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Design to Thrive

A comparative study between digital and scale model simulations of a luminous environment under a sunny clear sky

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Abstract: When comparing digital simulations with experimental field measurements, we often find references associated with a large margin of uncertainty. In other words, to what degree do the results come close to the real situations studied? Indeed, a number of research studies attest to the significant difference between the two simulated and real situations. This work consists of two comparative experiments: i) Comparison between the results of the digital simulation of the levels of illuminance on a work plan carried out by the two software Radiance 2 BETA and Ecotect5.5., As well as ii) Comparison of the results obtained by a digital simulation of the levels of illuminance on a work plan carried out by means of two software programs, namely Radiance 2 BETA and Ecotect 5.5, A simulation by models (models) under a clear sunny sky. The results obtained prove differences in the comparison. The most important ones are presented by the discrepancies between the data measured and simulated by the Ecotect 5.5 software. The data measured and those simulated by the Radiance 2 BETA software have smaller deviations.

Keywords: Digital simulation, level of illuminance, experimental comparison, scale model. Sunny clear sky

Introduction

During the recent years, digital lighting simulation tools have made considerable progress. They play a very important role in analyzing the availability of natural light to deduce optimal sizing and control strategy of lighting systems (Maamari, 2004)Today, there is a huge increase in the number of digital lighting simulation software at the international level. However, the credibility of this software and the accuracy of the results they provide remain dependent on their fidelity in the reproduction of real conditions in the form of an artificial environment.

The case of sunny clear skies is more than concerned with this issue. First, we must emphasize the important time lag separating the advancement in knowledge about the overcast sky and the clear one. In addition, the digital simulation tools were more developed for the case of the overcast sky than for the sunny clear one. Also, the research carried out uses, by constraint, inappropriate software for the case of the clear sky. However, some software was considered more reliable than others for the case of this sky following experiments carried out in situ.

Most of the existing evaluation work generally falls into three categories of research works comparing: i) computer simulation and measurements in experimental models (Grynberg, 1988), (Aizlewood et al. 1997), ii) computer simulations and measurements in

real scenes (Galasiu et al, 1998),(Mardaljevic 2001), iii) computer simulation of various software (Fontoynont et al, 1999). The objective of this study is to verify the existence and the significance of the gap between a real situation and a computer simulated one of a luminous environment under clear sky. This work will consist of a comparative assessment using the techniques of the first from the above categories. A comparison of the horizontal illuminance values obtained by measurements in the model and those obtained using Radiance and Ecotect. The reference is made to the case of the city of Biskra in Algeria where the sunny sky is frequent at more than 80% during the year (Satel-Light, 2014).

Methodology

The real sky experimental work led to the construction of a model of the simulated architectural office space. A similar model is drawn for the computer simulation. The horizontal illuminance values obtained by the measurements carried out in the model and those obtained with Radiance and Ecotect software are selected as a basis for the comparison between the outcomes of the computer simulation and the real sky field one.

Experimental field work

The experimentation on the model runs under a real clear sky. The model is designed at the (1/8) scale. This allowed to have a very detailed interior view (photos or videos) andto accurately study the penetration of the natural light (Figure 1).

Figure 1.the scale model (left) The openings in the walls to place the probes of the Light-meter (right)

The model was made with foam cardboard of 2cm thickness. The interior walls were covered by a cream-colored paper which is the color used in the majority of office buildings in the city of Biskra. We made holes in the vertical wall in order to pass the probe of the Light-meter.

The latter will be attached to the designated points on the worktop inside the model (Figure. 2). The measurement points are those of a grid with a depth gap of 100 cm from the front bay and 100 cm width. A total of 35 points is fixed. The height of these points was fixed at 75 cm from the ground (figure 3).

Experimental digital simulation work

The computer simulated model has the same geometric and photometric characteristics as the real field simulated one. The digital simulations were carried out using the software i) Ecotect 5.5 and; ii) Radiance 2.0 BETA .Two orientations were selected: iii) Orientation East with a window equipped with a "Flanks" protection system ii) South orientation with a "Light shelf" system added to the opening. The simulations were done for a clear sunny sky at 12 pm of the September 21 (Figure 4).

Figure2. Light-meterC.A 813 for indoor measurements (left) and Light-meter LX-107for outdoormeasurements (right).

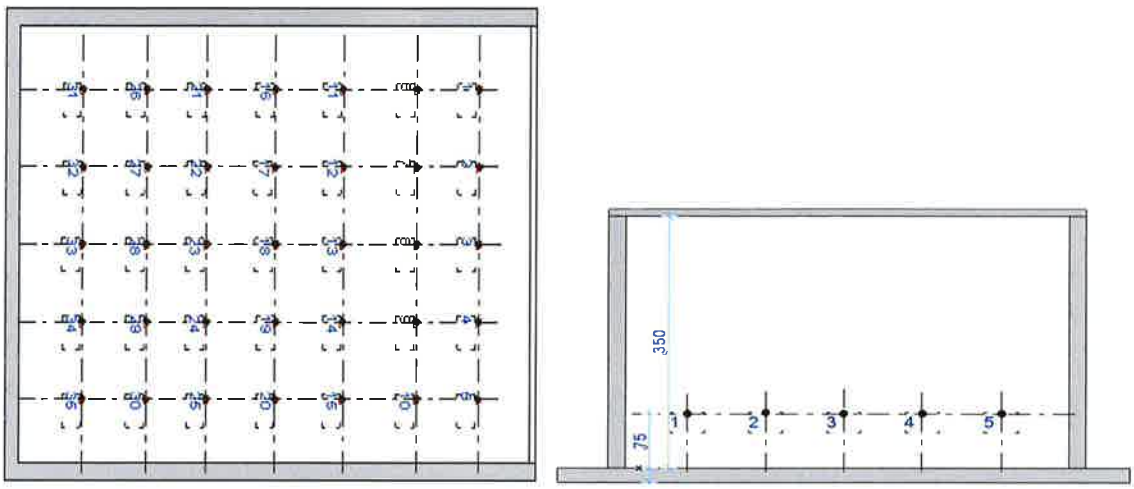

Figure3.Plan view of model - Positioning of measuring points (left) section (AA) indicating the measurement points levels (right).

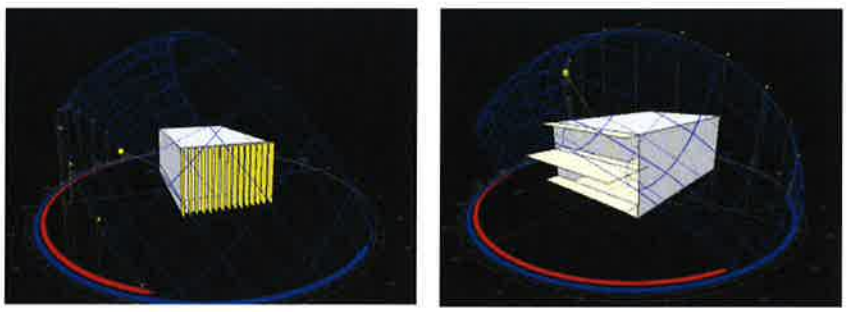

Figure 4: Both models simulated, the flank system (left), and the Light shelf system (right)

For the computer simulation, a set of meteorological decennial data was used to create a basis data file for the simulation conducted under Ecotect (using the split flux calculation method) and then transferred to Radiance (referring to the raytracing method).

Results

The results of the in-situ measures inside the scale model and the digital simulations made by means of the software Ecotect 5.5 and the Radiance 2.0 are presented on figures 5 and

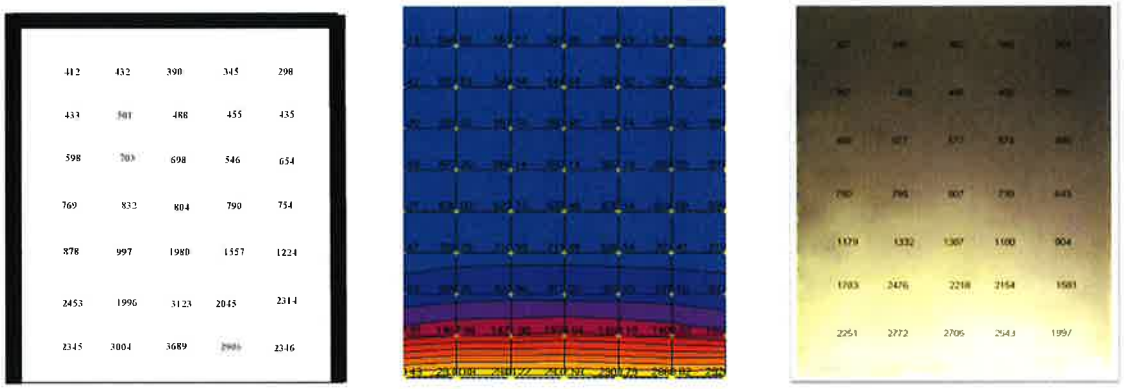

Figure 5. Illuminance output values on the work surface of the East-oriented model equipped with Flanks for the month of September at 12h (a) the model, (b) Ecotect, (c) Radiance

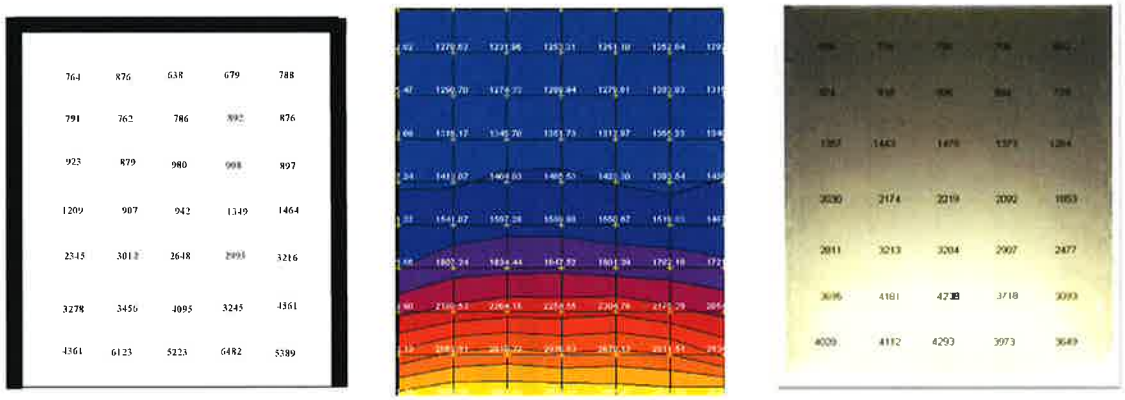

Figure 6. Illuminance output values on the work surface of the South-oriented model equipped with light shelf for the month of September at 12h, (a) the model, (b) Ecotect, (c) Radiance

The maximum and minimum values of the two orientations South and East for the three measurement tools are presented in Table 1. The points selected for the comparison between the values of the illuminance are (point p3 (near the window), p18 (middle) and p33 (bottom). The values in Table 2 are transformed into a graphical presentation, comparative reading (Figure 7) and Figure 8).

The comparison between the three renderings took place through a reading of three values for each of them. The first value is that of the measuring point located on the central axis of the office and the first measuring line close to the window. The second value is that of the measuring point located on the central axis of the office and the fourth measurement line at Middle of the window. The third value is that of the measuring point located on the central axis of the desk and the seventh measurement line at the bottom of the window for both orientations.

Table 1. Minimum and maximum illuminance values received on the work surface for the three measurement tools' Model, Ecotect and Radiance

		Scale model	Radiance	Ecotect
Light shelf	E (max)	5432	4293	2919
	E (min)	628	656	1231
Flanks	E (max)	3639	2772	1529
	E (min)	298	264	544

Table 2. The points selected for the comparison between the tools of simulation of the illuminance illumination (points P3, P18 and P33)

Tool for measuring the illumination values	E (Lx)Close to the window		E(Lx) The middle		E(Lx) in the bottom	
	Flanks	Light shelf	Flanks	Light shelf	Flanks	Light shelf
Scale model	3639	5223	804	942	390	628
Radiance	2705	4293	807	2219	360	756
Ecotect	1529	2837	633	1589	554	1253

Orientation East

For the East-oriented office equipped with a "Flank" system, we notice a clear gap between the three curves in the zone near the window (P3). However, Radiance software curve is closer to the scale model one than the Ecotect software curve. From the middle (P18) to the bottom (P33) the three curves follow the same course (Figure 7).

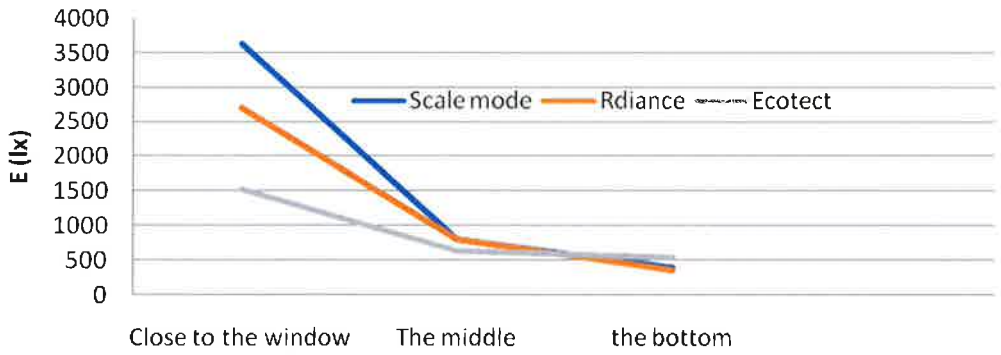

Figure 7. Comparative illumination values received on the work surface simulated by Ecotecte Model reduced, and Radiance of office equipped with Flanks, orientation East, for the month of September at 12h.

Orientation South

The difference between the three curves is always present up to the middle (P33). We notice an intersection of the curves at three different depths. We also notice that the curve (mock-up or model) which presented the value (P3), has the lowest values in the middle (P18) and in the background (P33) when compared to the Ecotect and Radiance curve. (Figure 8).

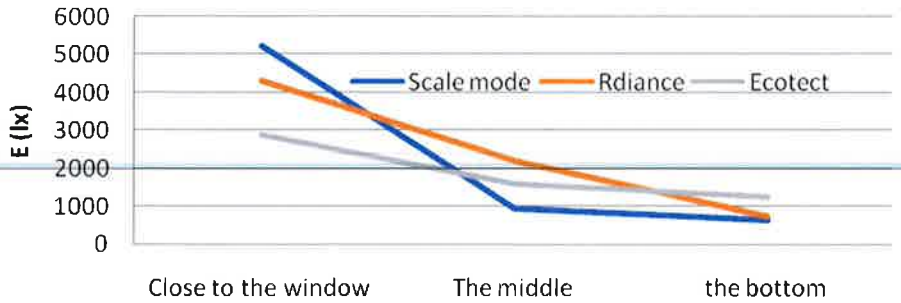

Figure 8: Comparative illumination values received on the simulated work surface by Model, Ecotecte and Radiance of office equipped with light shelf, orientation East, for the month of September at 12h.

Discussion

The results presented in the figures (figure.7 and 8) show that the highest values of illumination are in the points near the window for the three measurement tools. This increase is due to the fenestration and related to the important quantity of light passing through the transparent glazing which helps to maximize the illumination in this zone.

The results compare the simulated and measured light values in terms of percentage difference (table 3 and 4). Reinhart & Fitz (2006) research on the use of daylight analysis in building design has shown a growing confidence in the accuracy of Radiance's computer modeling (Sharples et al 2007).

The values presented in tables .3 and table .4 show significant differences ranging from (¼) to (½). However, the comparison (scale model and Radiance, System Flanks) in the middle (a difference of 0.37%) and at the bottom (7.69%) attests that this difference is insignificant. The comparison (scale model and Radiance) for the two orientations presents the least impotent differences that the comparison scale model/ Ecotect or Ecotect /Radiance.

Table 3: Difference Values (%) of Illuminances Received on the Work plane of the Three Measurement Tools for East Orientation at 12 H

	Difference (%) Close to the window	Difference (%) In the middle	Difference (%) In the bottom
Scale model and Rdiance	25.66 %	0.37 %	7.69 %
Scale model and Ecotect	57.98 %	21.26 %	29.60 %
EcotectetandRdiance	43.47 %	21.56 %	35.01 %

Table 4: Difference values of illumination received on the work plan of the three measurement tools for the South orientation at 12 H

	Difference (%) Close to the window	Difference (%) In the middle	Difference (%) In the bottom
Scale model and Rdiance	17.80%	57.54 %	16.93 %
Scale model and Ecotect	45.68 %	40.71 %	49.88 %
Ecotect and Rdiance	33.91 %	28.39 %	39.66 %

These results confirm the validity of the Radiance simulation tool that has been verified by several researchers through several methods. In the work of Mardeljevic (Mardaljevic, 1995), comparing the illumination obtained by computer simulation with measurements made in a room, the results showed a small average relative error of 5.6% between the measured and simulated data. This concordance of the data has made it possible to affirm that the Radiance software predicts adequately the lighting. It also confirms the previous research works revealing that the raytracing calculation method based software are more accurate than the split flux calculation method based ones (Yoon et al, 2014).

On their side, Aizlewood et al. (1997) had studied a very important validation analysis for Radiance in an atrium light box with various geometric and surface reflectances. Research has shown that luminance simulations are consistent with experimental measurements. Galasiu and Atif (2002), in a comparative analysis between the measured

data of a real atrium and the Radiance simulation, have shown that there is a more exact correlation between Radiance and experimental results under different sky conditions.

In summary, it can be deduced that a rigorous and objective comparison of lighting simulation software is anhard task and of considerable complexity. This is true for all software based on physical laws. Through the identification of the weak points of a software and these fields of application, one can lead to a responsible use of these computer programs (Maamari, 2004). Some errors may occur in the experimental process, such as reading errors, the precision of the model and the speed of change in brightness in the real sky (Ghasemi et al., 2013).

Conclusion

The use of computer simulation software is becoming increasingly important in the field of architectural design. These programs can help designers choosing the appropriate architectural and / or technical solutions for a comfortable environment.

The present study compares the outcomes of a computer simulation and a real sky field measurements in experimental models allowing the calculation of the values of illumination on the work surface of a 'transparent' office equipped with a system Light shelf for the South orientation and 'Flanks' for the East orientation under a sunny clear sky in Biskra.

The results obtained show differences in the outcomes. The most important ones are presented by the discrepancies between the data measured and simulated by the Ecotect 5.5 software. The data measured and those simulated by the Radiance 2 BETA software have smaller discrepancies or differences.

It has become clear that the Radiance software, which has demonstrated ahigh credibility in many of research works, including our work which presents the optimal choice of simulation software in natural light.

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