Daylight Simulation: Examining its place during Conceptual Stages in a CAAD Studio

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Abstract

This paper reports on our experiences using computer graphic visual simulations to encourage architecture students to examine daylighting aspects of their design solutions during conceptual stages in undergraduate design studios. Using computers for conceptual design was the major thrust of the investigation of these studios where daylight was one of the issues students examined for a four-week period. We present our experiences and student work with traditional CGI-based and physics-based radiosity rendering techniques. Our experiences show that although radiosity based visual simulation is capable of producing more realistic images, in the design process its success was limited to studying clearly defined interior spaces. CGI-based visualization, particularly when used in conjunction with traditional physical models, was more useful and effective in the design process, being closer to the fluid nature of the design process. Further work needs to be done to make the currently available radiosity-based software suitable for use in the design decision-making process.

Keywords: design process, daylighting, radiosity, CGI-based, electronic design studio

1 Introduction

The difficulty of predicting the performance of daylighting has been widely reported in the literature over decades (Lam 1986; Novitski 1990, 2000; Ubbelohde 1998). The successful use of daylight in a building requires that the associated forms and devices be conceived as an integral part of the architectural design from conceptual stages. This makes it very important to have an understanding of daylighting in the buildings during the design process. Numeric scheming and physical/computer model visual simulations are the principle methods of daylighting design. These methods could become laborious and non-intuitive to learn and thus does not spur enough enthusiasm in design students to bring it into their design process in the studio projects (Kang 1999).

Using the computer in design studios in architectural schools has been largely relegated to producing compelling visual imagery of design projects that demonstrate very little environmental, structural, or even functional understanding of the buildings themselves (Cuff 2001). However, the recent advances in computer-aided design and rendering compel another look at visually simulating daylight (Ubbelohde 1998).

Through this paper we discuss our experience with the use of computer-aided daylight simulation during the conceptual design process in an architecture design studio and its effect on student learning.

2 Related Work

We sought to understand if daylighting simulation could be integrated in the design process in an electronic design studio paradigm. We were interested in determining whether it could form an extension of the “acquired natural skills” of the students during the course of the studio, or if it “required specific skills” to get satisfactory results. As a methodology, we conducted a literature survey to find the related work that has been done in this area. We searched Copernic 2001 Basic, Google, CumInCAD, Northernlight, etc. search engines on the Web to find information in the architecture and science journals, articles, conference proceedings, and research papers. We also spoke to people conducting research in the field of architectural daylighting.

We found that work related to architectural daylighting falls under four distinct categories:

- Application of daylighting methods in a design studio structured on issues of light and design taught by faculty with an environmental focus (Stannard 1998; Chow et al. 2001; Tsou et al. 2000; Hanna 1996).
- Comparative evaluation of different daylighting software programs for use in architectural design (Ubbelohde et al. 1998; Ashmore et al. 2001; Roy 2000).
- Conducting comparative studies to evaluate the performance of different daylighting techniques like physical scale models, computer models, full-scale mockups, etc. (Ng and Wu 2000; Wu et al. 2000; Erwine 2001).
- Daylighting assessment methodologies and the working mechanics of the available tools being taught as independent environmental systems seminar courses (Kremers 1996; Massadi 1998).

So far, the need to conduct the analysis of daylighting of a project to seek insight into the design process, in a traditional electronic design studio setting, has been completely overlooked. Unlike previous research and literature, we seek to determine if there is room for daylighting analysis as one of the ingredients within the dynamics of an electronic design studio, without requiring a daylight seminar course or a studio entirely dedicated to exploring light and space.

3 Overview

Most architectural daylighting experts (e.g. Dale Brentrup, director of the Lighting and Building Energy Technology Laboratory at UNC Charlotte) are of the opinion that daylighting can be addressed in a studio only when supported by a parallel seminar course. There are firms that offer professional expertise to compare and evaluate lighting design options for architects using computer technology (e.g. http://www.visarc.com: April 2002). We also found that very few people worldwide can accurately model complex buildings with RADIANCE (e.g. Christian Humann cited in http://www.coolshadow.com/keypersonnel.html: April 2002).

Daylight, being a dynamic natural phenomenon, cannot be studied to its fullest. It is possible to only simulate “time and space” through daylight simulation. Architect Antoine Predock says that capturing light in a space at a given time is not as important as stimulating the mind’s eye through light; this is perhaps especially significant in a design process because architects primarily design for an “event and place”. Besides, much of what we see when confronted with a new scene depends on our goals and expectations as it does on the array of light that bombards our eyes (Healy and Enns 2002).

The phenomenological and psychological issues of daylight led us to the question that ‘Should daylighting simulation really require specific skills for use in the design process?’. Notable architects are known to have built very basic, crude physical models to study daylight within their designed spaces, with results accurate enough to base their design decisions upon (Figure 1). We address our concern in the use of computer-aided daylight visualization tools from a similar standpoint.

3.1 Studio Investigation

Two strategies were adopted for daylighting investigation in the studio based on the related technological advancements when the studies were performed, both striving to achieve equal ends.

The first investigation was conducted when radiosity-based software programs were not commercially available. A combination of CGI-based methods with the physical model results was carried out in the design studio, such that one extended the capabilities of the other. Crude scale models , which are the

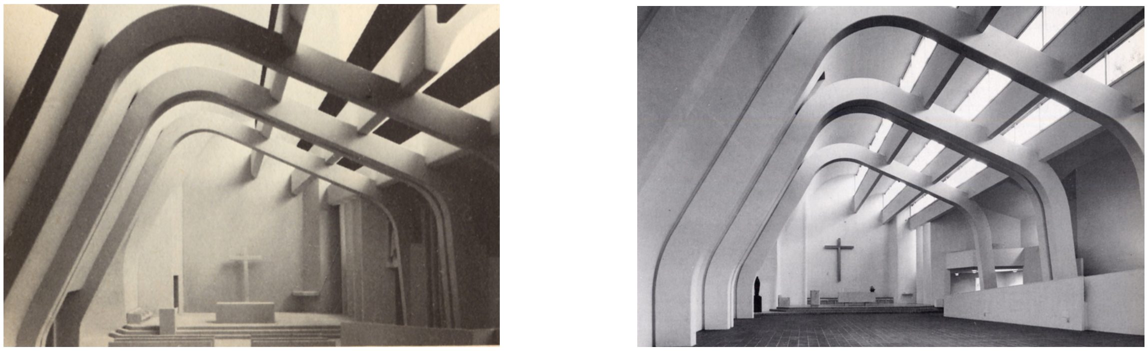

Figure 1. Physical scale model (left) and interior of completed Riola Church (right) in Italy designed by Alvar Aalto (Fleig 1974; Schildt 1989).

time-tested method to study daylight, provided quick and accurate results. The computer models generated in *Form.Z*, although still lacking the daylighting accuracy of the physical models at that time, provided opportunities for endoscopic inquiry of interior spaces, to study variations, movement through space, and generation of simultaneous representation of spaces (Greenberg 1974).

The second investigation included the radiosity-based daylighting visualization systems which had become commercially available for use in CAAD. We chose *Lightscape* as our software tool for daylight visualization because it is known for greater flexibility and ease of use (Laiserin 2001), brought forth by former comparative studies done with *Lightscape* and other software programs (Ubbelohde et al. 1998; Roy 2000; Ashmore et al. 2001). *Form.Z,* being inherent to the design studio pedagogy, was maintained as our choice for the 3d modeling tool. Our two approaches attempting to enhance the understanding of daylighting during the design process in a studio are as follows.

A. CGI-based approach: Using non-radiosity based, view-dependent software recording only direct reflections conducted in the fall 1997/ spring 1998 design studios.

The design studio worked on creating an exhibition space inspired by the design principles of the modern masters like Ando, Mackintosh, Kahn, etc. The students conducted the initial design explorations on the computer. Following this, they built quick study scale (physical) models of their designs to verify the daylight conditions corresponding to computer models of the scenes under investigation. These models were photographed outdoors testing multiple daylighting strategies simulating sun, site, and time conditions. The resultant photographs were then analyzed to learn the effect of indirect illumination for various schemes, and a choice of one scheme was made out of it. Once the scheme was chosen, the indirect lighting effects were emulated, employing additional point/ cone light sources and transparency texture maps (Figure 2, Figure 3).

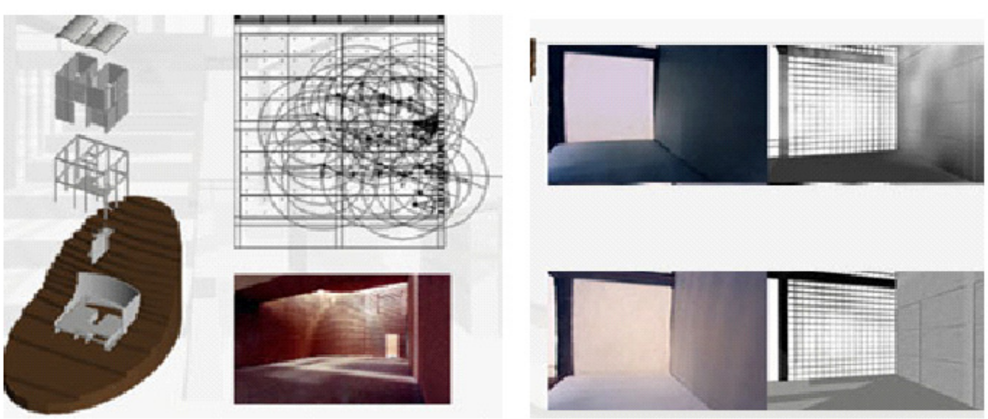

Figure 2. Creation of an exhibition space based on the design principles of Tadao Ando by Rob Mastro, Fall 1997.

Figure 3. Creation of an exhibition space based on the design principles of Charles Rene Macintosh by Becci Jake, Spring 1998.

Table 1: Observations of the process and outcome of the radiosity-based approach.

	Group 1 (Figure 4)	Group 2 (Figure 5)	Group 3 (Figure 6)
Process	Study of daylighting in a generic box-study using *Lightscape.*	Study of daylighting of only the existing space to understand the mechanics of *Lightscape*.	Study of daylighting of the existing space and the proposed extension using *Lightscape*.
Outcome	*Lightscape* was not used to study the daylighting design for the designed extension, since the process started to get cumbersome and tedious with added model complexity.	*Lightscape* was not used to study the daylighting design for the designed extension. Preparation of the model for *Lightscape*, before it could make any accurate daylight predictions, was time consuming.	The final design outcome demonstrated the incorporation of daylighting concerns in the project. However, the software strictly governed the overall design of the project.
Remarks	*Lightscape* works well only for clearly defined spaces. With increase in number of polygons and complexity in larger models, the results are not accurate enough to base design decisions upon.	*Lightscape* is appro-priate for well-known and precise geometry. It did not seem suitable for a working model that is a product of an iterative design process. The software was not intuitive and fluid to the thought process, working against the time-bound studio projects.	The student creativity was restricted by the software ability. Thus, although the results were spectacular to look at, the jury found the design moves to be conventional and not as creative as the projects in Group 1 and 2.

B. Radiosity-based approach: Using radiosity based, view-independent software recording indirect reflections conducted in the Spring 2001 design studio.

The studio worked on a project involving design of an extension to an existing art museum. A graduate student prepared tutorials focusing on the workability issues of the *Lightscape* after working on it for almost a year. The students used this to follow the basic principles of the software to work on their design in the studio. After carrying out initial design explorations on the modeling software, they exported it to *Lightscape* to examine the daylighting effects of their projects. When necessary, adjustments were made to the computer simulation settings. Three distinct student groups emerged based on their approach to using *Lightscape* for daylighting design (Table 1).

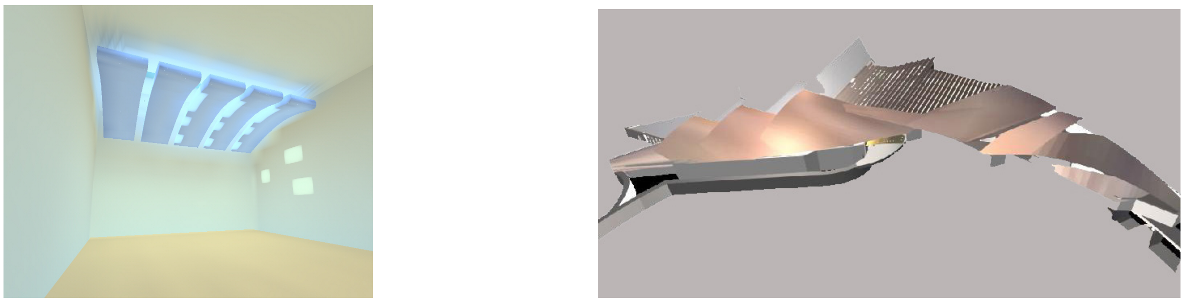

Figure 4. Art Museum Extension design by Kevin Stitak, Spring 2001. Radiosity software was used to test the regulation of daylight in a generic gallery space by ceiling mounted mechanical louvers (left). Decisions were made about the spacing, the materials and the size of the louvers, and the proportion and orientation of the openings. This was simply plugged onto the designed building without retesting the final designed space for daylighting (right).

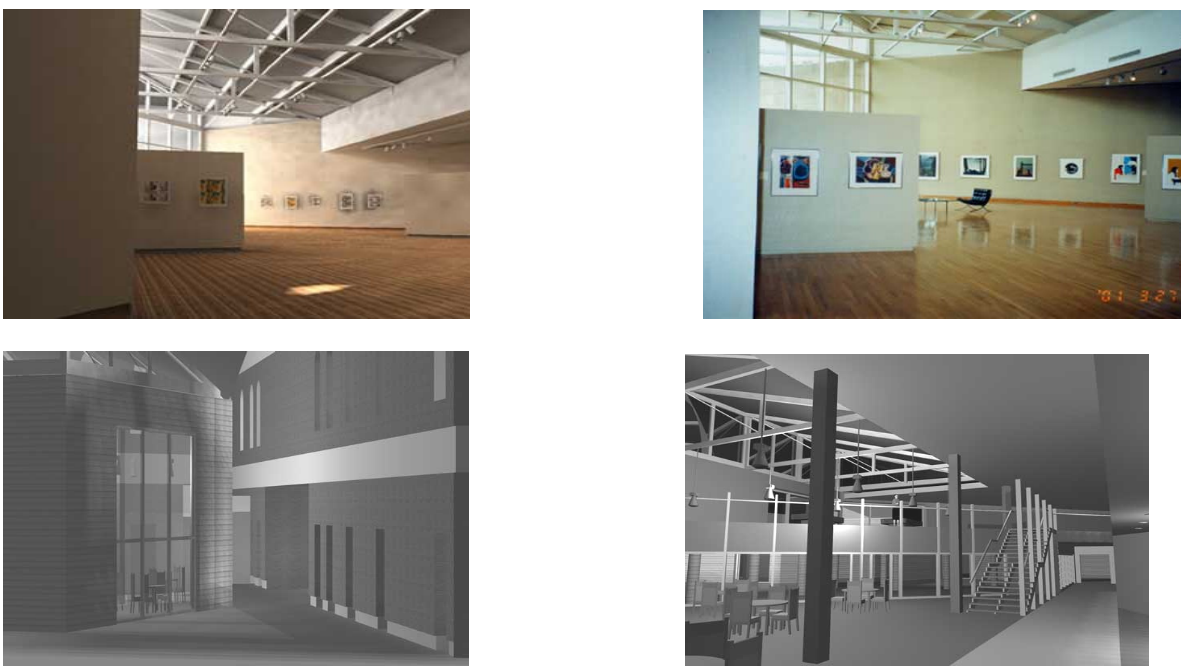

Figure 5. Art Museum Extension design by Matt Karp, Spring 2001. The student was successful in generating images (top left) that had a photorealistic feel of the existing museum space (top right). However, radiosity-based software was not used to prepare the final renderings of the proposed extension (bottom left and right).

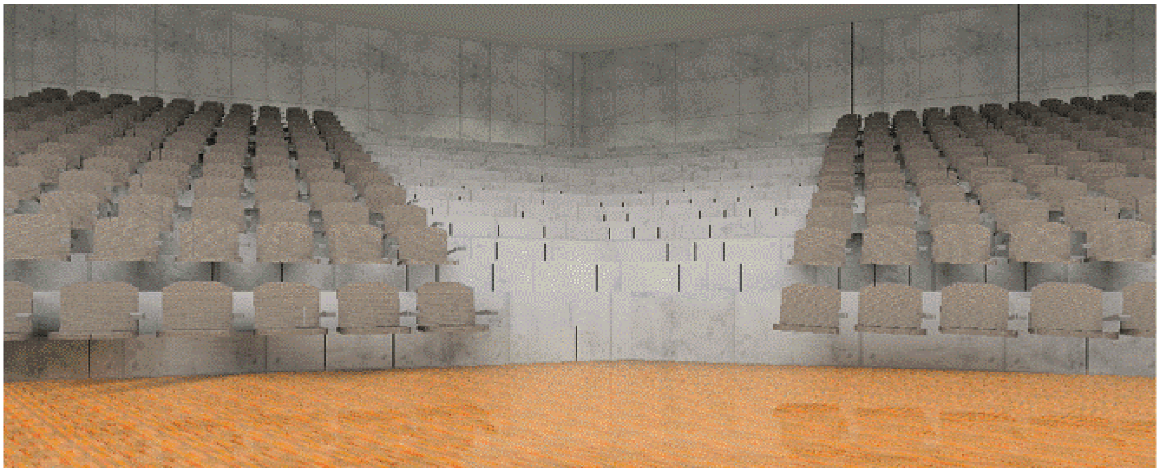

Figure 6. Art Museum Extension design by Matt Nudelman, Spring 2001. The student exactingly adhered to the rules of the software through the tutorial. An effective use of texture maps was made in a model with minimal complexity. It led to the creation of the most photorealistic project of all.

3.2 Study Limitations

This study is unscientific and has some limitations. First, this work addresses a design process in an electronic design studio setting only using *Form.Z* for modeling and *Lightscape* for daylight simulation. *Form.Z* was a natural choice as a 3d modeling software for the design studio because the students had prior experience with it. However, in spite of Form.Z having radiosity capabilities, we preferred to use *Lightscape* because it was widely acclaimed in the literature. Alternatively *AutoDesk VIZ 4*, a recently launched software product, combines *Lightscape* functionality with 3d modeling capabilities. We realize that the preparation of a model for lighting visualization in this integrated product could be more fluid. We plan to study it in our future work.

Second, we did not conduct the two approaches using a similar project. The project chosen for the second approach was to give the students enough time to familiarize themselves with the mechanics of the radiosity-based software through the existing building, and to apply it onto the designed extension.

4 Findings and Discussion

The CGI approach was natural to the design process because it was object or scene oriented, thus having a low level of abstraction. It engaged only the “naturally acquired skills” of the students. On the other hand, the radiosity-based approach “required specific skills” to be learned. It ran into a higher level of abstraction demanding the understanding of cryptic keystrokes and interface capabilities. The design models developed in the 3D modeling program could not be used in *Lightscape* without special preparation. Interoperability issues, fuzzy settings for materials and daylight, and understanding the limitations of the underlying simulation models and algorithms resulted in depletion of studio time from the design process.

Overall, the students were disillusioned by the second approach and its outcome in spite of *Lightscape* producing accurate photorealistic imagery and providing means of assessing lighting distribution through the false color renderings. *Lightscape* was not supportive of the design process, being less forgiving of modeling blemishes and high polygon counts, both characteristic of a design development model.

Although the algorithm is not entirely perfect at this point of time, it is the interface issue of the software that needs further resolution. Most buildings designed are more complex than a simple box or a cube with a limited number of rectangular apertures, which are often used for software development (Ubbelohde 1998). This agrees with our findings from the first group under the radiosity-based approach. We found that successful use of the radiosity software in its current state was possible only with simple geometry for studying clearly defined interior spaces or after a year's effort put into learning the tools and tricks of the software. Through our second and third group results we found that pre-defined geometry that has been specially modeled based on software rules is easier to assess in *Lightscape,* compared to imprecise geometry of a design model in progress. There are well-known, impressive, pre-designed, "*Lightscape*-precise" architectural day-lit spaces generated earlier (Larson 1999).

We thus feel that based on the current state of the software, our CGI approach is more fluid and integral to the design process and better suited for use in the design studio. It did not require any prior training or preparation by the students who were new to these techniques, and the results were as reliable as the radiosity outcome. It was also a more pleasurable experience for the students. It greatly enhanced the design process by providing all the benefits of computer-aided simulation and the physical model as mentioned earlier. The only drawback was that the outcome was not view independent. In our later work, we plan to address this issue by developing a hybrid of both our daylighting visualization techniques (CGI-based and radiosity-based), drawing on their potential benefits. We shall be testing this model in our future design studio.

5 Future Investigation

The study focus should be on developing adequate teaching resources based on determining quick and reliable conversion techniques from 3d computer models to importable models for a radiosity-based software program. Here, more than photorealistic imagery, the ease and technique of producing the desired results that are also photometrically accurate would be examined.

We are currently preparing a visual database through a project employing the study of daylighting techniques of Alvar Aalto based on these two approaches. This resource will include CGI renderings, radiosity renderings, photographs, panoramic movies of the existing space, and animations/panoramic movies generated from CG. This investigation will serve as a quick study teaching resource for the electronic design studio. We will be exploring this using *Form.Z, Lightscape* and *AutoDesk VIZ* software programs.

6 Conclusions

We believe that best learning happens in a studio-integrated environment. Fluidity is the key to allow explorations and iterations, which is crucial to any design process. What is needed today is a software program based on our hybrid approach that is a convergence of modeling and daylighting simulation to enhance student learning in a design studio setting. We also observe that the ability to model complexities of real buildings is essential for the daylighting software to be useful in the design process.

The idea of a single integrated model that can be used for several purposes, facilitating means to many ends, daylighting visualization being one of them, is still to be realized. Because it doesn't look likely that it will happen anytime soon, it is appropriate and necessary for educators and designers to find creative ways to use computers for the design decision-making process. Through our subsequent work in daylighting simulation and visualization, we hope to further develop ways to mitigate the difficult software interface bringing it closer to our natural design process.

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