I-LIGHT
A WEBBASED LEARNING SYSTEM FOR ARCHITECTURAL LIGHTING DESIGN

A NEW APPROACH TO CREATE, EVALUATE, AND COMMUNICATE QUALITATIVE LIGHTING DESIGN

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ABSTRACT

This paper describes an innovative learning environment, which integrates the Internet, 3D-CAD, and simulation tools in a web based learning system to ensure a better understanding of light perception in architectural space. The learning system comprises of a virtual laboratory, in which architectural planning examples can be represented three-dimensionally and be changed interactively. A developed semantic scene model ensures that lighting, material and surfaces can be varied and compared. The focus lies on the exploration and evaluation of both visual effects and important interrelations between light, material and form. Hence, the standards for the visual representation of luminaires (check spelling) and light distribution are transformed from the static 2D drawing code to an interactive 3D-representation. By using a methodology of learning by exploration the user merges 3D-CAD and simulation programs into a easy-to-use new system, in which the rendered photo-realistic image is regarded as an interactive tool and no longer as a presentation material. Finally the user can (access) sp this system with a standard web browser and no software for CAAD, simulation and presentation needs to be installed on the users PC as he remote controls this software that runs on a specific web server (Wittkopf, S., 2001).

KEY WORDS

Light, lighting design, architecture, design, virtual laboratory, visualization, 3D-CAAD, simulation, backwards ray tracing, Radiosity, World Wide Web, Java, RMI, VRML, Perl, HTML

INTRODUCTION

Computer-aided architectural renderings have become common tools in the presentation of architectural designs. These renderings can help to demonstrate more clearly the architect’s intention. The level of realism in these renderings is not necessarily the highest priority since they do not always provide an exact impression of what a project will look like when it is built. Greater emphasis is placed on using the advantages of CAAD and other graphics programs to demonstrate visual concepts in ways that would not be possible without computer technology.

3D-CAAD AND ARCHITECTURAL LIGHTING SIMULATION

The use of 3D-CAAD in lighting design includes both renderings for the purpose of presentation as well as simulations in the context of the design process. Computer-aided lighting simulation provides an excellent method for evaluating lighting designs according to both quantitative and qualitative criteria (Eissa, H., Mahdavi, A., 2001; Altmann, K; Apian-Bennewitz, P., 2000 ). This process is based on a three-dimensional CAAD model that includes information regarding the geometry, materials and lighting of a given project. Light distribution values are then calculated using accepted algorithms for global lighting (backwards Ray tracing and Radiosity) and result in almost photo realistic renderings.
These methods facilitate the demonstration of both qualitative lighting effects as well as a quantitative reproduction of values such as light intensity, light density and daylight quotients. The virtual camera can capture all aspects of the virtual model from all viewpoints without interfering with any lighting values within the model. This represents a clear advantage over the use of a standard camera with a real model since the “real” camera can interfere with experimental lighting values by physically “getting in the way.” The “real” method often requires complicated model openings to provide camera access, which can also lead to a distortion of lighting values.

A further advantage of a virtual model is that parameters for lighting, geometry and material can be altered one at a time, thereby providing a basis for isolating and analyzing the effects of changes in these parameters.

GENERAL DIFFICULTIES USING LIGHTING SIMULATION TOOLS

Lighting designers and architects are still somewhat reluctant to use computer-aided lighting simulation for several reasons. The calculations required to produce a workable simulation must be preceded by a time-consuming and labor-intensive pre-processing phase. Sometimes pre-processing takes so long that there is barely time left to explore or evaluate further alternatives for the lighting design. As a result, the user does not have the opportunity to take advantage of one of the most important and attractive features of a computer-aided lighting simulation, namely, its variability. Only seldom are the results of evaluated alternatives included in the final design. Users tend to underestimate the amount of time and effort required to produce a simulation, so that the actual goal of the simulation - the evaluation and optimization of a given lighting design - is seldom realized. As a result, lighting simulations continue to be used more often as presentation tools than as planning tools.

It is a common mistake to assume that a completed 3D-CAAD model is all that is required to produce a turnkey lighting simulation. In theory, this should be possible, but current CAAD practice looks quite different. For example, many users are unaware that a 3D-CAAD volume model, which facilitates construction planning and measurement, is not necessarily appropriate as a basis for lighting simulation. In fact, the preferred type of virtual model for lighting simulation is a 3D surface model that uses a special structure. Adapting a volume model to the requirements of a lighting simulation can be very tedious and time-consuming.

A further aspect of lighting simulation that can be very time-consuming is the need to provide detailed information about the nature of the materials and surfaces used in the design. Some materials are included in virtual libraries that provide the necessary data. For all other materials, detailed physical data must be assumed and entered individually. Some materials are particularly interesting to the architect precisely because of their characteristics with regard to light. A lighting simulation requires information not only about the base color of such materials, but also about their levels of diffuse or directed reflection and transmission. The characteristics of materials like polarized glass or brushed aluminum are even more complex since the interplay of diffuse or directed transmission and reflection does not remain constant but rather varies depending on the angle between the light source and the material surface.

Performing the calculations required for a simulation can also be a very complex process. Parameters often need to be adjusted and readjusted before a reliable and high-quality result can be achieved within a reasonable period of time. While real light travels across a real model at the speed of light, a computer must first calculate virtual light traveling across a virtual model. These complex calculations often take the computer several hours to complete. Such a slow response time is hardly acceptable for design purposes. One method of reducing the length of a calculation is to apply abstract features that influence, for example, how a shadow or the reflective qualities of a given surface are calculated. In this way, one can simplify or even deactivate the calculation of certain parts of the simulation, thereby reducing the overall amount of time required for the calculation. This method must be applied carefully, since it can also lead to unnatural-looking results if a process parameter is defined incorrectly. For example, a chair that touches the floor but does not cast a shadow (because this characteristic was deactivated) will appear to be floating above the floor.

The production of a computer-aided lighting simulation is characterized by time-consuming pre-processing work and by constant hindrances and delays. The intense effort of producing a simulation is not always justified considering the relatively few useful results that are obtained. This observation
is confirmed by the fact that most architects and lighting designers outsource their lighting simulations to specialized service providers.

**REQUIREMENTS FOR IMPROVEMENT**

In defining the difficulties associated with using lighting simulation tools, several key areas for improvement were identified. These key areas of improvement are as follows:

- Although the meaning of light in architecture and the impact and awareness of qualitative architectural lighting design has increased over the last years, there is still a lack of appropriate knowledge, knowledge transfer and knowledge application in most of the schools of architecture. The common emphasis lies in the knowledge transfer of the physics of light and lamp and luminaire products. However the application of that knowledge, meaning the designing and evaluation of architectural lighting is still very poor, as it requires appropriate laboratories that tend to be very expensive. The methodology of learning by exploration is still valid, but there is a need to develop alternatives to physical laboratories.

- The communication between architects and lighting planner is often difficult and misleading as both use a different code of representation for lighting concepts. Architects are only interested in a photo realistic representation of the visual impact, whereas lighting planner use a more abstract representation to communicate the source and direction of the light. A mutually agreed and appropriate representation of both visual impact and position and direction of the light is still missing.

- The usage of 3D-CAD and lighting simulation software is still not effective. There are no ready-made applications available and as such the user has to navigate through several different applications, one for 3D-CAD, another for the lighting simulation and a third one for the documentation of the findings. This complexity is compounded by common problems regarding data exchange amongst architects or lighting planners that are not very much familiar with IT.

- The Internet is mostly used for the presentation and distribution of already prepared information and data, but very seldom as an interactive media for planning.

**THE NEW CONCEPTUAL APPROACH OF I-LIGHT**

The objective of I-Light is to provide the user with a new kind of learning environment that enables him to understand the impact of light in the architectural space in such a way as, to gain knowledge of the interrelation between light, space and material. I-Light is meant to support the active design, evaluation and communication of qualitative lighting concepts (Wittkopf, S. 2000). I-Light is not meant to deliver passive knowledge of the physics of light, lamps and luminaires.

The main conceptual approach is as follows:

- To provide a virtual lighting laboratory that allows learning by exploration based on constructivism (Honebein, P.C; Duffy, T.M; Fishman, B.J., 1991). Lighting experiments can be conducted in an uncomplicated manner. These experiments should augment the user’s lighting design “vocabulary” in order to provide a solid basis for successful lighting design. Just as in a real laboratory, the user works with prepared lighting elements, room types and materials. Nevertheless, the virtual laboratory provides a greater degree of freedom in the variability of the lighting design. Walls and ceilings can be moved around easily. Materials and lighting elements can also be replaced both quickly and simultaneously.

- To ensure a dual representation of light that is equally accepted by architects and lighting planners (Gansland, R.; Hoffman, H. 1999). Therefore the static abstract 2D representation code of the lighting planners is transformed into a 3D representation of light objects with which the user can interact in order to vary the lighting design. This mode is called the Scene-Editor. The second representation (photo realistic representation of the visual impact of the light) will be generated by the system automatically. This mode is called the Scene-Viewer, which enables the user to quickly browse through and compare the effects of variations in light, space and material and their resulting interaction.

- To provide architectural lighting examples as different virtual laboratories. These examples are designed in a simple style which reduces the geometry to a minimum. -This ensures that the
focus of the exploration lies on the architectural lighting. The examples are kind of archetypes that occur very often in architecture, such as stairway, corridors, living and office rooms, foyers, shops, museums, galleries etc. The findings of the exploration in these rooms could therefore be applied to more individual projects

- To provide a learning system that enables the rapid development and evaluation of architectural lighting design alternatives. The focus is here not to simulate and evaluate one lighting concept but to design several concepts and gain knowledge by the comparison of different designs or experiments. The system is meant to create a hypotheses about the lighting and prove or improve the concept.
- To use the Internet and WWW in a new way. Mainly to use the WWW technology to develop a web based front ended/interface that integrates and remotely controls existing applications for 3D-CAD, simulation and HTML documentation. A user interface was developed for this system that enables the user to conduct experiments with lighting intuitively. As opposed to most software programs, the number of functions is reduced to a necessary minimum. Using object-oriented programming it is possible to endow an object with intelligent and realistic characteristics. The user selects a given website, whereupon the system is automatically loaded into a browser and connects via Internet to a high performance computer which can calculate a simulation within a reasonable period of time. The results of the simulation are then integrated into automatically generated WWW-documents, thereby facilitating the comparison of lighting alternatives.

THE APPLICATION OF I-LIGHT

The application of I-Light is divided into the following five steps:
1) Selection of the architectural planning example after accessing the system
2) Getting information about the available daylight or luminaire
3) Interactive modification of the planning example
4) Saving and automatically remote rendering of the individual modifications/lighting concepts
5) Comparing the concepts with the Scene-Viewer

Registered users can browse to a specific website to access I-Light. As a first step they can select an architectural planning example (Fig. 1). Before the user begins to modify the example, he should get information about the available light (daylight and luminaires) and their visual effects (Fig. 2). Subsequently, he can make modifications, e.g. moving walls or ceilings, change materials, insert and adjust light etc. (Fig. 3, 5). The user can also change his position and view at any point during the modification process. In a fourth step the user can save his modifications and can start a remotely controlled photo-realistic simulation automatically. The results from the simulation are embedded in automatically generated web pages. Here the system differs substantially from usual web-based applications, whose interactivity usually consists of browsing through -previously completed simulations. I-Light, on the other hand, allows a user to generate simulations of his own individual designs. These functions become possible by a Java applet, the so-called Scene-Editor. In a last step the renderings from the simulation can be studied comparatively in the so-called Scene-Viewer (Fig. 4, 6). Perspectives and versions can be changed very rapidly and easily for a better comparison. Furthermore it can be changed between the direct and indirect light, in order to isolate the influence of indirect light reflected by the material.

All data generated by the user is stored on a centralized web server, which enables the user to access I-Light and his individual lighting designs concepts from all over the world, and to share his findings with other users of I-Light.
Fig. 1  I-Light: Scene-Editor, showing a chosen example of an empty room

Fig. 2  I-Light: Getting information about the visual impact of available luminaires

Fig. 3  I-Light: Scene-Editor showing the chosen example after the individual editing as a design proposal

Fig. 4  I-Light: Scene-Viewer to browse through the photo-realistic rendering of the different lighting concepts in order to be evaluated

Fig. 5. I-Light Scene-Editor graphical user interface (GUI), comprising of 3D Scene (VRML rendered by Cosmo Player, Java Applet with fly-out window, both embedded in a standard HTML website)
THE SEMANTIC STRUCTURE OF THE DESIGN OBJECTS WITHIN I-LIGHT

The objects of a 3D-scene are divided into 5 main types with different semantic attributes. A space element builds up the environment of the space, namely as walls, floors, ceilings etc. They serve as father elements, and children elements can be attached logically to them. Those other elements are designed to build up the interior. The object-oriented implementation can be seen in the diagram of the specific classes (Fig. 7).

Overview of the object types and their ‘semantic attributes and functions’:

<table>
<thead>
<tr>
<th>Objects</th>
<th>Father</th>
<th>Children</th>
<th>insert</th>
<th>delete</th>
<th>move</th>
<th>tilt-turn</th>
<th>copy</th>
<th>scale</th>
<th>properties</th>
<th>Visibility mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
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<td></td>
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<td></td>
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<td>1)</td>
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<tr>
<td>Axis and Lighting track</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Luminaire</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
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<td></td>
<td>x</td>
<td></td>
<td>2) x</td>
</tr>
<tr>
<td>Interior</td>
<td></td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
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<td></td>
<td></td>
<td></td>
<td>1)</td>
</tr>
<tr>
<td>Scalable interior</td>
<td></td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td>x</td>
<td></td>
<td>1)</td>
</tr>
</tbody>
</table>

1) Material
2) Light distribution, light color, light intensity

Fig. 7. Diagram of the object-oriented java classes referring to the specific objects types and their semantic attributes and functions
THE TECHNOLOGY OF I-LIGHT

Front End (Webbrowser)

Fig. 8 The system comprises technically of a Back-End and a Front-End that communicate via HTTP and Java's remote method invocation (RMI)

I-Light is technically an interface that integrates existing programs and technologies in a new way in one system (Fig. 8). The **Backend** is a web server that comprises of all necessary data and programs that are remote controlled and partially submitted via HTTP to the **Front-End**, which is the users web browser. The **Backend** comprises of the commercial application *Lightscape*, the standard simulation program for architectural lighting using Radiosity and of the standard Microsoft *Internet Information Server* including a web server. New interfaces were developed in order to ensure the saving of data and executing of Perl-programs on the web server (*Server Module, Java Servlet*). The data file (*Szene.dxf*) contains the scene description readable both for Lightscape and the **Scene editor (Scene-Editor)**, which is a Java *applet*. The **Perl-programs** are generating web pages, which enable the user to access his individual examples. Furthermore they execute the Lightscape simulations that imports *Szene.dxf*, merge data from *Lightscape object libraries* and exports results as renderings.

The **Front-end** contains the 3D-Scene (VRML97) rendered by the *Cosmo Player* and the Java *Applet Szeneneditor*, which controls the objects in the 3D-Scene via the external authoring interface (EAI) once the system has been initialized. The appearance (attributes) of the objects is defined by the file *Konfig.txt*, in which further objects can be integrated. The attribute values of a 3D-Scene are described in the file *Szene.dxf*, which will be read by the Szeneneditor via remote method invocation (RMI) in order to build up the 3D-scene.

The **Scene-Viewer** comprises of a HTML page that contains *JavaScript* to ensure the switching between the different renderings. This HTML page is updated by Perl-programs when the user saves another scene.
SUMMARY

This approach of I-Light to provide effective and easy-to-use virtual laboratories to explore architectural lighting design demonstrates an innovative use of computer-aided lighting simulation and Internet. It serves as evidence that lighting is a significant design element, inspires the creative and precise application of lighting design techniques, and provides an opportunity to evaluate one’s own lighting design concepts.

Nevertheless, there are still certain designs that are not appropriate for lighting simulation since they would require standards of physical exactness higher than those currently available. Although rendering software continues to be developed at a very fast rate, and although one can assume that computer-generated renderings will continue to increase in acceptance and importance, the observation of real space and real light will always provide a more accurate impression than its virtual counterpart, only at a much higher cost.

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