Experimental validation for software DIALUX: application in CIE test Cases for building daylighting simulation

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Topic 5. Indoor and outdoor lighting, lighting control, and visual comfort

Experimental validation for software DIALUX: application in CIE test Cases for building daylighting simulation.

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SUMMARY

DIALUX (www.dialux.com) is a freeware that simulate artificial and natural lighting outwards as well as inside the building. Interface of this software, functionalities suggested and outputs (realistic rendering as well as physical values) makes DIALUX widely used software in lighting design domains in Europe. Therefore, it was interesting to verify the accuracy of this software.

While the software has already been tested with regards to artificial lighting simulations, there is no available information regarding its accuracy in daylighting simulation. Knowing that the software is already being used by consultancy firms for daylighting evaluations within green building design projects, it was important to assess daylighting functionalities in DIALUX.

The reference data for the comparison measurements / simulation is based on experimental measurements to the scale model. Experimental study environment is an artificial sky imagined by the ENPTE (Ecole National des Travaux Public de l'Etat, Lyon, FRANCE) Laboratory. The recommendations used for experimental protocol are given by the task 3.33 of CIE technical committee (2005).

One such study enables us to appreciate reliability of the software in relation to daylighting (natural lighting inside the building).

INTRODUCTION

The use of lighting computer programs is becomes more and more importance in the field of building design and simulation. Lighting programs can help designers or decision makers to choose appropriate architectural and/or technical solutions to achieve a comfortable built environment while reducing energy consumption.

Within this context, an increasing number of lighting (artificial and/or natural lighting) computer programs are proposed around the world. However, it is still difficult for the user to estimate the range of errors to be expected when using a particular program for a particular task. This is due to the lack of reliable and transparent validation studies.

A similar study on the validation of the model of artificial lighting used in DIALUX was already undertaken DIAL (2005).

The objective of the present paper is to assess the reliability of software to simulate natural lighting inside the building.

METHODS

In this paragraph, we present the benchmarking type, the geometric room (scale model) used, and hypothesis simulation for DIALUX. The description of these test cases includes the geometry, artificial sky, and a set of values to be used as a reference to assess the accuracy of a daylighting simulation. These reference values have been obtained by measurement in the experimental cases study.

Reference tests cases (benchmark)

Experimental cases (reference test cases or benchmarks)). The large fraction of these test cases was developed in the framework of a PhD thesis (Maamari 2004) at ENTPE, in French. The benchmark consist of a set of test produced using measurements with scale model, including 1:5 scale inside the ‘’mirror box’’.

Geometry type room, position to the scale model and reference point

Light sources were provided by the artificial sky. The scenario was conducted inside the ‘’mirror box’’ of the ENTPE, which has a dimension of 2mx2mx2.1m. Scale model was positioned at middle to mirror box. Six measurement points were used inside the model: 4 points measure at the floor (A1, A2, A3 and A4) and two (A5 and B5) at a wall surface. The scale model is a wood cubic box of dimensions of 80cmx80cmx60cm with variable roof or front wall opening (Maamari et al. 2006) and with matt black interior surfaces (4,5% reflectance). Two types of test case are provided: floor and front wall opening.

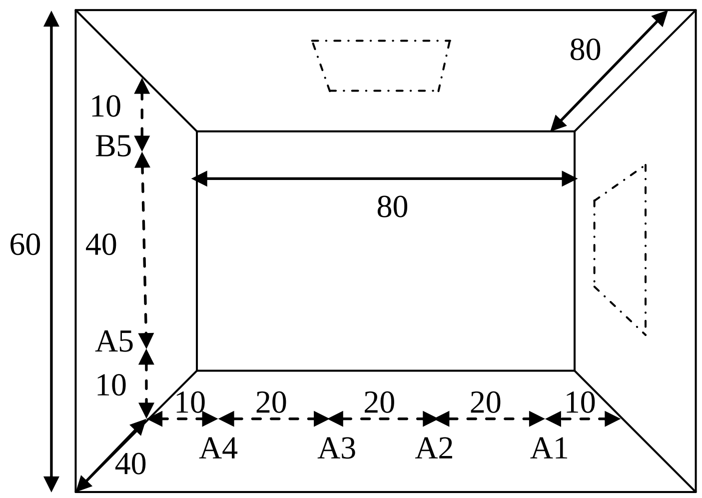

Figure 1. Geometry description and reference point position in scale model (variable roof or front wall opening)

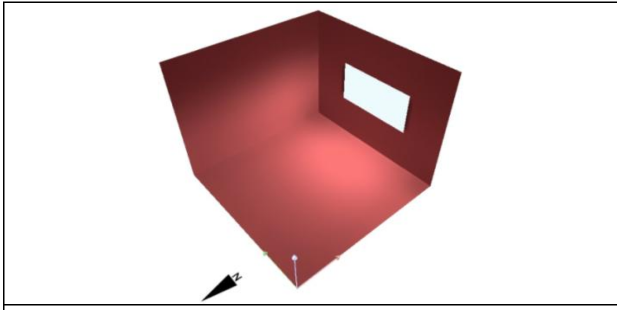	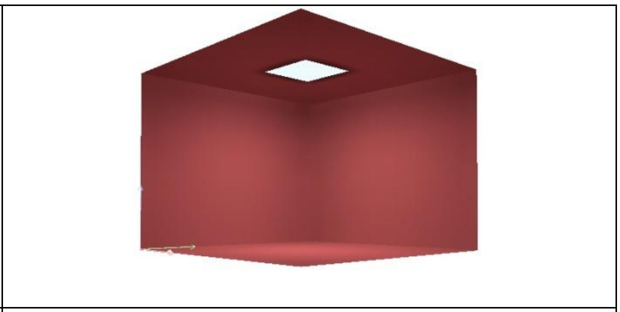
Figure 2. Front wall opening in model test room for DIALUX	*Figure 3. Roof opening in model test room for DIALUX*

Mirror skybox

The mirror skybox, also known as an overcast sky simulator, is a tool for measuring daylight in physical models. We can measure absolute and relative light levels in the physical daylight model. The artificial sky simulates the standard cloudy sky conditions, giving either uniform illuminance or the CIE illuminance distribution. There basic forms of artificial sky are rectangular (Figure 4. and Figure 5.). The rectangular sky has a luminous ceiling and four strictly vertical walls lined with mirrors. The multiple reflections between accurately parallel opposing mirrors give an infinite horizon effect. The mirror glass absorption through multiple reflections ensures a illuminance distribution similar to that of the CIE sky.

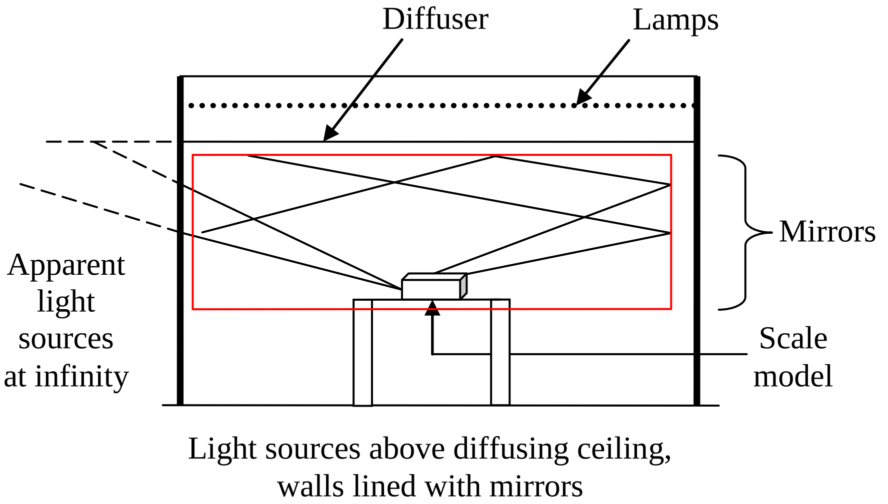

Figure 4. Rectangular (mirror-type) artificial sky to "Mirror box"

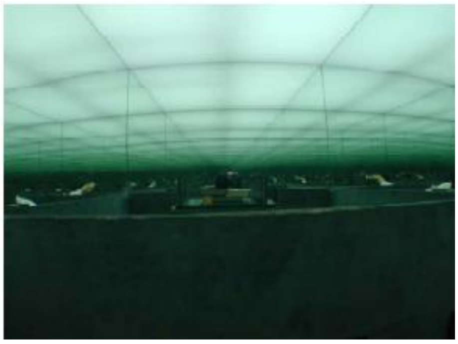

Figure 5. ''Mirror box'' to simulate the artificial sky (Maamari 2004)

Assumption of the simulation in DIALUX

Actually, DIALUX don't considered artificial sky. It is necessary to declare geographic position site the local room for the simulation. Therefore, the model to calculate illumination is based to Daylight factor (DF). Indeed, this factor depend only the geometrical building. So as to be able to do simulation, it would better to proceed of the kind:

- Insert building model under DIALUX for any locality.
- Then, calculate Daylight Factor (which takes account only of the geometry of the building).
- And finally, from the value of exterior illumination (from artificial sky) and DF, deduce interior illuminations.

This method calculate illuminance at every defined position measurements values by taking as horizontal exterior illumination value that defined in the experimentation to the mirror skybox. For the methodology error the estimations of CIE TC 3.33 were adopted. Hypotheses for the simulation in DIALUX are:

- Cloudy sky model.
- Geometrical test room is 4 m x 4 m x 3 m (equivalent 80 cm x 80 cm x 60 cm to the Scale model).
- Two type opening variable of: front wall opening (2mx1m, 3mx2m and 4mx3m dimension for opening dimension) and floor opening (1mx1m, 2mx2m, 3mx3m and 4mx4m opening dimension).
- In the case test to front wall opening, wall oriented in theoretical south.
- Light source values from Maamari (Maamari 2004).

RESULTS AND DISCUSSIONS

In this paragraph, comparison between simulation results of tested programs in DIALUX and the reference data for 7 tests cases defined by Maamari (Maamari 2004) will presented. The experimental benchmarks of daylighting scenarios based on experimental study of scale model and artificial sky (mirror box rectangular type) developed by the Laboratory ENTPE. Table (Table 1.) recapitulates the dimensions and positions openings of the room tests. For any points at measurements values given, is associated a global error Upper Limit (*UL:* Acceptable error Upper Limit for references values in percents) and global error Lower Limit (*LL :* Acceptable error Lower Limit for references values in percents). (Figure 6.) to the (Figure 12.) show the results obtained when compared the simulation and the references values to (*UL*) and (*LL*). For any cases Global Error Tolerance (*GET :* its acceptable percents average values simulation compared to average values references measurements in percents). Thus, a good conformity between the simulated values and the references values would be equivalent to a high percentage of the Global Error tolerance (*GET*) is given, Average Global Errors (*AGE:* its Average errors estimate for any point's references between values simulations and measurements values given in percents. Acceptable error must be smallest possible) and if it necessary, the Errors (*Er :* Error estimate for any point's simulate values compared to error Upper Limit (*UL*) or Lower Limit (*LL*) references values) between results of simulation points values and measurements for the points outdoor the two curves of the tolerances (*LL* or *UL*).

Table 1. Recapitulation for the dimensions and positions of opening to the tests cases

Tests cases	Opening	Dimension of opening (in m x m)
Case 1	Floor	1 m x 1 m
Case 2	Floor	2 m x 2 m
Case 3	Floor	3 m x 3 m
Case 4	Floor	4 m x 4 m
Case 5	Front wall	2 m x 1 m
Case 6	Front wall	3 m x 2 m
Case 7	Front wall	4 m x 3 m

Test case (1): Values obtained at the position A1, A4, A5 and B5 correspond for margin of error given at the reference. Errors observed in this test case are position A2 (*Er* : 1,02%) and A3 (*Er* : 7,03%). Errors in these points are certainly caused by the lack of information on the thickness of the roof opening during simulation. Indeed, it's impossible to declare dimensions thickness of the roof opening in DIALUX. However, we note that as a whole, simulated values correspond well to the benchmarking data (*AGE*: 1,34% and *GET* : 98,65%).

Test case (2), (3) and (4): The simulated values agreed to the values references to the situations described by Figures 7., 8., and 9. DIALUX gives coherent results in the intervals *UL* and *LL* by the experimental references of the test cases used (*AGE*: 0 % and *GET*: 100 %).

Test case (5): Values positions at A1 to A5 are correct. One error estimate is observed in this test case. It is about the value of illumination at the *B5* point. Error in this position is considerable (81,32%). Error is caused by the method applied to solve the problem of the artificial sky under DIALUX. However, as a whole, we observe a good similarity between the simulated values and the values of reference (*AGE*: 13,55 % and *GET* : 88,44 %).

Test case (6): At the position A2, A3 and A4 simulation in DIALUX is correct. Estimating errors arise (at the position A1 (12,5%) and B5(29,45%)). After analysis to these errors, suggested explanation of the situation presenting in case (1) i.e. DIALUX cannot declare dimensions thickness of the wall opening. Nevertheless, we can confirm accuracy of the values simulated on the whole of the data compared with the reference values (*AGE*: 6,99% and *GET* : 93,1%)

Test case (7): Values at the positions A1, A2, A3, A4 and B5 agrees to the measurements limits (*UL* and *LL*). Only the position A5 is slight error estimate (about 4,31 %). But, the results is relatively correct (*AGE*: 0,73 % and *GET* : 99,28 %).

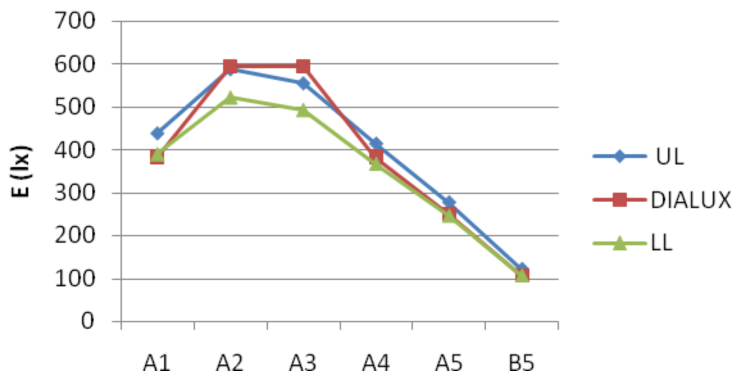

Figure 6. Case (1)

Er :

- ***1,02 %*** in the points A2.
- ***7,03 %*** in the points A3.

AGE :

- ***1,34 %***

GET :

- ***98,65 %***

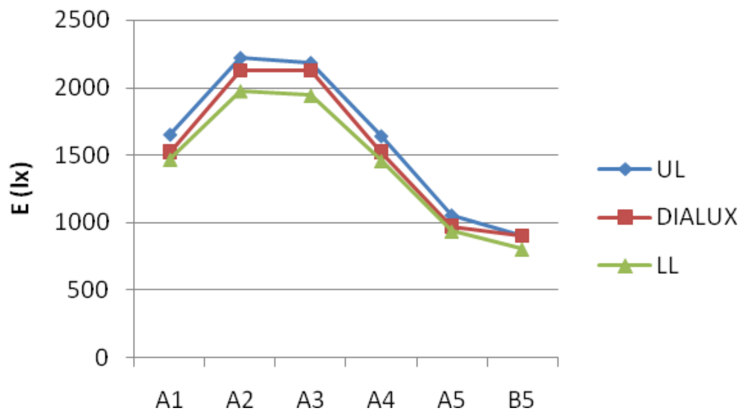

Figure 7. Case (2)

AGE :

- ***0 %***

GET :

- ***100 %***

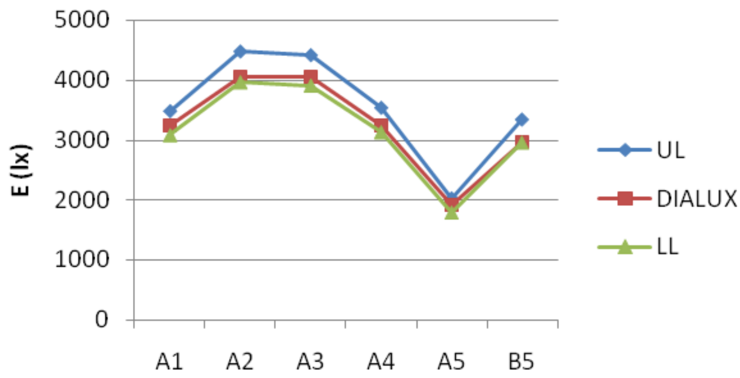

Figure 8. Case (3)

AGE :

- ***0 %***

GET :

- ***100 %***

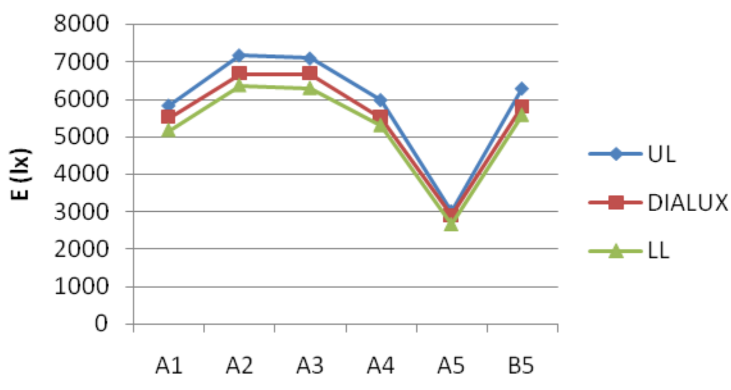

Figure 9. Case (4)

AGE :

- ***0 %***

GET:

- ***100 %***

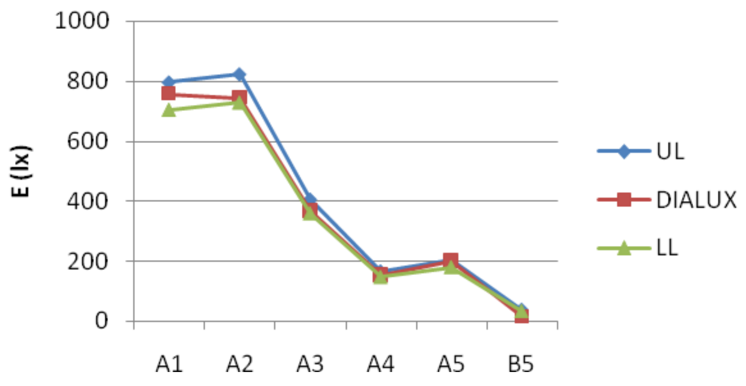

Figure 10. Case (5)

Er:

- ***81,32 %*** in the points B5.

AGE:

- ***13,55 %***

GET:

- ***88,44 %***

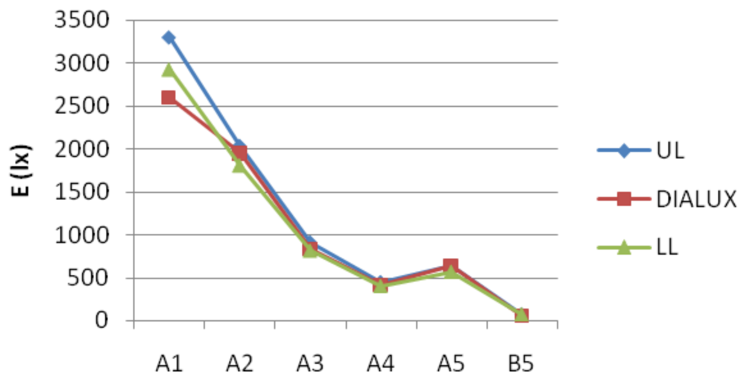

Figure 11. Case (6)

Er:

- ***12,5 %*** in the points A1.
- ***29,45 %*** in the points B5.

AGE:

- ***6,99 %***

GET:

- ***93,1 %***

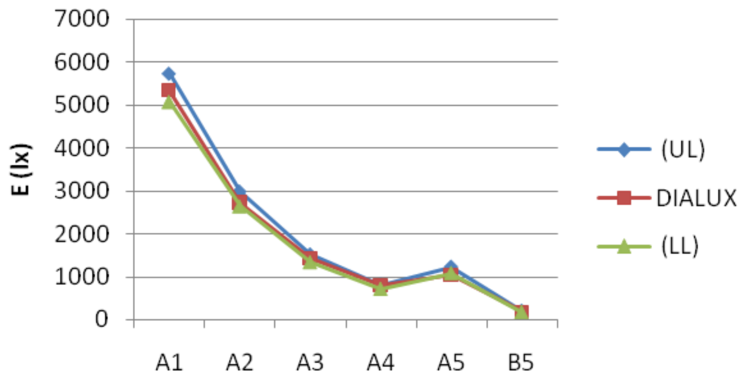

Figure 12. Case (7)

Er:

- ***4,31 %*** in the points A5.

AGE:

- ***0,73 %***

GET:

- ***99,28 %***

CONCLUSIONS AND PERSPECTIVES

It's very difficult to set up experimental test cases for daylighting in the room. The principal problem is to limit the errors of experimental measurements. Many studies were undertaken in this direction. In this article, we chose an experimental validation of the software of simulation of daylighting by basing us on the concepts structured and coherent of study of research to initiative of CIE.

In summary, explanations brought to the errors observed during this study are as follows:

- Recommendations of task 3.33 to the committee CIE on the experimental scenarios say clearly that it is very important to define precisely the sky used in the experimentation. However, the artificial sky is not a precise cloudy sky.

- Large errors between simulation and measurements are due to was imperfection of the scale model, mirror box and building description.

Of any obviousness, shape of the curves obtained starting from simulation; respect perfectly those of the illuminance references database.

Results obtained prove that although some shortcomings are observed on the method used to simulate the artificial sky in the software, DIALUX passed the tests successfully.

In general, simulation in DIALUX correspond to the references values of experimental cases tests in daylighting conditions environments.

Future work consists to simulate the software under the real experimental test room study. That will enable us to confirm our assumption on the source of errors observed in this article.

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