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ACCURACY AND USABILITY OF DAYLIGHTING SIMULATION FOR DESIGNING BUILDINGS IN URBAN SITES

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Abstract. The unique urban environment of Hong Kong presents designers and students alike unique challenges. Firstly, rules of thumb not longer apply. Secondly, few design tools, mostly developed for low-rise open sites could be used. Advanced computational lighting simulation software could be used to address the design need of information. This study examined the accuracy of two daylighting simulation software: Lightscape and Desktop Radiance, under heavily obstructed urban conditions in Hong Kong. In addition, it evaluates the performance and usability of these two software packages from the designer's perspective. It can be reported that, with due care, both software give reasonably accurate results. However, from the designer's perspective, the look and feel of the two software, and the need for a priori knowledge of lighting design determine their eventual adoptability.

1. Introduction

It has been reported that computer lighting simulation gave inexperienced users an illusion of knowledge and claims of understanding due to the very seductive pictures that could be created. Some users may be contended with the virtual results without evaluating them critically. It was also reported that since the computational process is 'discrete', it is very difficult to synchronise its methodology with the design process. The key hypothesis in the reported study was that computer simulation software could only be used if the users have a good understanding of the lighting knowledge required as well as an understanding of the key procedures of the computer added lighting design. (Wu W. et al., 2000)

To address the lighting design knowledge system in a holistic and systematic manner, this study attempted to address some of the following key questions posed by the designers and remained unanswered in previous studies:

1. Are the software accurate?
2. Are they easy to use?
3. Are the information presented in an easy to understand manner?

4. Are the information useful?
5. In what way the information are they useful?
6. What are my extra investment in terms of time to learn and time to work?
7. Is turnaround fast enough to cope with my design process? 8) Can options be quickly studied?
8. Can I get the same result quicker and easier otherwise?

The objective of this study is to validate the accuracy of the daylighting simulation of two software packages under heavily obstructed residential buildings in Hong Kong, as well as to evaluate the performance of these two software packages from the designers view. The software packages selected were Lightscape and Desktop Radiance. They are both "physically based" software and are in use by many lighting professionals. Vendors of the two package claimed that their software are capable of accurate and physically valid daylighting design with a user-friendly interface (Richard G., 2000; Wu W. et al., 2000). The basis of this research is to seek for software tool which could integrate scientific visualization techniques with the design process. As computational simulations are getting more popular in design practices and architectural schools, it is important that they are tested against the situations they are to be applied. Fail to do that will results in a false sense of achievement to the designers.

Although the applicability of various computer graphics techniques have been largely validated through a number of independent studies by researchers around the world, most of these earlier studies were based on a user-unfriendly UNIX environment which is more suitable for scientists than designers (Mardaljevic, 1995; Kevin et al., 1999, Ng et al., 1999). Recent advancements in PC-based simulation software allow, in principle, the possibility of a more integrated design environment. However, doubts have been cast if the validity and accuracy of these PC-based software could deal with the full complexity of real building environment particularly under the unique urban situations of Hong Kong. This is because buildings of Hong Kong are typically built to 30-70 storey high. The buildings and located very closely together and Hong Kong is the most densely populated city in the world.

The validation study compares the measured Daylight Factors collected on site against simulated results from Desktop Radiance and Lightscape. Interviews are used to obtain the user feedback and impression of the two software packages.

2. The Experiment

Ten architectural students whom have completed a lighting design course carried out the lighting measurement study of 2 housing estates in Hong Kong. Since the main governing factor is Daylighting performance at various external

obstruction conditions, 10 residential units which located at low, mid and high floor were measured. Apart from one vertical measuring point faced out of the window, all points are horizontally located at the measuring grid at working plane. Simultaneously measured of external daylight allowed the calculation of Daylight Factor. (Figure 4)

These units were measured over a period of 4 months under overcast sky. To ensure accuracy, time synchronized multi-channel photometers were used. The data collected were filtered and collated to limit the errors to approximately 10%. This carefully assembled data set was then used to benchmark against results obtained by computational means.

Two of these students with good CAD skills were invited to join the computer simulation study with the authors. Desktop Radiance 1.02 running under AUTOCAD 2000i and Lightscape 3.2 installed in a Window NT 4.0 platform were used to conduct the simulation study. Since the external illuminance which falls on the vertical window surface are important quantity to know at the early design stage, the buildings were modeled as basic block only. Surfaces of the residential buildings were described as homogeneous materials. The reflectances of the surfaces of the residential buildings were tested to 0.2 and 0.4 separately using the two software packages, while the reflectance of the surrounding buildings and ground were kept as 0.2. Corresponding to the conditions of the site measurement, the computer simulation studies were conducted with similar setting.

For the usability study, the students were interviewed for their evaluation of the performance of these two software packages at the beginning and after they have completed the computer simulation study.

3. Accuracy and Validation

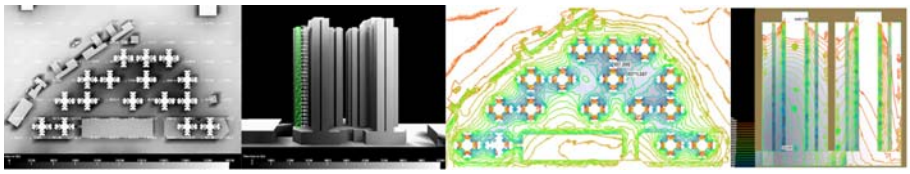

Figure 1. Simulation results of lightscape and desktop radiance respectively.

Figure 1 shows the rendering results simulated by Lightscape and Desktop Radiance respectively. Figure 2 summaries the mean daylight Factors obtained from Desktop Radiance, Lightscape Simulation and on-site measurement token at low, mid and high floor respectively. The relative errors are illustrated in Figure 3. The relative error "RE" is defined as:

$$RE = (DF_{measured} - DF_{simulation}) / DF_{measured} \quad (1)$$

Where DF measured is the mean values of the measured Daylighting Factor. DF simulation is the mean values of the simulated Daylighting Factors. From summarized the above data, finding can be reported as follow:

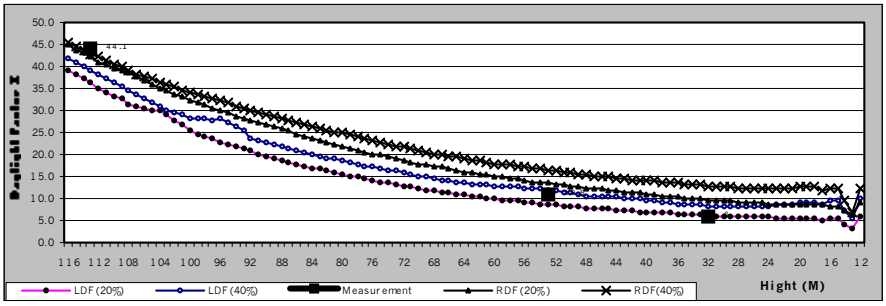

Figure 2. Mean value of daylight factor of desktop radiance, lightscape simulation and on site measurement

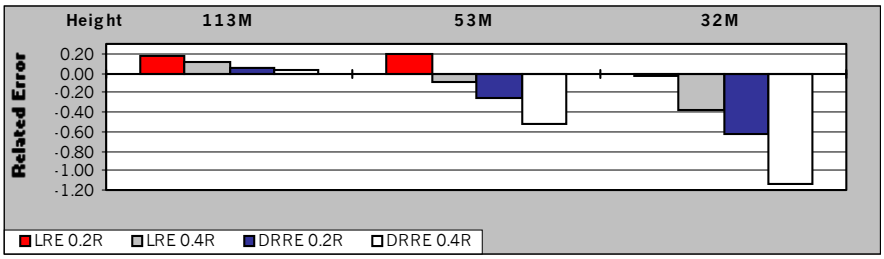

Figure 3. Related error of daylight factors of desktop radiance simulation, lightscape simulation at low, middle and high level obstruction angles.

1. Both Lightscape and Desktop Radiance were found to be reasonable accurate for simulating Daylighting Factor under overcast sky in heavily obstructed residential buildings in Hong Kong. And the daylighting simulation of Lightscape with 20% reflectance shows a higher accuracy in general, especially at low-level height, but a lower accuracy at high-level height.
2. Since there are differences in the treatment of material properties and the photometric input between the two software (Kevin W. et al., 1999), it can be noted that the Daylight Factors of Desktop Radiance simulation with 20% reflectance are higher than their Lightscape simulation with 40% reflectance. However, similarly shaped curves shown in Figure 2 could indicate that a constantly correlation exists between Desktop Radiance and Lightscape.

4. A Designer's Perspective

At the beginning of the computer simulation study, both students had the impression that Desktop Radiance was easy to learn because it was integrated with AutoCAD. Since they were good at AutoCAD before, almost every aspect of Desktop Radiance seemed familiar too them. However, when they mastered Lightscape later, they immediately favored its more flexible user-interface in comparison. The current version of bug torn Desktop Radiance causes students to lose interest very quickly. The students commented that Lightscape is a better productive software, because both of them agreed that it is intuitive — easy to learn and use – and have better user-interface. They also commented that Desktop Radiance looked like a very scientific software. (Figure 4)

Figure 4. View of the site, students learning how to take measurements, students carrying out computer simulation in the laboratory

May due to the fact that they took part in the site measurement, the students queried the accuracy of simulation results very much from the beginning. This contrasts very much with students' behaviors in our previous reporting (Wu W. et al., 2000). Given that both software are now validated, the students stated that they would use Lightscape at the initiate design stage, because the rendered results of Lightscape are more useful in making design presentations. However, they emphasized that won't mind using Desktop Radiance at the final design stage if it could give 'more scientific' information.

5. Discussions and Recommendations

This study shown that both Lightscape and Desktop Radiances were reasonable accurate in simulating Daylighting Factor under heavily obstructed surroundings in Hong Kong under overcast sky. As to the usability of the software, the look and feel of the two software, and the need for a priori knowledge of lighting design determine their eventual adoptability. The experiment demonstrated the importance of a priori knowledge when using simulation software. The students are far more conscious of what they are doing than those approaching the software from a 'graphical' perspective.

Although the user interface of Desktop Radiance has been vastly improved at present, it still has a look and feel problems and its bug problem remains a major deterrent to its acceptability and usability. No doubt Desktop Radiance will be improved in due course, with its development. The authors recommend that, at present, Lightscape is a more suitable lighting simulation tool for the initial design stage.

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