The RADIANCE Simulation Software in the Architecture Teaching Context

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ABSTRACT

Two methods of introducing the RADIANCE lighting and daylighting simulation software to architecture students in a relatively short time are presented. The production of visual teaching material using the same software is also discussed.

Paper presented at the 2nd Florence International Conference for Teachers of Architecture, Firenze (Italy), 16-17-18 October 1997.

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1. Introduction

RADIANCE is a powerful ray-tracing program that enables accurate and physically valid lighting and daylighting simulations [1] [2]. It is presently well established in the research community and has already been used for many projects.

RADIANCE was originally developed for the UNIX operating system. However, in the framework of an IEA task devoted to the development of daylighting design tools, it was integrated into the ADELINE software which runs on standard PCs [3]. Since then, RADIANCE has gained rising interest from designers, consulting engineers and glazing products manufacturers.

There are several reasons for this increasing success: its distribution through the Internet for free (see appendix), its reliability and its constant development, the effective and friendly cooperation between users and developers, its modular structure which offers a great flexibility to address various kinds of problems and, last but not least, the variety of its outputs. The production of highly realistic renderings is often considered as the first, if not the exclusive reason to use the software.

Some architecture schools have introduced RADIANCE to students mainly as a realistic rendering tool for studio work. Various connections to CAD software have been developed in order to facilitate the input of the data describing the model under investigation and to specify the viewpoints. The following step involves a specialized module of RADIANCE which automates the rendering process.

Since the visual system is able to adapt over a large range of conditions, the realistic appearance of a picture does not serve to ascertain that the physical phenomena have been modeled with sufficient accuracy. Thus, when emphasis is put on the quantification of the lighting/daylighting luminous interior environment (e.g. daylight factors, illuminance distributions and visual comfort assessment), many parameters controlling the ray-tracing algorithm have to be carefully adjusted. To achieve this task, the software algorithms have to be understood in greater details [4]. Unfortunately, to reach this level, a long period of learning and training is required (typically a few weeks). This burden seriously compromises the use of RADIANCE with students in the context of lighting or daylighting courses.

In order to overcome this problem, two methods have been developed and used with several groups of architecture students at the Federal Institute of Technology (EPFL) in Lausanne, Switzerland. The objectives pursued by these methods are first discussed in section 2. Both methods are then presented in sections 2 and 3. Finally section 4 discusses the usage of RADIANCE for the production of teaching material.

2. Objectives

The first incentives to find ways of using RADIANCE with students originated during seminars that presented simulation results obtained in the framework of daylighting research projects. Many students expressed their interest in using the software for their own projects. However, the limited amount of time they could spend on this task immediately appeared as a major problem.

A close look at the tasks sequence generally involved when using a computer simulation tool helped to devise appropriate solutions. As shown on figure 1, apart from the two rather technical tasks 3 and 4, the remaining are less tightly linked to a specific tool.

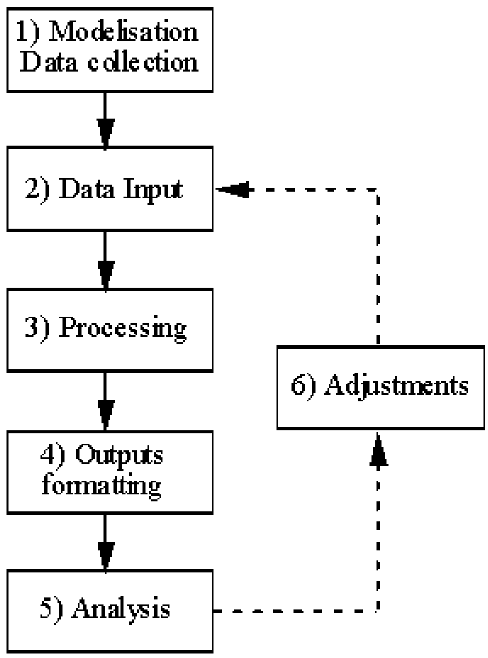

Figure 1: The sequence of tasks involved when using a simulation tool.

The basic idea is therefore to split the workload between the students and someone who fully masters the software and who will be in charge of tasks 3 and 4. Students are left responsible of the other tasks. Thus they can concentrate on the definition of the models they want to study and on the interpretation of the simulations results. In doing so, the software remains a "black-box" for them. As long as the teaching purpose focuses on the exploration of lighting and/or daylighting design issues, this constraint does not appear as a significant drawback.

Moreover, this approach puts each student in a similar situation as that of an architect who submits simulation studies to a specialized consulting engineer. This exercise gives a good opportunity to improve technical communication skills that are essential between both partners.

3. Method 1: parametrable models

This method principally serves for exercises following a course on lighting and daylighting. Students are asked to design an office room for which daylight is sufficient for a specified amount of the occupied time. In addition, they have to position desks that offer the best visual comfort conditions and to plan the layout of the artificial lighting installation. This short brief forces the students to make use of a wide range of knowledge presented during the preceding course. Thus the completion of task 1 implies a large effort.

In a second step, students translate their proposed designs into a set of parameters specified with a simple syntax and finally stored in a text file. Additional parameters that describe the desired outputs (e.g. viewpoints for realistic renderings, axis where to compute illuminance or daylight factor profiles) are also defined at this time. Figure 2 gives an example of such a file.

The available parameters do not give full freedom in defining complex geometries. However, the number of elements contained in a model (i.e. windows, partitions, desks and luminaires) is not limited and this allows sufficient flexibility for the purpose of an exercise.

An automated procedure then reads the description files and starts the calculations. The simulation process usually takes a few hours. Thus it is performed under supervision of the tutor in the period (usually one week) that separates two exercise sessions.

The results are computed for three situations: daytime (a standard CIE overcast sky is assumed), nighttime and daytime with additional task lighting (figure 3). Illuminance profiles and other performance indicators like glare indices are also provided.

Finally, the students are asked to make an analysis of their design based on this material and to make improvement proposals. After several tests conducted with groups of students, the following findings emerged:

- No more than 15 minutes are required to explain the syntax and conventions with which the parameters must be defined.

- Students appear to appreciate the freedom they have in defining the room they want to model. Nearly all of them take a real room as the basis for their investigations.

- The numerical parameters often contain slight errors which are difficult to spot before the simulations start. At that time the students are usually not present and the corrections have to be guessed. To avoid this kind of problem, a checking procedure with a graphical feedback is required.

```
# room dimensions (meters):
set length 6
set width 4
set height 2.8

# partitions ( <x_start> <y_start> <x_end> <y_end> ):
set partition_1 "0 1 1 0"
set partition_2 "3 0 4 1"

# surfaces reflectances (%):
set ro_floor 20
set ro_wall_east 60
set ro_wall_west 60
set ro_wall_north 60
set ro_wall_south 60
set ro-ceiling 80
set ro_partition_1 60
set ro_partition_2 60

# windows (<wall> <h_gap> <v_gap> <h_dim> <v_dim>):
set window_1 "wall_south 1.2 1 1.6 1.6"
set window_2 "ceiling 1 5 2 .4"

# windows transmittances (%):
set tau_window_1 80
set tau_window_2 "60 translucent"

# workplaces (<x> <y> <orientation>):
set workplace_1 ".6 2 0"
set workplace_2 "3 5.4 -90"

# luminaires (<type> <x> <y> <axis>):
set luminaire_1 "direct_indirect 1 1 90"
set luminaire_2 "direct_indirect 1 3 90"
set luminaire_3 "direct .8 5 0"
set luminaire_4 "direct 3.2 5 0"
set luminaire_5 "direct_indirect 3 3 90"
set luminaire_6 "direct_indirect 3 1 90"

# viewponts ( <x> <y> <angle> ):
set view_1 ".5 5.5 -60"

# illuminance profiles (<x_start> <y_start> <x_end> <y_end> ):
set profile_1 "2 0 2 6"
```

Figure 2: Example of an input file describing a daylit office room.

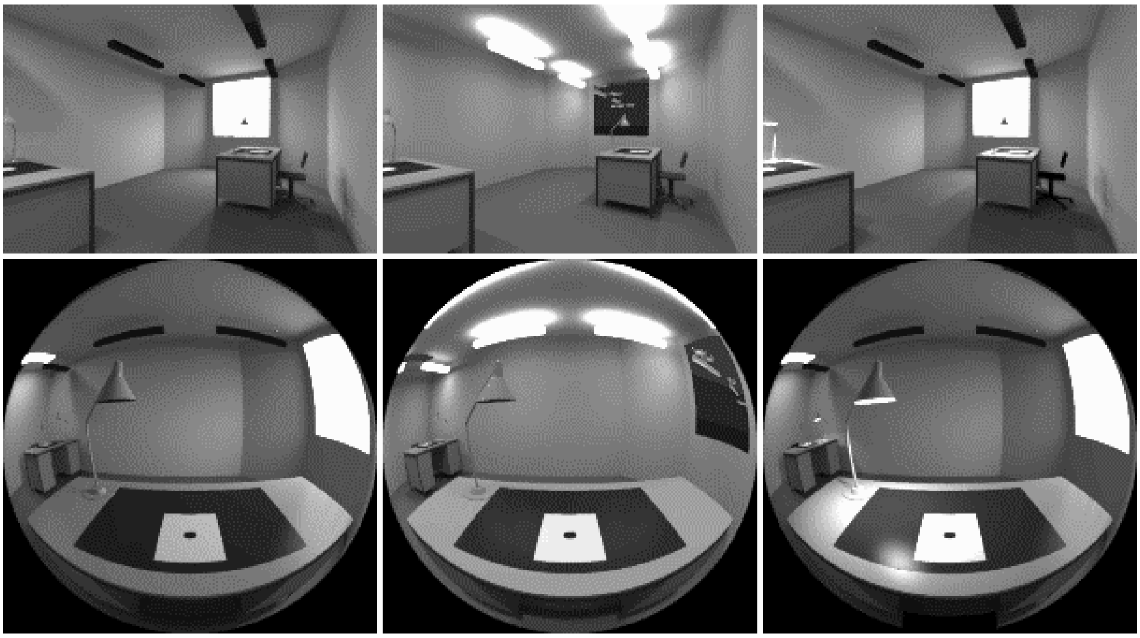

Figure 3: Realistic renderings of the office described in figure 2. Fish-eye views are produced at the workplaces in order to evaluate visual comfort conditions. Three situations are computed: daytime (left), nighttime (center) and daytime with additional task lighting (right).

- Surprisingly, no complaints regarding the hidden status of the simulation software were recorded.

- Result interpretation appears to be the most difficult part of the exercise. The students seem sometimes overwhelmed with the amount of information provided by the simulations.

- Due to the limited amount of time available for the exercise, a second loop through the whole process is almost never possible. To allow comparisons to be made between variants, students are asked to prepare two designs for the same room right from the beginning of the exercise. However, this strategy often fails to give interesting results since students usually vary too many factors at the same time.

These findings appear to be encouraging. Many other exercise scenarios could take advantage of this method. A limitation of the number of available adjustable parameters could help the students to target their investigations and to interpret their results more precisely.

4. Method 2: a consulting service

To satisfy the frequent request of students to perform simulations on their own projects, a kind of consulting service is established. A first meeting is organized between the students and their tutor to discuss their objectives and to make them aware of the data they have to assemble to fully define their model. At this stage modelization issues are also discussed. For instance it is unnecessary to model a full building if all the rooms it comprises are similar and arranged on a repetitive layout. Furthermore, details that are unlikely to affect the propagation of light may be omitted. On the other hand, specific elements (e.g. daylighting systems) may require further details to be modeled accurately. The students then proceed on their own with task 1.

A second meeting takes place once the material that describes their model is ready. At this stage, students are considered as clients requesting a simulation study for their specific project. They have to formulate clear requests regarding the type of results they want and the parameters they wish to investigate. Tasks 2, 3 and 4 are then performed by the tutor. Finally, the results are delivered to the students for analysis. Their conclusions serve later either to adjust their design or as confirmations of initial choices.

The following findings were gathered from several studies performed with this method:

- Students are highly motivated.

- It is difficult to convince students that a model of a subpart of their design is sufficient to obtain the information they really need. There is a great temptation to model whole buildings.

- The students have difficulties in formulating clear requests. Their main interest is often focused on the production of realistic renderings.

- The integration of the outcomes of the simulations in their project appears to be straightforward. However, students may present numerical results represented as daylight factor profiles or iso-lux contours superimposed on renderings without being able to fully justify their choices with technically sound arguments.

- The time the tutor has to spend on the project is often underestimated.

Although this method seems to satisfy the students, it still needs further improvement to fully meet the teaching objectives it is aimed to address. To help in this direction, case studies for which simulations played a significant role should be more frequently presented during relevant courses.

5. Production of teaching material

It is well recognized that teaching is significantly improved by adequate visual material. Due to its versatility, RADIANCE offers numerous possibilities in the field of lighting and daylighting design education. For instance, as opposed to photographs taken in real buildings, models can be created to demonstrate specific effects without incorporating disturbing or insignificant details.

A large potential also exists in using the software to produce illustrations that are either difficult or even impossible to obtain by other means. The following applications have been successfully tested to date:

- Illustration of the propagation of beams of light rays traced through various daylighting systems.

- Representation of transmission characteristics of daylighting elements.

- Calculation of illuminance vector fields.

- Production of stereographic or cylindrical projections of complex environments or shading devices with superimposed sunpath diagrams.

- Transformation of a photographed scene into a Waldram projection to enable a rapid evaluation of the daylight factor sky component.

- Evaluation of the yearly shading effect of a building over its surroundings.

- Separation of the three illuminance components of a daylit room (i.e. the sky component, the externally reflected component and the internally reflected component).

This material will soon be used in relevant courses where it could enhance the learning process by making visible things that often remained too theoretical.

6. Conclusions

Two simple methods have been developed to introduce RADIANCE to architecture students. Although the first tests indicate that the students were mostly satisfied, the two methods require some further refinements. The main issue consists in improving the students' ability to properly interpret the numerous results produced by this simulation tool.

To date, this kind of knowledge seems to be lacking. This is confirmed by a recent paper [5] which demonstrates that the use of daylighting simulation tools remains limited to a few specialists. A large proportion of practicing architects keep using simple hand calculation methods or never use any daylighting design tool at all.

A common belief is that this situation will change since simulation tools incorporating sophisticated graphical user interfaces become available. Recent developments [6] tend to confirm this hypothesis. However, complex simulation tools like RADIANCE will still offer much more versatility.

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Appendix: RADIANCE distribution

The RADIANCE UNIX version is distributed on the Internet for free. The latest version is available by anonymous ftp from one of these WWW servers:

http://lesowww.epfl.ch/radiance/radiance.html
http://radsite.lbl.gov/radiance/

Only the source code is distributed. Although an interactive automatic installation procedure is provided, some knowledge of the UNIX operating system is necessary to compile and install the software. RADIANCE users share their questions, problems, suggestions and solutions through a dedicated discussion list. To subscribe to the list send a request to:

radiance-request@radsite.lbl.gov

The ADELINE software also has dedicated WWW servers but it is not available for free:

http://www.ibp.fhg.de/wt/adeline/adeline.htm
http://radsite.lbl.gov/adeline/

R. Compagnon, EIF, 17 Feb. 98