computer-based visualization, we can create a camera path and move freely inside the building. Material and texture of surfaces can be adjusted to match the intended surfaces. We can also simulate the light in different times of the day and days of the year to get different results (Figure 8).

Figure 8
Simulation of daylight using 3D digital animation in the Hurva Synagogue (from 6am to 6 pm)

Light has a vital role in architecture and it should be represented accurately in computer graphics. To create accurate lighting in still images or animations, there are some features that need to be manipulated properly. These features can be listed as, Modeling issues, Texturing issues, Lighting Issues, and Camera path.

Modeling Issues: A model may sometimes react poorly to lighting. The model is not necessarily poorly constructed, but may not have lighting in mind when constructed. The problem lies mainly with models that are angular in edges or organic in shapes that cannot receive light properly. A sharp edge does not create specular highlights whereas the small bevel on the edges creates a subtle highlight which looks more accurate. In the case study (similar to real life) all the elements in the project are constructed with a bevel in their edges to create a realistic lighting effect.

Texturing Issues: If not improvised, Computer Graphics textures can create sterile super perfect scenes, very unlike to a real life environment. It is easy to create shiny and plastic-like materials, which do not look realistic. In real life, materials are much less reflective and have much more dirt and scratching. In the case study animation, the materials are generated by considering these facts such as adding dirt and scratch on the concrete and blurriness on the floor.

Lighting Issues: Lighting is a different matter entirely, relying on the careful positioning with a specific reason. The lighting scheme should emphasize and highlight the 3D forms when rendered. There are many types of lights available in lighting software such as point light, spotlight, area light, ambient light and directional light. In this case study, since the main focus is to simulate the sunlight inside the building, the directional light was chosen. The role of directional light (some 3D software refer to it as sunlight) in 3D scenes is to cast parallel light rays in a single direction similar to how sunlight works in real life. The use of directional light is simple to control as long as its geographic location and time of the day and date are set up correctly to the sun's position.

As a second light source, skylight was used to create a diffuse light in the environment. Skylight can be considered as a separate element that operates like an array of lights located around the sky, like a dome, all casting only blue diffuse light. Global illumination calculates every light interaction to generate a photorealistic image or animation. Global illumination mimics the subtlety of natural light by tracing the light rays bouncing between a collection of radiating objects and carrying their diffuse color properties with them. (http://www.richardrosenman.com/global.htm). The output of this technique provides much more photorealistic quality than radiosity based solutions.

Camera Path: Camera path is the last element that also has a vital role in the scenes. If a realistic effect is wanted, an overuse of camera movement, such as moving the camera with a fluid ease that a

real camera cannot do, should be avoided. By using unrealistic movements in 3d scenes, we can remind audiences that they are watching Computer Graphic work. In our case study, two types of cameras were used. The first group is the dynamic ones that move inside and outside of the building to highlight the space and form of the project. The second group of the cameras is the immobile ones, which are located inside and outside of the building to record the simulation of sunlight. It is preferable to avoid both sunlight and camera that are animated at the same time.

Conclusion

The purpose of this paper was to understand Louis I Kahn's theory of lighting and its practice in real life by the use of computer visualization. Since Kahn left a number of masterpieces un-built, it is essential to understand what he wanted to achieve in those buildings. This paper finds that computer visualization, particularly 3D animation with accurate lighting, is an effective tool to simulate light and examine how light reacts with a building's form and space. The goal of this paper was to create direct and diffuse light inside Louis I Kahn's Hurva Synagogue and illustrate its effects throughout the interior spaces using 3D animation. For most Computer Graphics artists, lighting is a painful issue to get realistic effects. This paper finds that if the set up of certain elements are done correctly, then computer visualization becomes a great tool to understand light.

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