Computer Simulation Technology and Teaching and Learning Interior Lighting Design

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1 Introduction

This paper shares the author's experience of using computer simulation technology in an interior lighting design class to improve the teaching and learning environment. The focus of discussion is on how the simulation technology can change the way of teaching and learning, enrich and expand the course contents, and access unlimited resources beyond physical and fiscal limitations.

2 Background

Computer simulation programs have long been used in lighting classes [Bernecker and Mistrick 1986]. In recent years, simulation programs that visualize the lighting design have been successfully used in school lighting design projects and allowed the students to achieve what would have been impossible in the past [Moeck 1998]. For instance, the lighting effect that is determined by the aiming angle of a luminaire can never be effectively studied or experienced by a student in typical classroom settings without today's computer simulation technology. However, the use of computer simulation in the lighting classes in interior design programs has not been as much as in the architectural engineering programs. Many lighting educators expressed their reservation to the use of computer graphics in lighting design education. A major opposition to the use of computer simulation in lighting design classes comes from a believe that computer simulation can never replace the real-world experience of practice in lighting design, and sometimes the results of computer simulation may be misleading [Zekowski 1998]. Whether computer simulation should be used in lighting design classes remains a question. This paper shows support for using computer simulation in lighting design education and discusses from a pedagogical viewpoint the process of a classroom experiment that used the computer simulation and visualization program Lightscape as the major design tool.

3 Pedagogical Problems

Teaching and learning lighting design in a classroom setting without physics-based simulation and visualization are very difficult. In the past, effective teaching and learning lighting design depended on a student's ability of imagination and visualization obtained from stringent artistic training. In addition to producing a 2D lighting plan, a student needed to imagine the lighting effect of a design scheme and depict the imagined scene in conceptual sketches or finished renderings. This type of imagination-based visualization may be sufficient to convey the designer's intention, but can never be objectively verified as a true representation of the finished result. Therefore, the students could not obtain reliable feedbacks from the imagination-based visualization to further improve their design. To continue the learning process from this point, the instructor had to be involved to evaluate the student's design based on his or her own professional experience. The instructor had to imagine the effect of the student's lighting scheme to evaluate both the accuracy of the student's depiction of the lighting effect and the quality of the lighting solution. Usually, the inter-subjective communication between the instructor and the students was not easy. The instructor's critiques were seen as subjective judgment and they were difficult to understand because the students had to rely on their imaginations again to comprehend them. There was no objectively reliable common ground of perception in the communication between the student and the instructor.

Meanwhile, the quantitative design tools were not very helpful either. The traditional lumen method and point-by-point calculation were not only tedious but also limited in accuracy and application. The average illuminance of a space tells little about the quality of lighting in a space. The illuminance at particular points can hardly show the relationship between the highlighted spot and its background. Therefore, it has been difficult for the students to understand the relationship between the lighting layout and the physical measurement of lighting and to link the artistic effects with the technical data.

Although full-scale mockup may be useful to solve these problems, few schools can really support such facilities technically and financially.

In a sum, without simulation technology, teaching and learning lighting design in an interior design program could only be an imagination-based guessing game. The question here is not whether the computer simulation and visualization can replace the real-world experience, but how the new technology can help us to improve the learning environment that has been confusing and uncertain.

4 Technical Challenge of Using Computer Simulation Technology

The reason why computer simulations have not been widely used in interior lighting design classes may have been the steep learning curve of the lighting simulation software in addition to the demanding hardware requirement. This became more challenging in an interior design program that had been traditionally lack of adequate technical support for such type of intensive computing. This problem, however, has quietly dissolved in the rapid development in the computer industry in recent years. The software runs faster on desktop PC's with fewer bugs than ever before. The software interface has been so simplified that an average interior design student can learn how to use it in a week. Meanwhile, with the growing use of CAD in the discipline, both students and faculty are more ready for the adoption of the computer simulation and visualization technology.

5 Process

In the experimental interior lighting design class, the students were first introduced to Lightscape 3.2 to design a general lighting system to light a 20'x30'x10' room. The students constructed the room model using the Lightscape block library, and used luminaires from the luminaire library to light the space. The radiosity solution was created less than a minute. Then the students were taught how to use the lighting analysis tool to measure the illuminance and luminance of the room planes. After visual and quantitative analysis of the result, the students could easily figure out whether their initial lighting layout worked or not, and changes were made accordingly in the next round of simulation. In this process, the students became comfortable with the program. They were then asked to experiment with different luminaires, surface color (reflectance), and room height. In this simple exercise, the students learned a lot of things. 1) Basic operation procedures of the software; 2) the visual lighting effect of different types of luminaires; 3) the effect of the location of the luminaire on the visual lighting effect of the space; 4) the shape of the candlepower distribution curve and its relationship with the visual lighting effect; 5) the lighting metrics (illuminance, luminance, and luminance ratio) and how the measurement values relate to the visual lighting effect; 6) how the change of surface color (reflectance) relates to the lighting effect; and 7) the impact of the space form (proportion) on the lighting effect and statistics. Since this learning experience was dynamic and interactive, the understanding of the inter-relationship between these important aspects of lighting design was enhanced.

The class proceeded with three major design projects dealing with residential, retail, and office lighting respectively. In all these projects, Lightscape was used to simulate and visualize students' lighting schemes. For each project, a student was required to complete the design through at least two rounds of simulation and refinement, and to record in-process images and statistics. In the process, the students developed their ability of critical evaluation of their own design. Design critiques were made much easier when the photo-accurate images of the spaces and the statistics were readily available. In the final presentation, VRML models of the radiosity solution were created and posted on the students' web sites for the instructor and fellow students to immerse into the lighted space interactively to experience and evaluate the design. In the office lighting project, daylighting was simulated. Students were required to conduct quantitative analysis of the lighted scene to produce design responses to solve the problem of excessive brightness and contrast, and uneven distribution. In the past, the exploration of daylighting design had been very much limited to the sun pattern study of an interior space. It had been very difficult to reach such depth of exploration in the topic of daylighting design due to the complexity of the problem without simulation tools.

6 Benefits of Using Simulation and Visualization Technology

1) Since the simulation process is done in an interactive 3D model of the space, the students see the space more as a 3D entity than a flat 2D lighting plan. 2) The photo-accurate visualization of the lighted space makes the lighting effects of the design scheme visible. It provides a reliable common ground of perception to improve the communication between the students and the instructor. It makes the evaluation and critique more objective and therefore more constructive. It enhances the student ability to critique his or her own design, and therefore automatically enter the refinement cycle, even without the instructor's involvement. It allows the students to obtain virtual design-build experience and therefore become more self-confident. 3) Since the analysis tools are readily available and the technical data are mapped on the 3D model of the space. The visual image of the lighting effects are integrated with physical measurements. This promotes the integration of art and science of lighting design. 4) The simulation software provides expanded technical capabilities such as the daylighting simulation functions. Therefore, the areas of investigation can be expanded. 5) Since the design is better revealed as a result of the simulation and visualization, more design criteria can be applied. 6) Since the simulation shows the different lighting effects of luminaires of different models or brand names, the student can obtain better knowledge of product information. 7) Since luminaire photometrics files are readily available from lighting manufacturers' websites and used in simulations, the students have actually unlimited resources for lighting experiment. 8) Models used in simulations can be easily altered in terms of from and color (reflectance) to allow more freedom in design manipulation.

7 Problems and Limitations

There were problems in the use of Lightscape in lighting design projects. In the design process, the students taught themselves how to use material texture and other visualization objects such as people and plants that have little value in lighting simulation and analysis, and they became very indulged in doing that. Although the created images were more photo-realistic, they distract the students' attention from lighting design and analysis. This "too real" problem has been discussed in the design profession recently when the computer generated rendering became more readily available than ever before [Zekowski 1998]. In future experiment, the involvement with texture mapping of the computer model should be restricted until design software can provide us with tools that can deal with material texture meaningfully for lighting simulation purposes. Another problem found in this experimental class is that some models created by students are too large and complex to process. The large models are often resulted from importing complex 3D objects from the Internet. Although the current desktop computers have made it possible for us to adopt the lighting simulation technology in our classroom, it has not reached the point that allows us to do whatever we want. The limitation of the processing power should have been made clearer to the students before they started modeling their spaces.

8 Future Development

For future development, this experiment with the simulation technology shows a possibility to apply a luminance-based design approach in future design project due to the fact that luminance data are readily available to the designer in the simulation. One can easily evaluate the brightness value and contrast of the design elements in a lighted scene. Then the luminance value of individual objects can be manipulated by adjusting luminaire placement and material reflectance (or color). Although pioneer works have been done in developing computer programs to design brightness in a space [Moeck 2001], the eventual application of such design approach very much depends on the participation of interior designers who specify the interior surface materials. In this sense, the need to control the surface reflectance may eventually lead to the integration of lighting design with interior design.

Summary

The use of simulation technology has revolutionized the teaching and learning environment of lighting design. Compared with similar designs in previous years before the use of computer simulation, the projects completed by students using computer simulation show obvious improvement in design quality in both artistic and technical terms. Through the virtual experience of the complete cycle of design, build and evaluation, the students obtained better understanding of the relationship between lighting plans, specifications, selection of interior materials, and actual lighting effects and technical measurement. The use of simulation technology also opens up new possibilities to support our effort in the paradigm change from illuminance-based design to luminance-based design, and eventually realize the integration of interior design and lighting design.

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