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RADIOSITY METHODS IN THE LIGHTING RESEARCH

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ABSTRACT: The lighting research often requires human surveys for defining subjective qualities rating new settings, new test scenarios is usually a time and resource-consuming task. The article deals with designing internal artificial lighting as part of the working environment, which is subject to certain rules, derived from the nature of lighting. Good lighting exerts an impact on visual comfort which contributes to overall psychological well-being and indirectly also to the quality and productivity of performance to reliability of the visual performance, which must be maintained, especially for visual demanding operations and in adverse conditions to ensure quality of work and safety. Modeling and simulation technologies are tools to streamline the presentation and assess the risks for the implementation.
KEYWORDS: Working environment; light; lighting microclimate; simulation

INTRODUCTION

The project of a lighting system is a complex and laborious task that requires not only technical knowledge, but also knowledge of architecture, production, and the physiology of vision. The role of the designer is not only to select the type of solution; this task is often complex and might be of a research character, leading to the development and manufacture of the lighting systems testing, analysis, and finding the optimum lighting conditions of the workplace and the area as a whole. The lighting of workplaces puts on light-technical solution the following requirements:

- sufficient horizontal and vertical lighting value for a particular type of the work performed,
- appropriate distribution of brightness in the area,
- suppressing the creation of glare and protecting against it,
- satisfactory psychological impact of the colour of the light and colour of the administration premises,
- appropriate colour change in the environment,
- stabile lighting,
- reasonable uniformity,
- suitable orientation of the impact of light on the desktop. [7]

In compliance with all the quantitative and qualitative parameters of illumination, we must design a lighting system based on the principles of maximum performance. Lighting systems with streamlined operation, regulation and management of lighting may also significantly contribute to energy savings. [6]

MODELING OF LIGHT-TECHNICAL PARAMETERS

In the past there were three basic types of light-technical models:

1. Calculation (without taking into account the actual dimensions, with tables).
2. Accurate (for models in the scale 1:1).
3. Using of mock-ups that generate a display similar to visual perception designed lighting system. [1]

Modern visualization programs can reproduce the brightness, color and surface structure of the complex three-dimensional space rather realistic, since in the calculations include inter reflection of light between surfaces in space and in many optical effects arising in the day, an artificial joint or lighting. Simulation methods are based on classical optical, thermodynamic, respectively light-technical models of the spread of radiation.

SIMULATION METHODS

There are two basic methods used in computer simulations luminous environment, namely Monte Carlo method, which does apply technology tracking light beams (ray tracing, this name is used for follow-up of beams, also used the term "ray casting" sending light beam when a beam of light comes from the light source), and radiation (also radiosity). From a physical point of view both methods are similar, the difference lies in algorithmization.

The method of monitoring the beam has a very small spot stochastic manner (results of re-calculation may differ slightly). The radiation method works with larger surfaces deterministically - repeated calculation results are always the same. [5]

In principle, the ray tracing technique solves the following integral equation (1) for the energy balance of each nearly the same surfaces in space. [5]

$$L_r(\theta_r,\varphi_r) = L_e(\theta_r,\varphi_r) + \iint L_i(\theta_i,\varphi_i)\times \rho_{bd}(\theta_i,\varphi_i,\theta_r,\varphi_r)\times|\cos\theta_i|\times \sin\theta_i \times d\theta_i \times d\varphi_i \qquad (1)$$

where:

Θ - Polar angle as measured from the surface at normal levels

Φ - Azimuthal angle of the surface at normal levels

$L_r(\theta_r,\varphi_r)$ - The total radiation [W.sr-1.m-2]

$L_e(\theta_r,\varphi_r)$ - Own radiation [$W.sr^{-1}.m^{-2}$]

$L_i(\theta_i,\varphi_i)$ - Incident radiation [$W.sr^{-1}.m^{-2}$]

$L_i(\theta_i,\varphi_i,\theta_r,\varphi_r)$ - Two-way function of the reflectivity distribution [sr^1]

Although the ray tracing algorithm produces perfect results in modeling the mirror reflectivity and undispersional refractional transparency, the algorithm has a shortcoming; specifically, it does not take into account the physical laws of some of the important visual effects, for example shade staining by the influence of the reflection of light from another object. It is due to the fact that ray tracing only monitors the final number of rays emanating from the observer's eye. The radiation method is attempts to remove this shortcoming.

The radiation method is based on the principles of the spread of light energy and the energy balance. In the algorithm of shading, the light sources have always been considered independently from the surfaces that are lighted. In contrast to the above, the radiation method allows any surface to emit light, i.e., all the light sources are modeled naturally as an active surface. Consider the distribution of the environment as a final number of n discretes surfaces (patches) and each of which has its final respective size and emits and reflects light evenly across its surface. The scene then consists of surfaces acting both as light sources and reflective surfaces creating a closed system.

If we consider each of the surfaces as an opaque Lambertian diffuse emitter and reflector, then the following equation applies for the surface due to energy conservation (2):

$$B_i = E_i + p_i \sum_{1\le j\le n} B_j F_{j\ i} \frac{A_j}{A_i} \qquad (2)$$

where: B_i, B_j - Intensity of radiation areas i and j [W.m-2]

E_i - Power of light radiated from the surface i with the same dimension as radiation

p_i - The reflection coefficient (reflectivity) of the surface i and is dimensionless

F_{j-i} - Dimensionless configuration factor (form-factor)

A_i, A_j - Surface levels i and j

Dimensionless configuration factor F_{j-i} (form-factor), which specifies the energy leaving the surface i and the energy incoming to the surface and taking into account the shape, relative orientation of both of the surfaces, as well as the presence of any areas that could create an obstacle. The configuration factor takes its values from the interval <0, 1>, while for the fully covered surfaces it takes the value of 0.

Equation (2) shows that the energy leaving the unit part of the surface is the sum total of both light emitted and reflected. The reflected light is calculated as a product of the reflection coefficient and the sum total of the incident light. On the contrary, the incident light is the sum total of the light leaving the whole surface changed in the part of the light which reaches the receiving unit content of the receiving surface. $B_j F_{j-i}$ is the amount of light leaving the unit content of the surface A_j area and incident on the entire surface of A_i. It is therefore necessary to multiply the equation by the ratio of A_j / A_i for the determination of light leaving the entire surface A_j and incident on the entire surface A_i [2].

A simple relationship is valid between the configuration factors in the diffuse medium:

$$A_i F_{i-j} = A_j F_{j-i} \qquad (3)$$

By simplifying equation (2) using equation (3) we obtain the equation:

$$B_i = E_i + p_i \sum_{1\le j\le n} B_j F_{i-j} \qquad (4)$$

By subsequent treatment we get the equation in the form:

$$B_i - p_i \sum_{1\le j\le n} B_j F_{i-j} = E_i \qquad (5)$$

Interaction of light between the surfaces may be expressed in the matrix form [6]:

$$\begin{bmatrix} 1-p_1F_{1-1} & -p_1F_{1-2} & \dots & -p_1F_{1-n} \\ -p_2F_{2-1} & 1-p_2F_{2-2} & \dots & -p_2F_{2-n} \\ . & . & \dots & . \\ -p_nF_{n-1} & -p_nF_{n-2} & \dots & 1-p_nF_{n-n} \end{bmatrix} \begin{bmatrix} B_1 \\ B_2 \\ . \\ B_n \end{bmatrix} = \begin{bmatrix} E_1 \\ E_2 \\ . \\ E_n \end{bmatrix} \qquad (6)$$

Note that the contribution of a part of the surface to its own reflected energy (which may be hollow, concave) must be taken into account. Thus, in general, each term on the diagonal need not necessarily equal to 1. Equation (6) must be solved for each group of wavelengths of light in the model, since pi and E_i depend on the wavelength. Equation (6) may be solved by employing the Gauss-Seidel method obtaining radiation for each area. In order for radiological methods to become partial, one had to start calculating the form factors for absorbed surfaces. To find the form factor, we must find the fractional contribution that a single patch makes upon another patch [2].

VISUAL COMPUTING

Currently, the development of computer graphics software products exist to enable a comprehensive design and calculation of parameters of lighting systems, which would reflect light effects that arise in artificial and day lighting.

The computer programs will be able to calculate and visualize the daylight, lighting scenes, plan the color and intensity of the lights, position on the project the emergency lighting, with the right legal number of luminaires, prepare photo realistic visualizations of light planning. The furniture, surfaces and luminaires can be placed simple dragging and dropping elements from the provided libraries. For a better realism, the programs can use different textures and furniture, and it uses an integrated ray tracing or radiosity module [8].

Computer graphics is the field of visual computing, where one utilizes computers both to generate visual images synthetically and to integrate or alter visual and spatial information sampled from the real world. The computer visualization, which goal is to see the photo, is often described in detail of the model and simulates the propagation of light in space. Modern visualization programs can reproduce the brightness, color and surface structure of the complex three-dimensional space rather realistic, since in the calculations include inter reflection of light between surfaces in space and in many optical effects arising in the day, an artificial joint or lighting.

These programs are designed for light-technical parameters calculation and on the presentation of projects and usualy offers the following program modules for lighting design:

- *Interior lighting - utilisation factor method.*
- *Interior lighting - point by point calculation.*
- *lnterior lighting- direct glare (UGR calculation).*
- *lnterior lighting - glare by reflection on visual display terminals.*
- *Exterior lighting - area lifting.*
- *Exterior lighting - street lighting.*

For purposes of this contribution to the possibilities of simulation outputs in the DIALux and Relux shows Figure 1 and Figure 2.

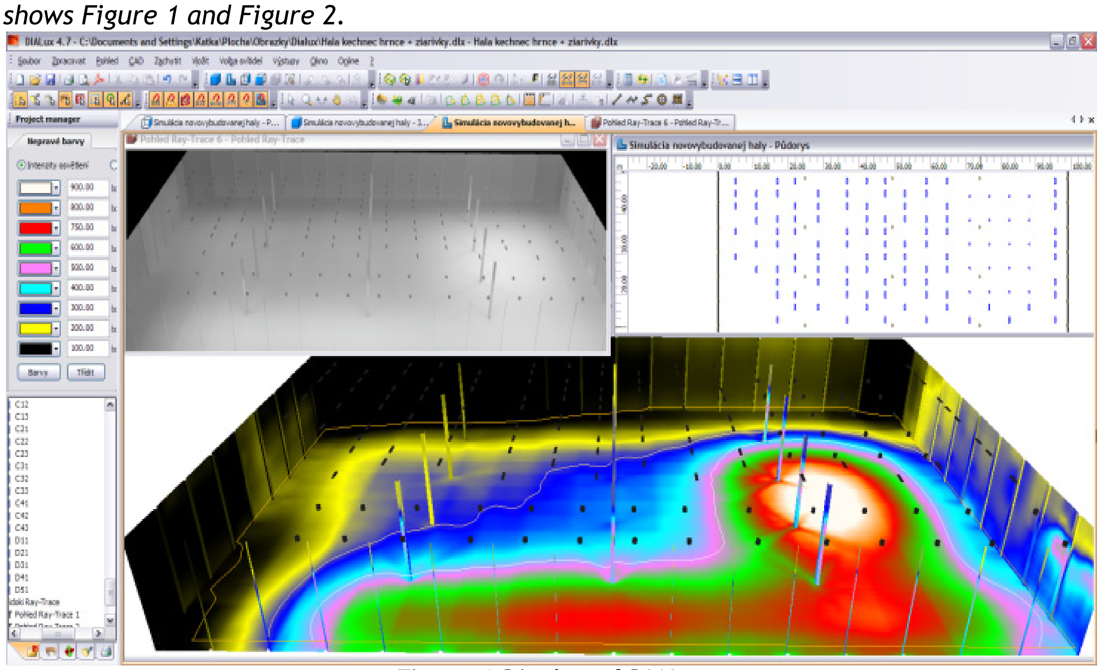

Figure 1 Display of DIALux

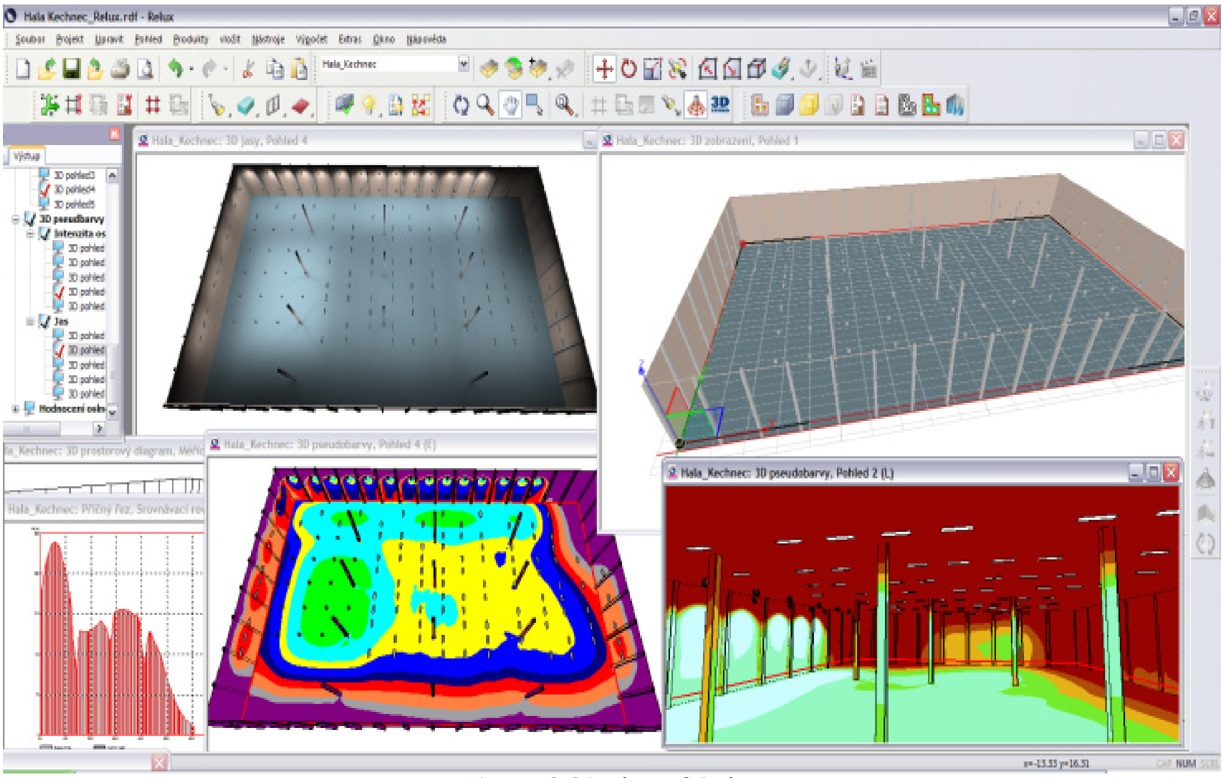

Figure 2 Display of Relux

This simulation programs offers the following options selected lighting system and various options for presentation of results as graph values, isolines maps, light maps - colour scale, false colour rendering, summary tables of lighting or brightness, three-dimensional model lighting, visualization of day light respectively economic evaluation of the lighting design in terms of energy consumption and so on [3].

Figure 3 shows isoline maps, which display equal values of illuminance measured in the vicinity of a luminaire.

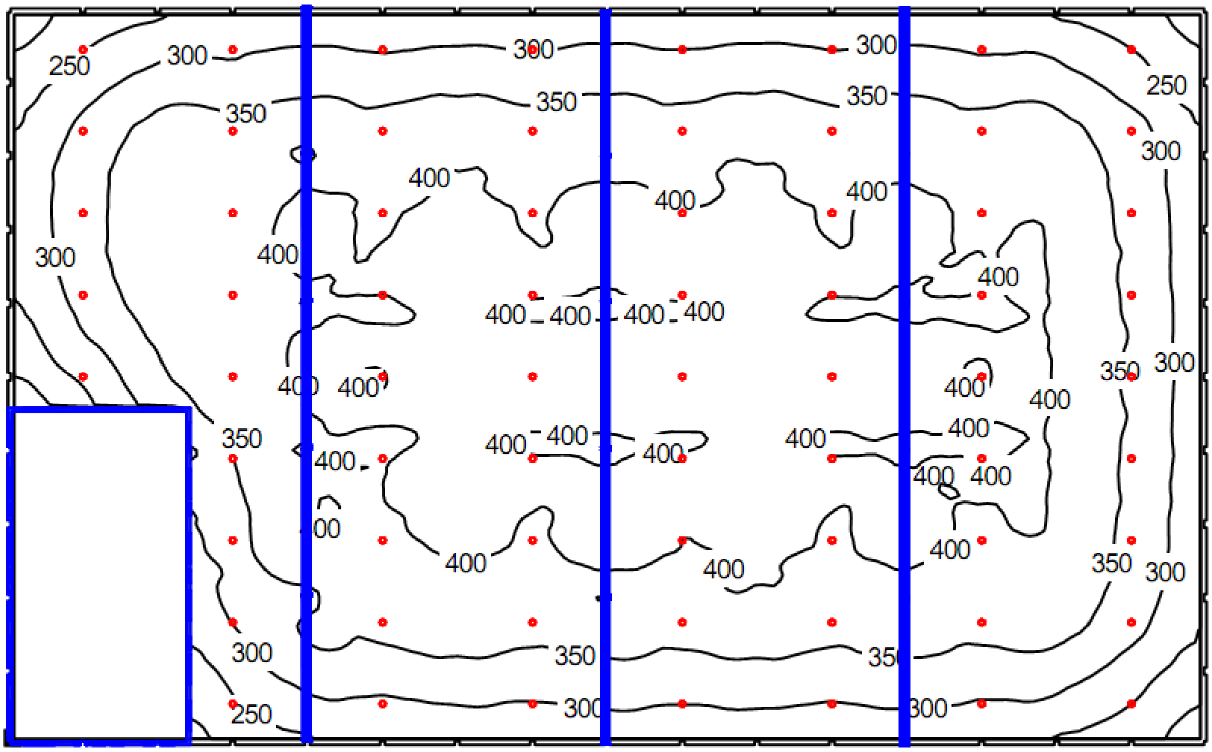

Figure 3 Isolines map

With DIALux the user has the option to display the 3D rendering in a false colour rendering presentation, see Figure 4. The presentation of illuminance and luminance with freely scalable value ranges and definable colour gradients is now available.

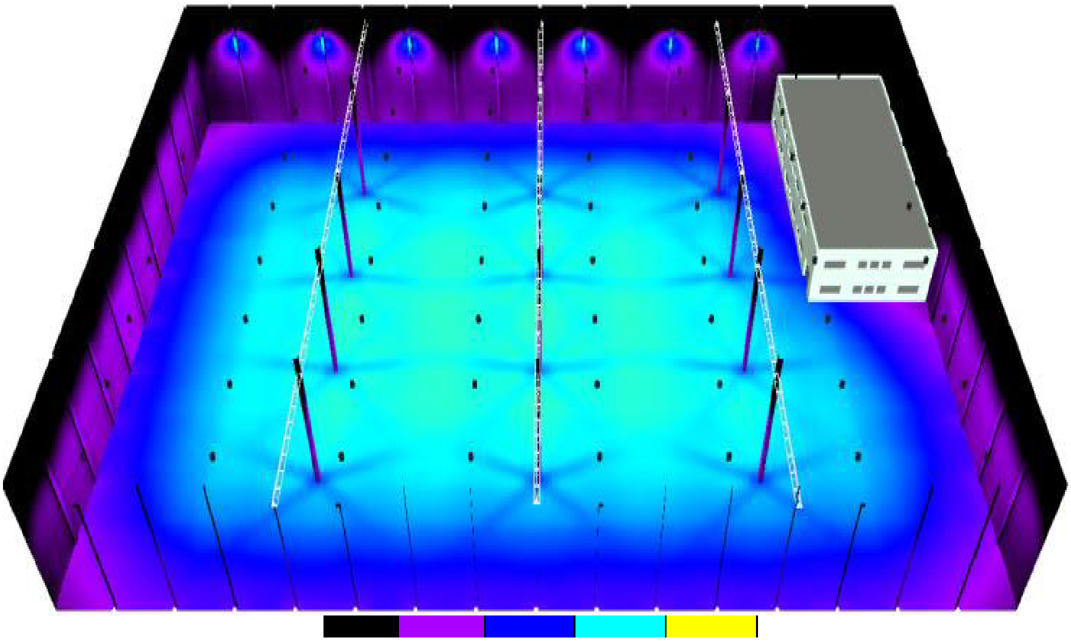

Figure 4 Layout of false colour rendering created by DIALux

Relux offers the raytracing calculations which are based on a version of radiance that has been revised by this software (Fig. 5). This verified method, which has been validated worldwide, is noted for its accu - rate calculation results.

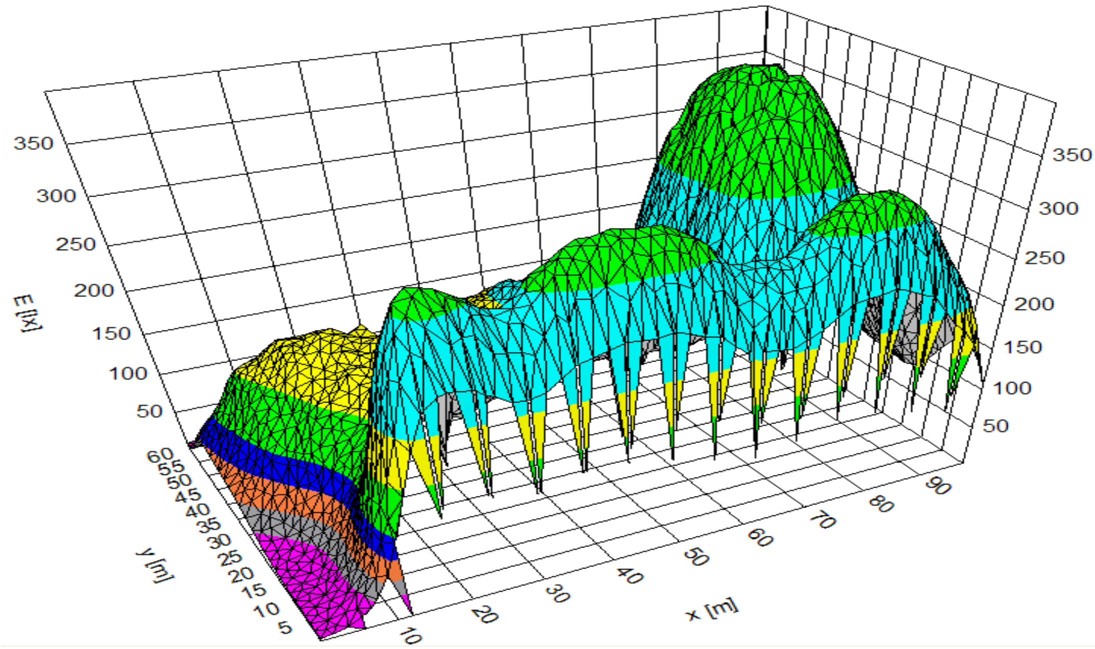

Figure 5 Raytracing calculations in Relux

CONCLUSIONS

In terms of the quantity of information, a person registers 80% to 95% of all the information visually in the work. The primary role in creating the work environment is to ensure optimal conditions of vision and ensure a safe working environment. Visibility must therefore be seen as a precondition for the implementation of high quality, safe, and reliable work operations. It is necessary to pay close attention to this issue. When dealing with light-technical projects, the visualization of lighting parameters is a useful tool by using programmes realistically displaying the lighting parameters.

Despite numerous possibilities that the current software tools offer, in some cases there is a difference between the modelled and actual light-technical parameters. One of the reasons affecting the result of the computer output may be the inadequate definition of certain inputs - the colour shades and quality of the room's surfaces, the lightning effects on the scattering characteristics of light sources, etc.. However, these differences do not affect the overall relevance of computer outputs and may be virtually eliminated by qualified estimation.

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