COMPARISION OF NUMERICAL METHODS USED IN THE LIGHT SYSTEMS

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ABSTRACT

The paper deals with numerical methods, which are used in the light systems calculations. There are the principles, advantages and disadvantages of this method. The main part of the paper is description of two numerical models. The first of them was built in the Ansys system. The second of them was built in the MATLAB by the Ray-tracing method. Both models were verified by experiments and results were compared.

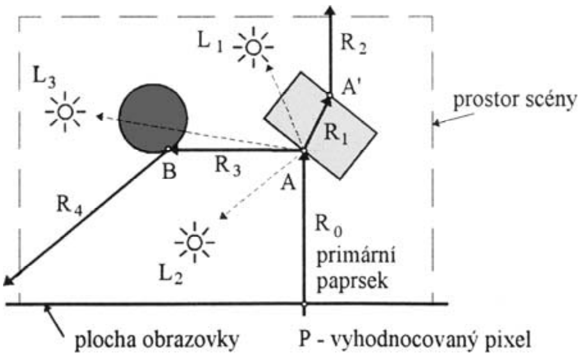
1. INTRODUCTION

For the numerical modeling of the light systems were used this numerical method: Ray-tracing, Radiosity, Flow method, Point method and Elementary transformation method. The Ray - tracing and the Radiosity methods are most widely used methods in the light systems. We can get realistic projection with this method. These methods are often used for 3D scenes projections and lighting calculation, enable modeling indirect lighting, shadows and color transition, by this we can manage realistic projection of the scene. The Flow method, the Point method and the Elementary transformation method are intended for lighting calculation. The Elementary transformation method is used for lighting calculation from a reflector or for calculation of light source with reflector based on requirement on surface light. The Flow and Point methods are intend to lighting calculation of scenes based on initial conditions. In this paper are described the Ray-tracing and the Radiosity methods which are used for creation of the numerical model.

2. DESCRIPTION OF USED METHODS

2.1. RAY-TRACING

Principle of the Ray-tracing method is searching of light rays which come through scene and falls on screen or into eye. We don't proceed from light sources but from screen pixels in search of the rays. This ray originates by sum of fragmental (secondary) rays, which originate by reflection and refraction at a point of intersection ray with objects and shadow rays from light sources in the space of scene. We create a point of intersection tree from rays originate on refraction with objects. The light model is computed in all point of intersection. The resultant ray is given by a sum of separate rays from point of intersection tree from top of tree up to root. Demonstration of the scene and point of intersection tree is shown in fig. 1. Figures are assumed from [1]. Tracked ray is drawn by solid line and shadow ray by a dash line. Shadow ray indicates which light sources are directly share in lighting of point of intersection and which in point of intersection drop shadow over object on the scene.



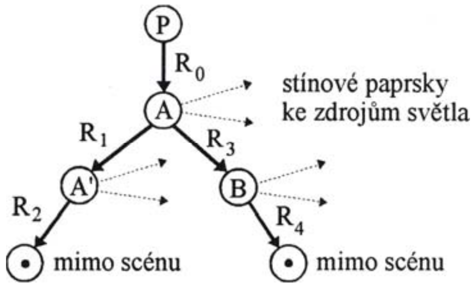


Figure 1 Demonstration of scene, point of intersection tree

Light model is compute by next equation:

$$I_v = I_s + I_d + I_a + I_r + I_t \tag{1}$$

where I_s is component of reflection, I_d is diffuse component, *Ia* is component of surround relevant only for light sources, I_r represent reflected or refract ray and I_t is intensity of ray on crossing through the transparent object.

2.2. RADIOSITY

This method is called radiating method. Radiosity appears from hypothesis, that the scene is closed to power and containing all needed light sources. Surface is divided to n plane facets. These facets prove receive, radiate and reflect light energy. We find out physical value called Radiosity B on these facets. Radiosity is representing total energy de-excitation from surface to time unit. This energy is equal sum of emitted and reflected energy. Radiosity on separate facets is constant. All surfaces are considered as emitter, surfaces can emitted own energy or only reflect energy. Power transmission from surfaces in scene is described by equation:

$$B_i = E_i + \rho_i \sum_{i=1}^{n} B_j F_{ij} \tag{2}$$

where B_i is Radiosity of surface P_i, E_i is own emissivity of surface P_i, F_i is reflectivity of surface, FdA_jdA_i is form factor and ρ is radiant reflectivity. Equation (2) is called basic Radiosity equation. If we use this equation for all n surfaces, we are getting system of n equations with unknown B_i. Valuables of E_i are non - zero only for light sources. Form factor describes cross power exchange between surfaces. Form factor F_{ij} describes, what part of energy is emitted of surface P_i land on surface P_j. Value of form factor is depending only on geometry of surfaces.

$$F_{ij} = F_{A_iA_j} = \frac{1}{A_i} \int_{A_i} \int_{A_j} \frac{\cos\varphi_i \cos\varphi_j}{\pi r^2} V_{ij} dA_j dA_i \tag{3}$$

where A_i is area of surface, r (φ_i, φ_j) is distance (angel) between surfaces.

3. RAY- TRACING NUMERICAL MODEL

MATLAB software was chosen for creation of numerical model of the Ray - tracing method. Numerical model was created along the table lamp, its dimensions are on fig. 2. Numerical model was simplified against physical model. Model was created in vertical section, this simplification we can use because table lamp is rotational symmetrical. Light bulb was replaced by omnidirectional light source. The top hemisphere part of shield was ignored and replaced by abscissa EF. The upper part of shield was filled by dark dead color.

3.1. DESCRIPTION OF ALGORITHM

There were engaged points by x ordinate and y ordinate of these points, from this coordinates was created common equations of this bisectors. This equation was modified to possibility of coordinates of points substitution. For points A, B is the common equation in form:

$$(b_2 - a_2)x - (b_1 - a_1)y - [(b_2 - a_2)a_1 - (b_1 - a_1)a_2] = 0 \qquad (4)$$

Where a_1, b_1 are x coordinates of point and a_2, b_2 are y coordinates of point.

There was set radiant reflectivity on abscissas. On abscissas P1, P2a, P2b and P3 was set radiant reflectivity to 0,7 and abscissa P2c to value 0. The illuminance of one ray was calculated by:

$$E_p = \frac{\phi_z / A_z}{N_p} \qquad (5)$$

where E_p is illuminance of one ray, ϕ_z is luminous flux of light bulb, A_z is area of light bulb and N_p is number of raies.

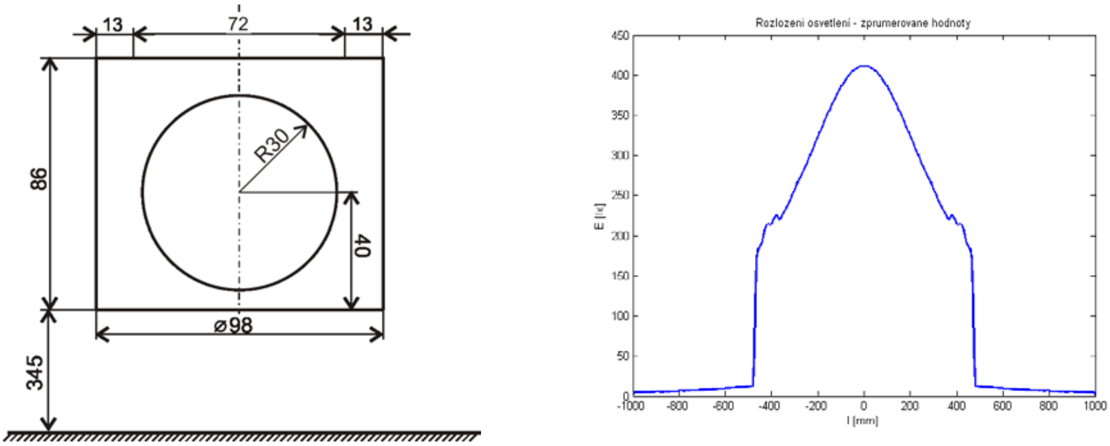


Figure 2 Dimension of model, distribution of illuminance

In the main part of algorithm is broadcast of 3600 rays with angle 0.01°. There are tested points of intersection of all rays with defined bisectors. If it is found the point of intersection, there was calculated angle of reflection and illuminance of ray is lowered by radiant reflectivity. Following of ray is finished when number of rays is larger than 20 or when ray lands to bisector Pp or P2c. Interpretation of the illuminance is performed on bisector Pp in interval < -1m; 1m>. In this interval are values of the illuminance summed in 5mm intervals. The results of the numerical model are in fig. 2 (right).

4. NUMERICAL MODEL OF THE RADIOSITY

ANSYS software was chosen for creation of the numerical model of the Radiosity method. ANSYS is using Radiosity method for calculation of thermal transmittance by radiating. We can use this method for solving light tasks thanks to analogy between thermal and light field. The light source with illuminance E_s (lx) is accordant with density of heat flux q'' and luminous flux ϕ (lm) is accordant with heat flow q'. The resultant luminous flux is given by equation (6), described in [2], [3].

$$\Phi_e = \frac{T_{f,e}}{S_{n,e}} \tag{6}$$

where Φ_e is luminous flux on a element, $T_{f,e}$ is heat flow of element and $S_{n,e}$ is area of element. According to Stefan- Boltzmann law of heat transfer between surfaces with indexes i, j, radiating described

$$q_{ri} = \sigma \varepsilon_i A_i S_i \left(T_i^4 - T_j^4 \right), \ \ na\, \Gamma_T, \tag{7}$$

where Γ_T is bound of Ω_T, q_{ri} is specific heat of transferred from surface with index i, σ is Stefan-Boltzmann constant, ε_i emissivity of surface, $A_{i,j}$ is factor of projection, S_i is area of surface i, T_i, T_j are temperature of surfaces i, j.

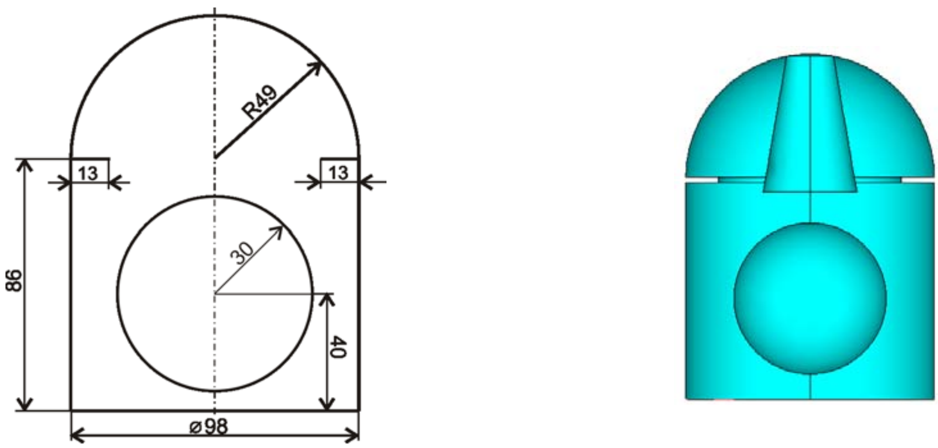


Figure 3 Dimensions of model, geometric model ANSYS

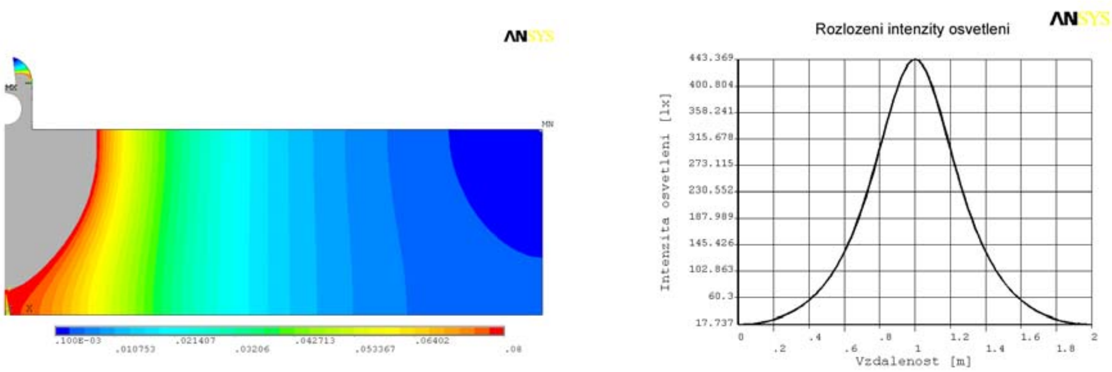


Figure 4 Distribution of heat flow and illuminance

2D geometric model was created regarding to rotating symmetry. Dimensions of numerical model are shown in fig. 3 together with the model in ANSYS. To create a mesh was chosen element PLANE77. For material model was set heat conductivity $k=10^{-6}$ $W/m.K^{-1}$, emissivity (determinates how many energy is radiated and how many is absorbed) on side of shield is 0.7 on top shield and socket 0.2, on light bulb 0.9 and on monitored surface 0.1. Heat flow 450 W was set on light bulb. The results of numerical model are shown in fig. 4.

5. MEASUREMENT VERIFICATION

Both models were verificated by measurement. Measurement was proceeded in dark chamber with stable luminous flux flow. Light characteristic was measured in 1/4 (rotating symmetry) in measuring points distanced 0.1m. Measuring points were organized in square mesh. Light source was bulb 40 W / 230V, 450 lm. For measurement was used illuminometer BEHA UNITEST 93514. Measured values in x axis are in table 1.

Table 1 Measured values

l [mm]	0	100	200	300	400	500	600	700
E [lx]	442	387	292	194	111	47	21	12

6. CONCLUSION

Comparison of results both numerical models and results form measurement are in Fig. 5. We can see that the results of Radiosity and measured results are identical. Confrontation of the Ray-tracing results and measured results are biggest deviation is on distance 0.4 m that is due to sharp transients between light and shadow in Ray-tracing method. After confrontation results we can see that both methods can achieve highly exact results.

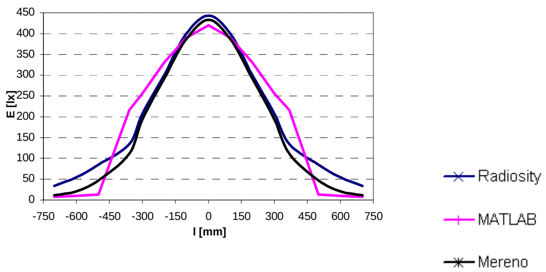


Figure 5 Confrontation of results

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