

# THE VALIDATION OF AN ORIGINAL MATLAB FUNCTION FOR THE NATURAL LIGHTING CALCULATIONS

## VALIDAREA UNEI FUNCTII ORIGINALE MATLAB PENTRU CALCULUL ILUMINARII NATURALE

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### SUMMARY

This paper realizes a comparison of prediction with experiment for the algorithm for daylight factor method, for the general model of the natural lighting, made by the author, himself. There are used test problems and measurement on a scale model with artificial diffuse sky.

As a testing technique it is used the "black box", calculating the value on natural lighting and after that making a comparison with the expected values [1].

The differences between measured value and the calculated ones are satisfactory, confirming the general model for natural lighting.

### INTRODUCTION

Daylight factor (*D.F.*) is defined as the ratio of the illuminance at a point on a plane produced by the luminous flux received directly or indirectly at that point from a sky of a given luminance distribution to the illuminance on a horizontal plane produced by an unobstructed hemisphere of this same sky. In the above definition, direct sunlight is excluded. Thus the basic daylight method has been limited to the overcast sky case, in particular to the uniform overcast sky.

The analytical problem is to establish the relationship between plane and spherical triangles, and also the relationship between triangular patch and sky zone (figure 1) [2].

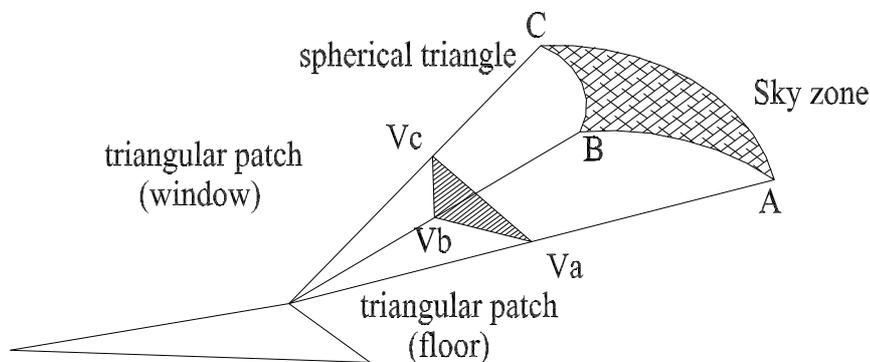


Figure 1.

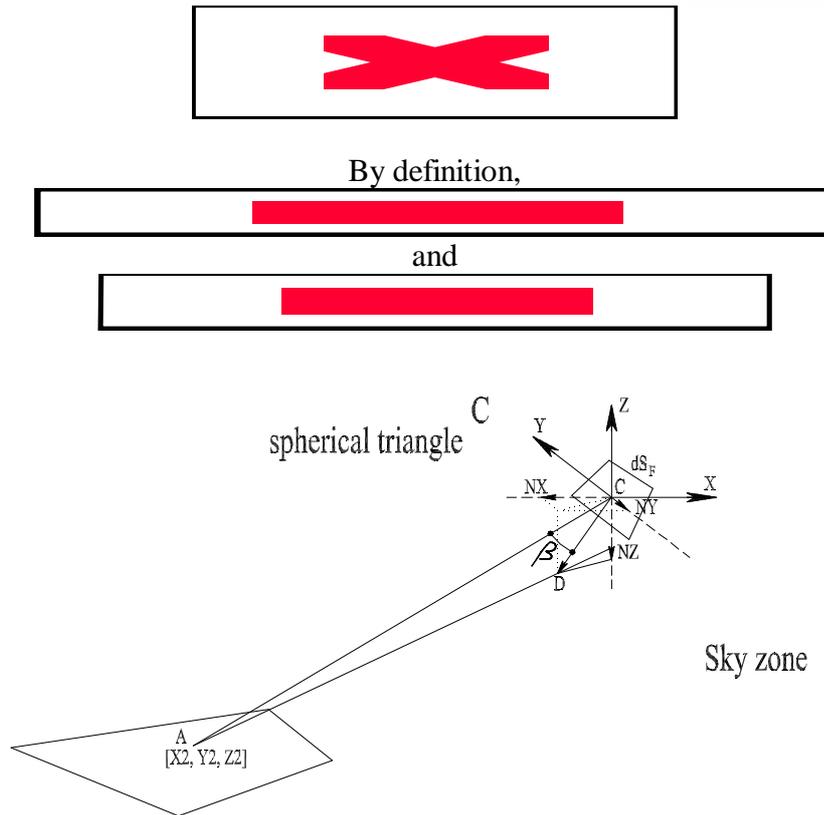
### Basis for lighting calculation

Using MATLAB, it is not necessary to use triangular patch. MATLAB has facilities in using quadrilateral patch. Thus, the author find a direct relationship between quadrilateral patch and his projection on the sky (figure 2), for the current radius. This method avoids calculus of the subtended area of the spherical triangle.

Geometrical aspects are shown in figure 2:

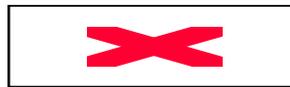
- the illuminated point is "A", with its coordinates  $[X_2, Y_2, Z_2]$ ;
- the area of the finite patch for which the current calculus is performed (belonging to the window) is  $dS_F$  and it has the weight center in the point  $[X, Y, Z]$ ;
- the vector (the module of which is 1) to describe the normal direction on the finite patch has the coordinates  $[N_X, N_Y, N_Z]$ .

The direction cosines are found as follows:

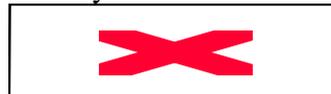


**Figure 2**

The finite patch projection on the sky, at the current distance  $AC$ , is the small contribution at the daylight factor:



The total daylight factor generated by the whole fenestration is given by:



These are, on short, the theoretical aspects about the generalized modelling of natural lighting, achieved in MATLAB by the author. These function improve the performance of MATLAB and allow to obtain all the results without geometrical, dimensional or any other kind of limits.

**METHODOLOGY**

Any model, be it theoretical or experimental, it have to be validated [1]. In the case of (natural) lighting, the theoretical model is unanimous accepted, because it is based on some relations obtained directly by general laws of illuminating.

But the solving method of this relations needs a careful check for being able to validate the entire model (inclusively the geometrical aspects). The validation of the numeric method can be made with the help of the test problems – with known solutions – or with particularized cases, for which we dispose the analytical solution.

*This method of validation is the deepest for the case of numeric solving of mathematical relations.*

In many situations, especially when the theoretical pattern has to be validated, it resorts to the measurements usage. The disadvantage of these method consists in the fact that the experimental scale model has to be validated in the somehow as any other. In the case of scale model used for natural lighting, the validation consists in:

- some checking of the scale model geometry;
- some checking of the point and orientation of luminaire;
- the determination of the real type of reflection (possible distinct by the perfect diffused reflection – Lambertian )
- the determination of the real coefficient of reflection of the involved surfaces.

The original MATLAB function for the lighting calculations drawn up by the author, implies different approaches for the two situations: artificial and natural lighting. In this paper it is presented the validation of the natural lighting modeling.

**CASE 1.** The natural lighting modeling validation using the test problem: the greenhouse.

The calculation of the surface of the spherical triangles [2] involved in the evaluation of the natural lighting coefficient, in the hypothesis of general geometry of the window (as shape and disposal) is particularly complex, being necessary the testing of the calculus correctness.

The test problem consists in the disposal of the calculus point in the interior of a cubic greenhouse (its side heaving 40m), in a certain eccentric position.

Obvious, the natural lighting coefficient has to be unitary because that point is lightened by the entire sky. The global result delivered includes all the procedures involved in that calculus, validating practically the author's subroutines.

The result of the natural lighting is 0.9997, validating the natural lighting model.

**CASE 2.** Validation of the natural lighting using measurements on the scale model.

The measurements on the scale model, in the case of the natural lighting, present major difficulties on account of the artificial sky. The usage of the natural sky lighting isn't recommended because of the instability of the luminance. For the natural lighting systems study, there are used [3] equipment's for artificial sky, respectively lab made cupola. The big size asked by such a cupola (much bigger than those of the scale model) make the construction difficult to be approached.

For the validation of the natural lighting, there are used the measurements mentioned in [3, page 112]. There are available two series of measurements for zenithal window and for lateral window.

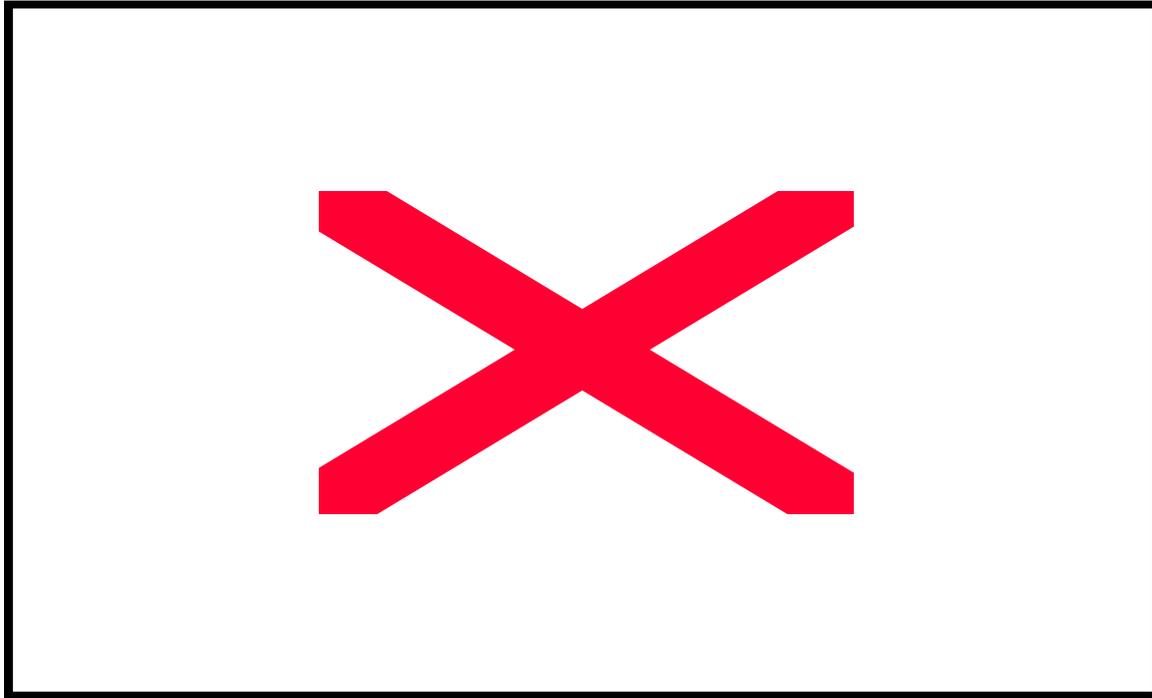
In figure 3 there is presented the scale model used, with the measurement's points.

There aren't presented in this paper details of the measurements program, that ones being available in [3, pages 110 – 115].

The situation of the scale model has been modeled with black walls, this aspect making discernible the direct component of the natural illumination. There are also presented (in appendix) the file witch adapt MATLAB for the scale model from [3], showing in this way the formal simplicity of using this means of study:

- a) the model for zenithal window;
- b) the model of lateral window.

The results are compared with measured results:



**Figure 3** – The scale model used for the validation of the natural lighting model, specifying the points of measures.

Table 1. The case of zenithal window.

Measurement point	MATLAB function [lx]	Measured value [lx]	Measurement point	MATLAB function [lx]	Measured value [lx]
1	1.22	1.0	1'	0.751	0.5
2	1.77	1.8	2'	0.970	0.8
3	2.31	2.3	3'	1.157	1.0
4	2.55	2.5	4'	1.233	1.1
5	2.31	2.3	5'	1.157	1.0
6	1.71	1.8	6'	0.970	0.8
7	1.23	1.0	7'	0.751	0.5

Table 2. The case of lateral window.

Measurement point	MATLAB function [lx]	Measured value [lx]	Measurement point	MATLAB function [lx]	Measured value [lx]
1	24.3	28.5	1'	19.92	26.0
2	22.5	20.0	2'	17.85	18.0
3	17.4	14.0	3'	13.80	12.8
4	13.1	10.4	4'	10.70	9.0
5	10.0	7.50	5'	8.37	7.0
6	7.80	5.50	6'	6.60	5.50
7	6.17	4.50	7'	5.40	4.50

## CONCLUSIONS

It is observed, in some cases, sensitive differences but these ones can be caused by some details witch weren't accessible to the author:

- the type of the luxmeter used;
- the details about the artificial sky luminosity;
- the real coefficient of reflection, witch is considered 1 in calculus.

Theoretical prediction obtained by using the MATLAB function made by the author have been compared with experimental data reported by [3] and also with test problem. It has been found that the predicted illuminance values are in good agreement with experimental data and have an error of less  $\pm 10$  % in both cases (horizontal and vertical window). In the case of the test problem, the values are practically correct. Therefore, it can be concluded that the function developed in MATLAB has great potential for application to lighting calculations.

## APPENDIX: Using the original MATLAB routine

Using MATLAB function is very easy, and the day-lighting calculation may be linked with CAD or other general environmental software.

This is a welcome simplification due MATLAB. In this appendix it can be seen the software model for the scale model with zenithal window:

```
[x,y]=meshgrid(0:.1:.8);           % These are the measured points coordinates
z=zeros(size(x));                  % placed in the plane z=0.
[xp,yp]=meshgrid(.335:.005:.465); % This is the window
zp=zeros(size(xp))+.37;
eee=natural(xp,yp,zp,x,y,z)*118    % The original procedure "natural" gives the
                                   % illuminance in the points [x,y,z] produced by
                                   % the window with finite patches [xp,yp,zp],
                                   % when the exterior level of illuminance is 118
                                   % lx, diffuse sky.
```

## REFERENCES

1. Cem KANER, Jack FALK, Hung Quoc NGUYEN, *Testing Computer Software*, International Thomson Computer Press, New York, 1993
2. P.R. TREGENZA, *Daylighting computation: Radiosity method using triangular patches*, Lighting Research and Technology, 1994
3. Dumitru VERNESCU, Alexandru ENE, *Insoirea și iluminarea naturală in arhitectură și urbanism*, Editura Tehnică, București, 1997

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CHARACTERISTICS ON VISUAL AND NEUROPSYCHIC  
PERFORMANCE AT VDU OPERATORS**

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ОПЕРАТОРИТЕ НА VDU**

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