Determination of daylight conditions in office room using digital images as a light source.

D Knera[1] **and D Heim**

Department of Environmental Engineering, Lodz University of Technology, Poland

[1]dominika.knera@p.lodz.pl

Abstract. The paper presents comparative analysis of daylight conditions in office room simulated with two techniques of sky and surrounding modelling. The luminance distribution in the surrounding environment was determined using CIE standard sky model and image based lighting (IBL) technique. In IBL method the sky and surrounding environment was defined by high dynamic range (HDR) image. Used HDR images were captured by camera with fisheye lens with 180˚ viewing angle which enables the projection of the entire hemisphere of the sky and surrounding environment. Determination of daylight conditions were performed for two days characterised by overcast sky conditions. Simulations were conducted using Radiance Lighting Simulation and Visualization software. Obtained results show differences in luminance and illuminance distribution in analysed room for both techniques of sky and surrounding modelling. Reason of the observed divergences is uneven cloud layer distribution at HDR images and influence of surrounding environment visible at HDR images. IBL technique allow more precise modelling of daylight distribution, especially in urban environment where surrounding buildings and vegetation significantly effect on the light availability.

1. Introduction

Providing the appropriate lighting distribution in building is significant to ensure comfortable environment for occupants. Visual comfort effects on occupant work capability and efficiency as well as their well-being and health. Sufficient lighting conditions are achieved by ensuring required lighting level, uniformity of illuminance values, suitable contrast conditions and avoiding the glare effect. Moreover, access to daylight is also very important in the human circadian system's regulation. Therefore, detail analysis of daylight distribution in indoor environment is very important for building assessment and design process. Daylight conditions in indoor environment can be assessed by different calculation methods: simple mathematical models, scale models or complex numerical modelling by computer tools [1]. All of them consider many parameters connected with solar radiation (direct, diffuse, reflected radiation) incident on analysed surfaces, sun position, building geographical location or properties of material and glazing elements. In detail analysis all mentioned parameters should be precisely defined.

One of the most frequently used computer simulation tool is Radiance Lighting Simulation and Visualization software – professional and complex tool kit for visualizing and simulation of lighting in virtual environments [2]. Radiance enables the lighting assessment in specific point at a time but also annual analysis. Moreover, it has many possibilities for modelling of sky: using generic CIE, Perez

weather or image based sky models [3]. CIE sky models represent the sky brightness based on location, date, time, and sky type ranging from cloudless skies to overcast skies and they are commonly used in simulation analysis. However, detailed experimental analysis shown that CIE sky models insufficiently map the real sky conditions and the more advanced sky models should be considered for detail simulations [4, 5]. One of the methods which allow modelling the real parameters of sky and surrounding for analyses location and time step is Image Based Lighting (IBL) technique [6, 7]. This method allows illuminating the analyzed scene with light from image of the real world. In IBL were used High Dynamic Range (HDR) images which represent real-world luminance through capturing of scene images with extended dynamic range [8, 9].

The main aim of this paper is analysis of the daylight conditions in indoor space using two techniques of sky and surrounding modelling: CIE and IBL methods. Simulations were performed by Radiance computational tools for overcast sky conditions. Obtained results allow evaluating the daylight distribution in office room with comparison of the impact of sky and surrounding models.

2. Case study

HDR images used in analysis were performed according to the HDR image technique [9] by the digital camera Nikon D80 equipped with wide-angle lens Sigma Fish-eye. Lens with 180° viewing angle enables the projection of the whole hemisphere including sky and surrounding environment noticeable by the window at a single digital image. In every time step were made set of five digital images with the same aperture and different shutter speeds. Each image was made in the same position capturing entire hemisphere of the sky and surrounding environment visible by the window of analysed room. Next, obtained digital images were merged to high dynamic range image using the computer program Photosphere with consideration of the previously determined camera response curve and vignetting correction. In table 1 were presented performed HDR images used in daylight analysis.

Table 1. HDR images used in analysis.

	9:00	12:00	15:00
III			
IX			
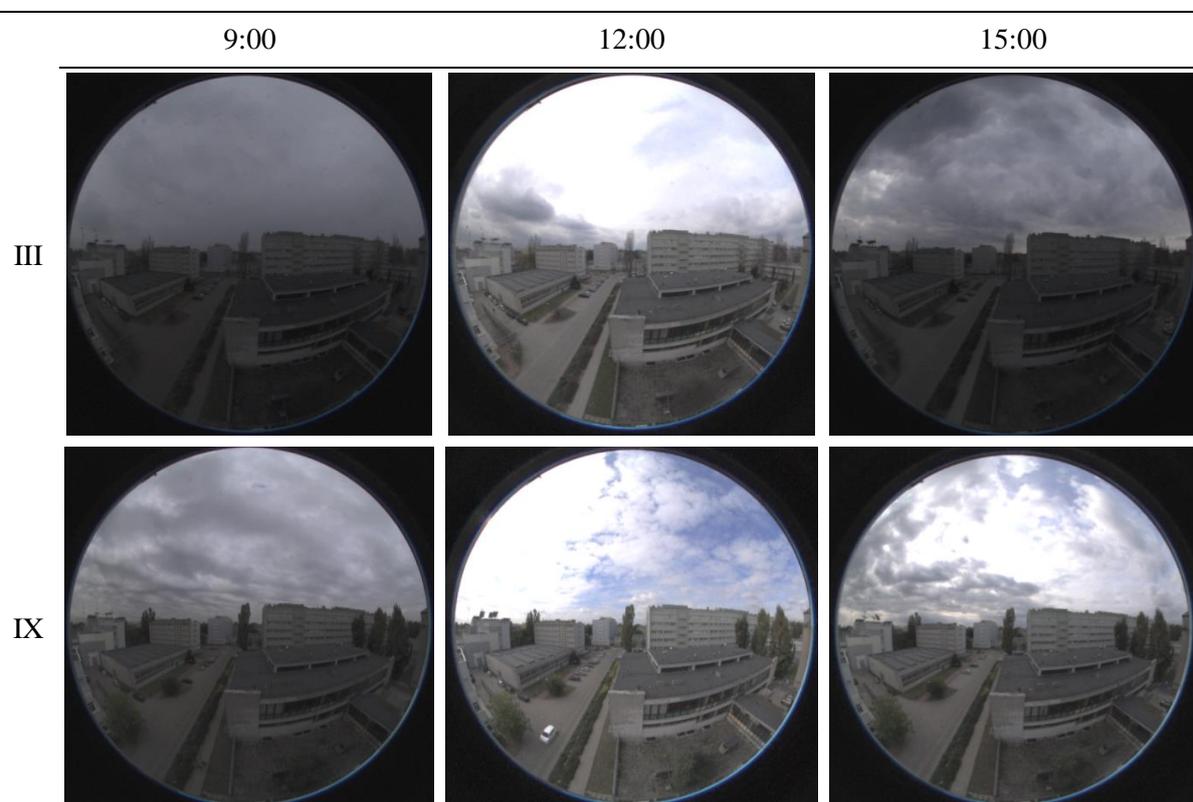
Daylighting analysis was performed for modeled office cell representing the existing experimental office room. Dimensions of indoor space are respectively width, length and height: 2.6 m, 4.4 m and 2.6 m. Window is situated in a center of the exterior wall at the height of 0.7 m and dimensions of the glazed unit are 1.1 m of width and 1.1 m of height. Exterior wall is oriented on the west. The RGB values of the interior surfaces of walls, floor and ceiling were determined based on the measurements using spectrophotometer Konica Minolta CM-2500d. Furthermore, analyzed office rooms were located at the level of 4th floor which corresponds with real location of the experimental room.

Analysis was performed for the location of the office room in the Central Europe (51°46′N 19°27′E) under the temperate climatic conditions. Simulations of the daylight were made for two selected days close to the equinox day in March and September characterised by overcast sky conditions (hereinafter named III and IX respectively). Furthermore, three selected hours where considered: 9:00, 12:00 and 15:00. For each time step were defined two models of the luminance distribution in the sky and surrounding environment using: CIE standard overcast sky (hereinafter named CIE) and image based lighting technique with previously prepared HDR images (hereinafter named IBL). Simulation of the daylight distribution in indoor space using Radiance tool were performed for each mentioned time step.

## 3. Results

3.1. Luminance

Results of the daylight simulation obtained from simulations made using Radiance tool were divided into two parts. In the first part, daylight luminance is presented in the form of false color images of the analyzed office room for each time step and luminance of the sky and surrounding model (table 2). Images present view of the room from the position of internal wall situated opposite to the window represented by square surface in the middle of the image. It can be noticed that luminance in room is rather low, only for IBL model image in IX at 12:00 luminance exceed 275 cd/m^2. Luminance distribution for all cases with CIE model is similar regardless the hour and day because position of the sun and hence the radiation intensity of overcast sky for both days are similar. On the other hand, luminance distribution for cases with IBL method differs slightly. In III (9:00 and 15:00) and IX (9:00) luminance distribution for cases with IBL technique is very similar to cases with CIE model, only little higher on the floor surface. Remaining cases with IBL method are characterized by significantly higher luminance. The reason of the noticed differenced is uneven cloud layer at HDR images defining light sources. Sky captured at HDR images in III (12:00) and IX (12:00 and 15:00) are not uniformly overcast, the cloud layer is lower, therefore solar radiation intensity is higher than for CIE standard overcast sky model.

3.2. Illuminance

Second part of the analysis concern on illumiance in indoor environment determined for analyzed cases. Results obtained for illuminance are presented in the form of the images with contour lines shown in table 2. It can be noticed that similarly to the luminance analysis, illuminance in III (9:00 and 15:00) and IX (9:00) for both sky and surrounding models is similar when in remained cases illuminance for IBL method is significantly higher. Described divergence is also caused by the differences between cloud layer in the IBL and CIE models.

However, in illuminance maps for III (9:00 and 15:00) and IX (9:00) can be observed additional small differences between cases with CIE and IBL models. Illuminance in indoor space for IBL technique is lower and not symmetric - higher values are at the left side of the room. Noticed differences are effects of surrounding urban environment, visible through the window, which influence on the uneven illuminance distribution in the room.

Table 2. False color images of luminance distribution in the analysed office room.
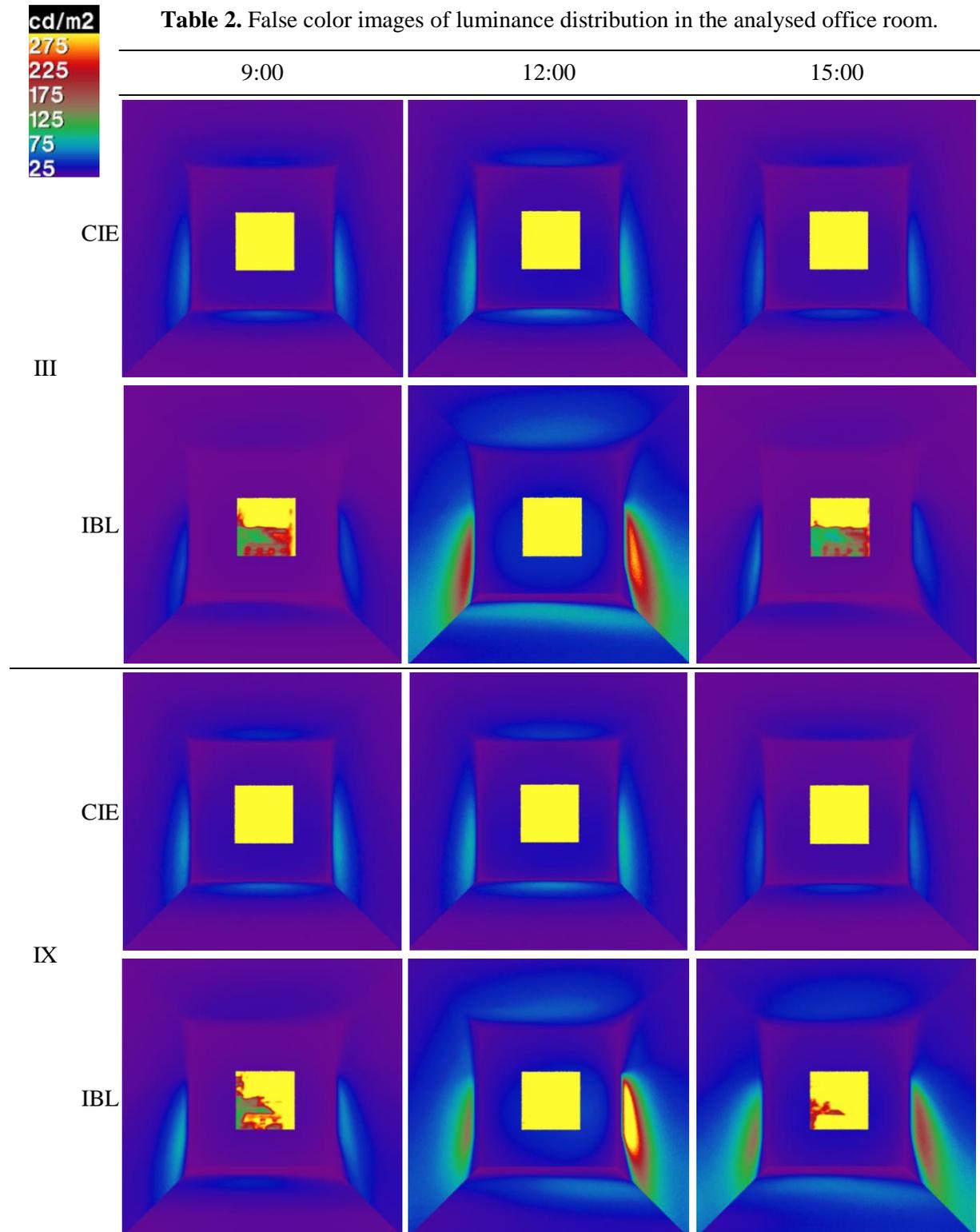
Table 3. Contour line images of illuminance distribution in analysed office room.
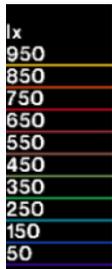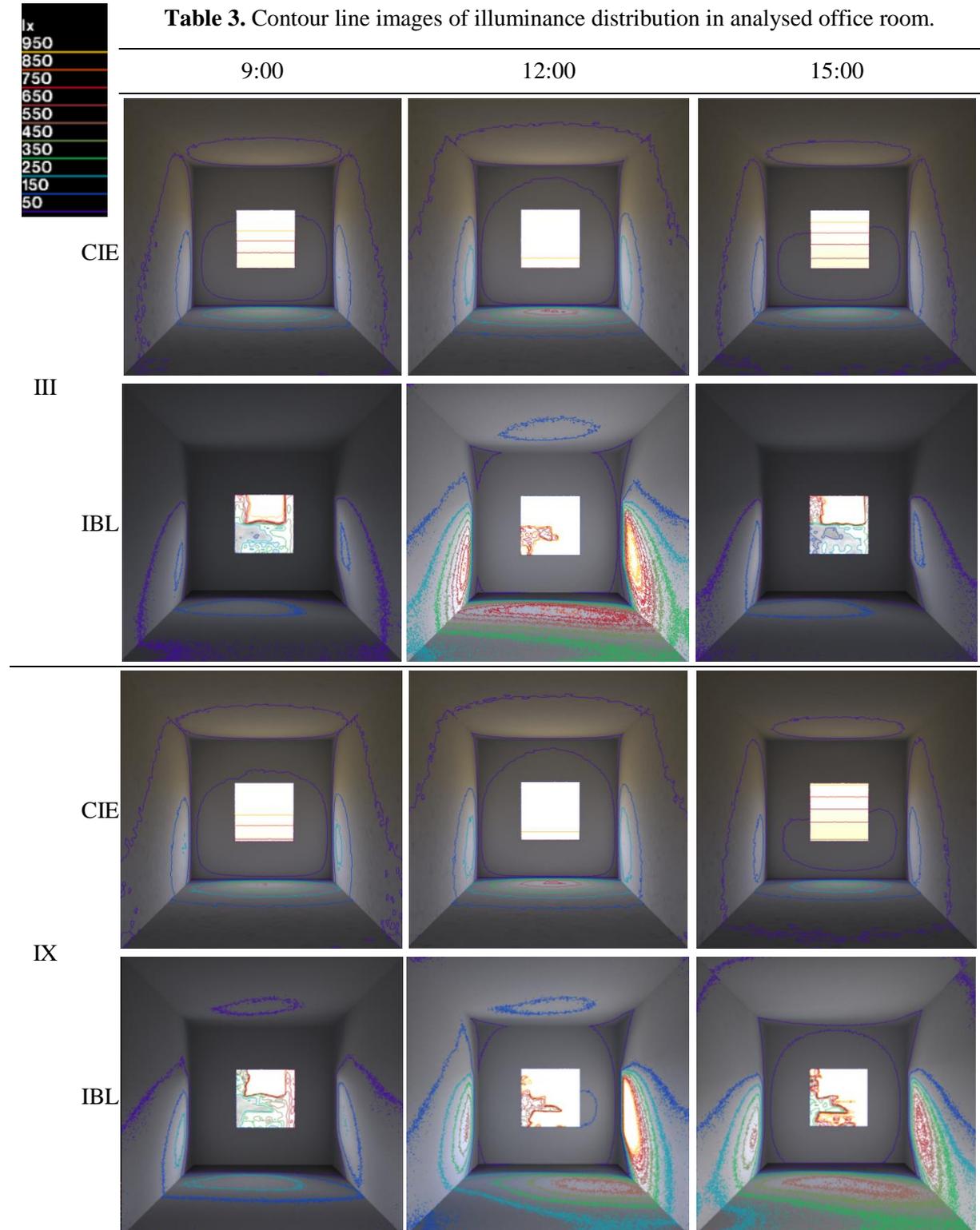
4. Conclusions

In presented paper the numerical analysis of the daylight in office room under overcast sky conditions is performed. Two techniques of sky and surrounding modelling were considered. The luminance distribution in the sky and surrounding environment was determined using CIE standard sky model and image based lighting (IBL) technique. Results obtained for both modelling techniques show differences in luminance and illuminance distribution in indoor space. Noticed variances are mainly results of uneven cloud layer at HDR images comparison to uniformly overcast CIE sky model. Moreover, of radiation reflected from surrounding environment captured at HDR images can also influence on the luminance and illuminance distribution in analysed indoor space. CIE standard sky models are commonly used for general analysis of light distribution in indoor environment. However, for analysis requiring detail modelling in the real location, especially urban environment, more comprehensive model of sky and surrounding should be introduced, like image based lighting models.

References

[1]   Wong I L 2017 A review of daylighting design and implementation in buildings *Renewable Sustainable Energy Rev.* **74** 959–68

[2]   Ward G Shakespeare R 1997 *Rendering with Radiance* (San Francisco: Morgan Kaufmann Publishers)

[3]   Inanici M Hashemloo A 2017 An investigation of the daylighting simulation techniques and sky modeling practices for occupant centric evaluations *Build Environ* **113** 220-31

[4]   Heim D Szczepanska E 2011 Daylight Distribution in a Building Space: a Comparison of Real Conditions and Theoretical Sky Models *Proc. 12th Conf. of Int. Building Performance Simulation Association* Sydney 14-16 November pp 14–6

[5]   Szczepanska-Rosiak E Heim D Gorko M 2013 Visual comfort under real and theoretical, overcast and clear sky conditions *Proc. of 13th Conf. of Int. Building Performance Simulation Association* pp 2765–73

[6]   Debevec P 2002 Image-based lighting *IEEE Comput. Graph. Appl.* **22 (2)** 26-34

[7]   Inanici M 2010 Evaluation of high dynamic range image-based sky models in lighting simulation *Luekos J. Illum. Eng. Soc.* **7 (2)** 69-84

[8]   Jacobs A 2007 High dynamic range imaging and its application in building research *Adv. Build. Energy Res.* **vol 1** 177-202

[9]   Reinhard E Heidrich W Debevec P Pattanaik S Ward G Myszkowski K 2010 *High Dynamic Range Imaging Acquisition, Display, and Image-Based Lighting* ed 2nd (Burlington: Morgan Kaufmann Publishers)