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DAYLIGHTING SIMULATION: COMPARISON OF SOFTWARES FOR ARCHITECT'S UTILIZATION.

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ABSTRACT

Daylighting Simulation is a complex task, involving many parameters, but an important step to design buildings, especially when the main purpose is more comfort and energy conservation. For architects, simulation is still something far from the professional practice, due to the software's complexities, difficulties to use software's interface, hard interpretation of the results and many other reasons.

This article analyses and compares 4 daylighting software: **Desktop Radiance**, **Rayfront**, **Relux 2004 Vision** and **Lightscape**. The objective of the study is to find the main advantages and limits of each one, taking into account the priorities for the use of the software by the architects in their professional practice. Some criteria like interface, flexibility, help manuals, and others are analyzed, intending to establish a frame of the main points to be considered when choosing daylighting software for architects use, both in architecture schools and offices.

The methodology includes simulations with a test room, varying some parameters to verify the performance of the main criteria. The results show the potential of software's improvement, especially regarding the user interface and help manuals.

INTRODUCTION

The possibility to visually internal spaces before it's effective construction has always been an architect's desire. In this way, the computational visualization with synthetic images is a powerful tool which effectively helps to the architect's project in many ways. Among them, we can mention the possibility to understand and optimize the architectural propose from the point of view of daylighting utilization. Daylight prediction can contribute to environmental comfort and energy efficiency optimization in architecture.

Therefore, daylighting simulation softwares can offer these facilities and should support architects in many steps of the design process, from conception to implementation of daylighting strategies and innovative techniques in real spaces.

However, the architects usually find some difficulties to use those tools, due to their complexity, the lack of user friendly interfaces, and incomplete user manuals, and so on. For this reason, the high potential of utilization of simulation software in architectural projects is not enough utilized, especially in the Brazilian context.

This article studies daylighting simulation in the Architectural Project, through the evaluation of 4 simulation tools - **Desktop Radiance**, **Rayfront**, **Relux 2004 Vision** and **Lightscape -** from the architect's point of view in the context of the design process**.** In that sense, intends to contribute for the best understanding of daylight simulation with the analysis and evaluation of the software above mentioned. The evaluation has been performed taking into account criteria like User Interface, Geometry, Output, Daylight Parameters, Materials Description, Processing, Validation and User Support. Among these criteria, User Interface is especially important to the architect, as it is the best form to surpass the natural barriers to the use of digital processes in architectural design, aiming to reach environmental comfort and energy efficiency. The used methodology includes a large number of simulations, intending to test the simulation tools in different conditions of daylight. The results of this evaluation shows a large potential for a better use of simulation tools by architects, through the best understanding of the tools and the use of material produced for complementation of manuals, the tutorials.

State of art

Mathematic models used in Computer Graphics (CG) to generate images (from 3D models) aiming to predict daylighting, are based in Global Illumination models, to evaluate all the contributions from direct and indirect sources in light transportation. Among these models physically founded there are basically two types: scene-based methods – independent from the observer point of view (as the *Radiosity)* – and image-based methods, dependent of the observer

point of view (as the *Ray Tracing)*. Both of them can produce numerical outputs and high quality images, with the purpose of quantitative and qualitative evaluations of daylighting in architectural spaces.

Studies of ALTMAN (2000), ROY (2000), INANICI (2001) have performed comparisons between some softwares (LIGHTSCAPE, DESKTOP RADIANCE, RADIANCE SIS) that use physically founded methods as the exposed above, in order to investigate specially numerical precision, outputs and so on.

SIMULATION

Methodological procedure

The methodology of this work has adopted the following steps:

- Study of the main existing daylighting simulation software and it's application on architectural projects;
- Selection of 4 simulation softwares to be evaluated, among those available in LACAM (Laboratorio de Controle Ambiental) in Post-Graduation Program in Brasilia .
- Definition of evaluation criteria to selected softwares, based in previous studies (ALTMAN, ROY and INANICI, above mentioned);
- Definition of geometric model to the simulation, called standard-space;
- Definition of contour conditions to the simulations and score;
- Planning and achievement of simulations;
- Simulations analyses, through a matrix with established evaluation criteria;
- Elaboration of tutorials and complementation for softwares manuals, considering the needs of each one and their use by architects.

Modeling the test room, the standard-space

A paralelogram shaped with dimensions of 6.60 x 3.30 meters. A central window with 1.65x1.65 meters and a light-shelf measuring 1.65 x 0.40 meters, at 2.20 meters above the floor. The ceiling is 2.75 meters high and measures 9.60 x 6.30 meters. This 3D model was generated with AutoCAD R14, them imported to three simulation softwares, the only exception was RELUX 2004 PRO + VISION, that does not imports generated 3D models in CAD. (figure 1)

Optical properties of materials

Table 1
Optical properties of materials

Surfaces	reflectance	Transmittance	Specularity	roughness
Walls: White paint	65,61%	0%	0%	0%
Floor : gray granite	35%	0%	0%	0%
Ceiling: White paint	68%	0%	0%	0%
Light shelf: White paint	65,61%	0%	2,68%	1%
Clear glass - 8 mm	82%	89,90%		
Furniture	Table: beige, brown and metallic colors. Chair: orange and metallic colors.			

Climate and daylighting data

Table 2
Simulations site: Brasilia-Brazil

Latitud	15º 52' S
Longitud	47º 55' W
Altitude	1060 m
Sky conditions	
March/September	Cloudy Sky -var. 3.000 to100.600 lux
June	Clear Sky - var 8.000 to 90.000 lux
December	Cloudy Sky – var 3.000 to 20.600 lux

Evaluation of software

4 simulation softwares were selected among all simulation software available at LACAM, Laboratory of Ambient Control: LIGHTSCAPE, DESKTOP RADIANCE, RAYFRONT and RELUX 2004 VISION. The choosing criteria took into account specially:

- Flexibility, in the direction of its possible adaptability to the architect's workflow;
- Using state of art algorithms;
- Numerical precision (validation);
- Possibility of access from a Brazilian architect.

The evaluation criteria were established considering researches on some previous works, as ALTMAN (2000), KHODULEV (1996), INANICI (2001) and

ROY (2000). The adopted criteria and its respective values for the evaluation of simulation softwares, considering the flow of work and it's importance are as follows:

Table 3
Evaluation criteria and values

1-Modeling - Input of Geometry	1
2-User Interface	2
3-Output	1
4-Daylighting Parameters Inputs	1
5-Optical Properties of the surfaces	1
6-Processing – efficiency of simulations	1
7-Validation – precision of output	1
8-Support to the user -	1

Value 2 was assigned to interface criteria, due to the fact that is one of the most important barriers to the use of complex daylighting simulation software.

DISCUSSION

Daylighting simulation in architectural design is connected with environmental comfort studies and energy conservation strategies. The difficulties to find simple methods or a suitable tool to architect's utilization is the main barrier in the simulation use in design process.

In order to evaluate simulation software, a 3D standard space with precise characteristics and located in the city of Brasília was used, with the purpose to study the performance of these tools in daylighting prediction in architectural projects.

By this evaluation, following the criteria previously established, the results were:

RELUX VISION 78 points, LIGHTSCAPE 60 points, DESKTOP RADIANCE 23 points and RAYFRONT 17 points. (figure 2 and 3)

The simulation of the test room generated 144 synthesized images. Here a brief discussion about the qualities, limitations, difficulties and errors that was possible to identify. LIGHTSCAPE uses as calculation method the Radiosity algorithm and a post-processing Ray Tracing . Daylighting simulations have a inherent characteristics to this algorithm, as the calculation of diffuse inter-reflections and the independence from synthetic camera. The hybrid approach adopted by the LIGHTSCAPE cannot be understood as an advanced method, because there is no indication that Ray Tracing participates in the calculation of the light transport to surfaces. The numerical and tonalities analysis are generated independently of the post-processing Ray Tracing. DESKTOP RADIANCE and RAYFRONT are based on the calculation engine of RADIANCE SIS, a validated and precise algorithm. They produced synthetic images in the simulation of the standard space with qualitative and quantitative consistency. The variations between its results are resultant of adjustments and parameters available in the interface of each one. RELUX 2004 PRO + VISION, according to it's manufacturer, also makes use of calculation engine based on RADIANCE SIS slightly modified. It uses also the Radiosity algorithm for calculations limited for the diffuse illumination generated by the overcast sky.

Lightscape

The LIGHTSCAPE had been used in the last years in the production of "photo-realistic" images. The use of this software for architects can be useful project's presentation, due to its animation and VRML resources; however, as simulator, it has some limitations. One of its main impediments concerns to the fact that the correction of programming problems will not happen due to its discontinuity, and therefore the evolution of its algorithm is compromised, beyond the problems of support to the user. The LIGHTSCAPE totalized 60 points in the evaluation. Its strong point happens in the matrix of the Interface and its worse performance: in the matrix Daylight Parameters.

Desktop Radiance

The interface has restricted interaction with the user; however, the fact of running as plug-in in the AUTOCAD partially compensates the limitations of the interface, facilitating the integration of the simulation within CAD; this approach is ideal to integrate the simulation software to design process. Moreover, the interface of the AUTOCAD is well known by the architects for some years; The adjustments of precision level of the simulation and the simulation manager provides a very efficient process of the point of view of the necessary time for the simulation and backward the feeding of the process for study of alternatives of the architecture project. This does not mean that software is adjusted to the use in the initial phases of the design, therefore its algorithm needs accurate information of input and complex adjustments to get it resulted correctly. DESKTOP RADIANCE totalized 18 points in the evaluation. Its strong point happens in the matrix of Geometry and its worse relative performance happens in the Interface.

Rayfront

When used with the 3DSOLAR has a great potential to support architect's process of design. This approach provides the integration of the software of simulation to the design process. Its ideal to study alternatives of the project of

architecture, especially in the initial phases. Without the aid of the 3DSOLAR, the RAYFRONT has a very low potential of application in the work of the architect and is better adjusted to the work of researchers. All the potential of the RAYFRONT is shown when it is running associated with the 3DSOLAR and the addition of plug-in RAYDIRECT. It becomes ideal tool to analyze the advanced daylighting devices. The RAYFRONT got 16 points in the evaluation. Its strong point happens in the Output matrix and its relative worse performance in the Interface.

Relux 2004 Vision

The user interface has a perfect interaction to architect's work flow, becoming intuitive, what facilitates its learning besides being in Portuguese; internal modeler, simple but powerful, to elaborate geometry. It uses objects and not geometric entities, that is, walls are created (it does not create lines or faces that represents walls), windows, flagstone, skylights, doors, tables, chairs, lights and etc.; Geometry and the properties optics of the materials attributed to objects, in the same interface; It allows output such a numerical evaluation of glare, annual energy efficiency, pseudo-colors (falsecolor) and curves of iso-countour in all the plans of geometry 3D, walls, etc.

Its applicability in the design process is sufficiently promising therefore it has all the conditions and capacity to support the diverse phases of the architecture project. It has a great number of possibilities of qualitative and quantitative analysis of the behavior of the light in the architectural space. It uses graphical and numerical outputs for almost all the necessary parameters for this task. Its user-friendly interface is very appropriate for the architects. RELUX VISION got 81 points in the evaluation. Its strong point happens in the Interface and its relative worse performance in Geometry.

CONCLUSION

Among the softwares analyzed, RELUX PRO 2004 + VISION is the most adequate for architect's use; RAYFRONT and DESKTOP RADIANCE presented more difficulties to be used in the design process. Both presented similar problems. DESKTOP RADIANCE has the advantage to be enclosed in AUTOCAD, a graphical interface very known by the architects. Moreover, it uses dialogue boxes to materials and glass selection and visualization with synthetic cameras. LIGHTSCAPE has a user-friendly interface, but not as intuitive as RELUX. Some aspects of the lacks of precision of the calculations are mainly related to the sky models and the absence to treatment of the specular surfaces in the optical properties of the materials. It is discontinued by the manufacturer; no doubt is an important negative point, especially when the support for the user is concerned. RELUX VISION joins the precision of the calculation engine, with a correct interface, user-friendly and extremely simple. The interaction with the user, architect not specialist in CG is very easy. To this user, that intends to use the tool as support to the process of design of the architectural space, it provides easy learning and applicability, without excluding the possibility of correct calculations and precise synthetic images. The interaction of the interface is in the Portuguese language – of Portugal - what it deserves a great prominence; therefore it provides comfort to the user. RELUX has the prerequisite to support the project in its diverse phases, importantly contributing to add to the space architectural the qualities of the daylighting.

The evaluation showed the need of improvement of daylighting simulation softwares, especially regarding interface and help manuals. Then, was considered the elaboration of a WWW site with tutorials for the softwares of simulation. (figure 4). DESKTOP RADIANCE and RAYFRONT have high potential for evaluation of the daylight in the architecture project.

The methodology adopted for evaluation of software showed to be adequate. Also as result of this evaluation, concluding that still the ideal software of simulation does not exist. The ideal daylighting simulation software should combine edition and modeling tools, beyond luminous evaluation and thermal consequences of daylight use. It should also considerl the project architectural as an integration of diverse factors, giving to the architect the possibility to integrate knowledge, using accessible digital processes.

Finally, we can consider, that there is a great potential to simulation softwares use in the architecture design. Computational tools – simulation softwares - must facilitate their use by architects, but clearly, they must be adequately prepared to deal with them.

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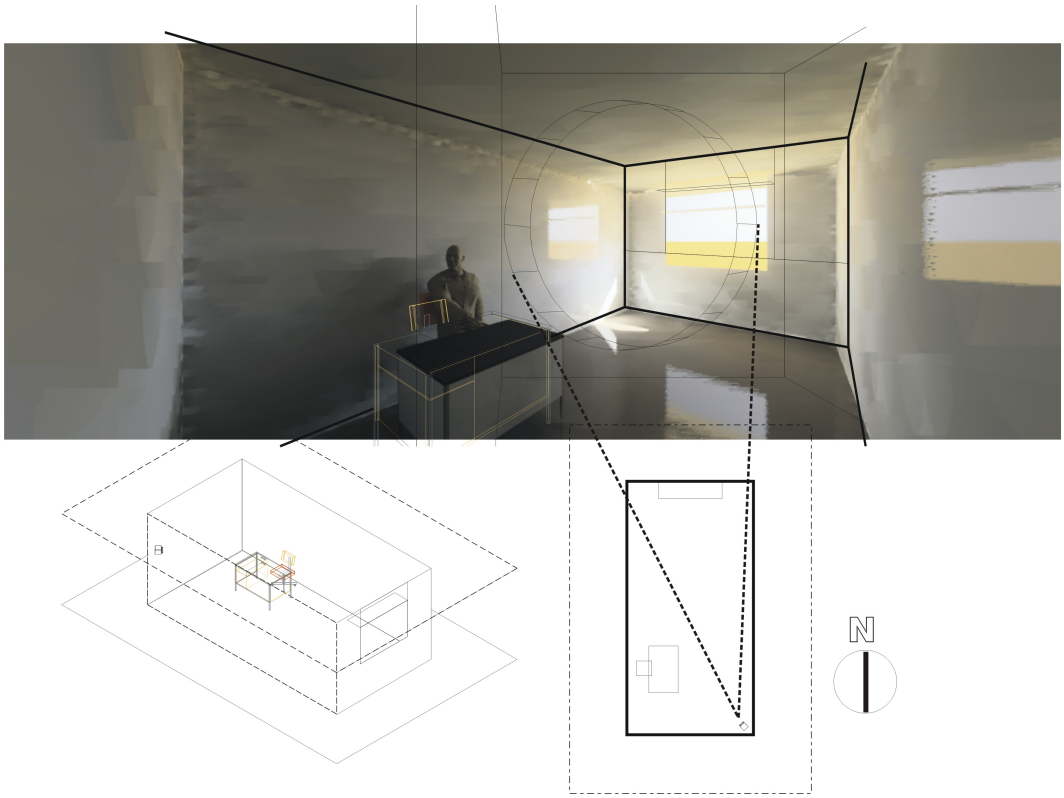

Figure 1 – Plan, Perspective and rendering of standard-space.

	LIGHTSCAPE	DESKTOP RADIANCE	RAYFRONT	RELUX VISION
1- MODELING - INPUT OF GEOMETRY	5	6	3	3
2- USER INTERFACE	38	-2	-10	62
3- OUTPUT	8	9	12	3
4- DAYLIGHTING PARAMETERS	0	1	6	1
5- OPTICAL PROPERTIES OF THE SURFACES	4	4	4	4
6- PROCESSING – EFFICIENCY OF SIMULATIONS	2	-1	-1	-1
7- VALIDATION	2	2	2	2
8- SUPORTE TO THE USER	1	4	1	4
TOTAL	60	23	17	78

Figure 2 – Score of Evaluation .

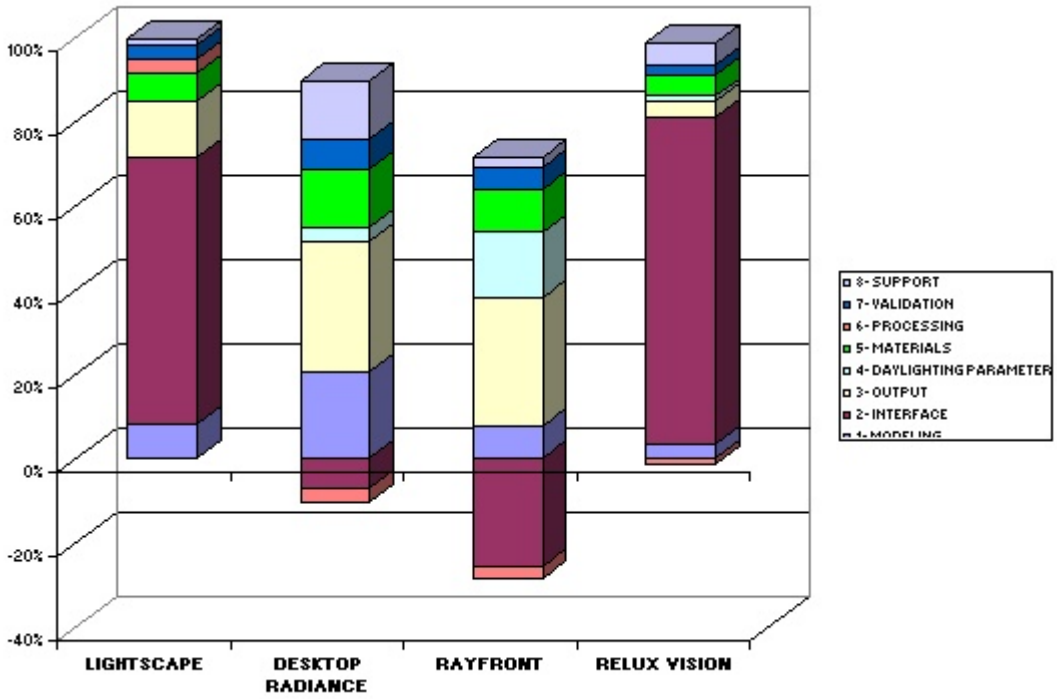

Figure 3- Graphical Analysis of evaluation.

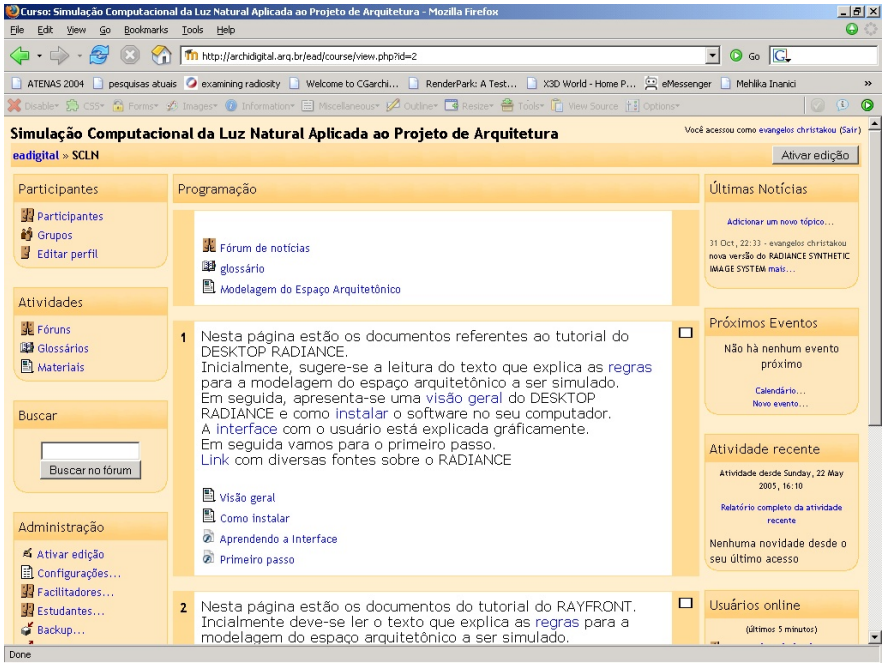

Figure 4 – Site WWW with tutorials