THE APPLICATION OF PSEUDOCOLOR ANALYSIS TO ASSESS THE OBTRUSIVE LIGHT PRODUCED BY OUTDOOR LIGHTING INSTALLATIONS

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ABSTRACT

The appropriate placement and selection of light sources for outdoor lighting installations is rapidly becoming a very important issue when considering the need to mitigate the effects of the obtrusive lighting. The appropriate control of outdoor lighting equipment is one of the main concerns of ordinances being produced by municipalities all over the world. Lighting consultants must be prepared to present a lighting master plan capable of meeting strict lighting ordinances with recommended practices to be followed by cities and communities to achieve the goal of quality yet confined lighting.

This paper discusses the merits of using the pseudocolor analysis feature provided by some lighting software programs to assess the effects of obtrusive light produced by common outdoor lighting installations and to verify the compliance of the lighting parameters of these installations with the CIE requirements.

Some practical examples developed with the AGi32 lighting software are given showing the influence of fixture positioning, photometric distribution and lamp wattage in the results. These examples also demonstrate the efficacy of this analysis process as a useful tool to assist the lighting professionals in refining their outdoor lighting design.

Keywords: Outdoor Lighting, Obtrusive Lighting, Pseudocolor

1. INTRODUCTION

Obtrusive lighting, also known as “light pollution”, is an issue rapidly increasing in importance as a design parameter in exterior lighting applications. The non-profit organization titled the International Dark-Sky Association (IDA) has been a driving force since 1988 in an effort to preserve and protect the night time environment and our heritage of dark skies through quality outdoor lighting. The main issues of IDA concern the growing threat to the environment caused by outdoor lighting installations due to glare, light trespass, clutter, energy waste, and urban sky glow. [1]

Until recently, the assessment of the obtrusive lighting was primarily subjective. With the rapid development of computer technology, this assessment can now be quantified via computer analysis, thanks to the development of lighting software which allows the designer to foresee the appearance of the illuminated environment at the design stage. The pseudocolor analysis techniques presently used in several fields of modern science including biology and medicine, have emerged as a powerful tool to assess some kinds of obtrusive lighting produced by outdoor installations, particularly the excess of vertical illuminance on surrounding properties (light trespass) and the average surface luminance of building facades and signs.

2. LIGHTING DESIGN CRITERIA

The CIE Publication No. 150:2003[2] establishes the relevant parameter limits to be considered in outdoor lighting installations in accordance with four lighting environmental zones E1, E2, E3 and E4. These limits are defined for pre-curfew and post-curfew periods during the night. Table 1 shows the definition of the environmental zones and the applicable limits to be considered in the lighting design for the vertical illuminance (E_v) on surrounding properties (light trespass) and the average surface luminance of building facades (L_b) and signs (L_s)

Table 1 – Environmental zones and relevant limits of E_v, L_b and L_s

Environmental lighting zone	Surrounding and Lighting Environmental	Light on properties*		Luminance	
		E_v (lx)		L_b (cd.m^{-2})	L_s (cd.m^{-2})
		Pre-curfew	Post-curfew	Building facade	Signs
E1	Natural surrounding; Environmental intrinsically dark (e.g. national parks or protected sites)	2	0	0	50
E2	Rural surrounding; Low district brightness (e.g. industrial or residential rural areas)	5	1	5	400
E3	Suburban surrounding; Medium district brightness (e.g. industrial or residential suburbs)	10	2	10	800
E4	Urban surrounding; High district brightness (e.g. town centers and commercial areas)	25	5	25	1 000

* Limits apply to relevant surfaces or parts of surfaces of nearby dwellings or potential dwellings especially where windows are.

3. SOFTWARE TOOLS FOR ASSESSING OBTRUSIVE LIGHTING

Rendering

Modern lighting software is capable of analyzing a three dimensional model of any lighting problem. The model geometry can either be created within the lighting program or imported from 3D-CAD. Each surface in the model is assigned a color or reflectance value and Radiosity or Raytrace calculation and visualization methods are then employed to predict the luminance for all surfaces in the model. All surfaces are considered to be Lambertian surfaces (ideal diffuse) having constant radiance or luminance that is independent of the viewing direction[3]. Once all surface luminance's are known, the calculation of incident illuminance is easily derived. Traditional point-by-point methods of numeric display as well as RGB visualizations are standard output. However, it is the use of the specialized Pseudocolor display for rendered imagery that is often the most valuable, creating a visual representation of the model which allows the user to gain insight into the structure of the data, or to communicate aspects of this structure effectively.

Pseudocolor Analysis

Pseudocolor analysis is a technique used to artificially assign colors to a calculated range of values associated with 3-dimensional model surfaces. Software's pseudocolor analysis feature provides a scaled color view of the lighted environment with each luminance or illuminance value based on the so called **rainbow colormap**. In this hue-based colormap, the lowest value is mapped to blue, the highest value is mapped to red, and the intervening values are mapped continuously onto values corresponding to a rainbow of colors interpolated between these two colors in red-green-blue space. When this scale is mapped onto scalar data, the user is conceptually mapping a linear scale in hue onto a scalar variable. Alternatively to the linear scale, a power law scale can be used when there is a wide range of values displayed in the rendered environment (luminance or illuminance) and the values within the lower end of the range need to be displayed in detail. Power law expands the lower range of the scale yielding more detail (the smaller values are spread over a larger range on the scale). This type of scaling is especially powerful when there are a few surfaces in the environment with very high luminances and the remainder contain much lower values.

The result of this process is a richly colored image which provides a detailed and absolute picture of the distribution of light within the environment without the need for grids of computation points and numeric values. The pseudocolor analysis also has the advantage of being able to display either incident illuminance or luminance, immediately showing the significance of surface color and reflectance on how humans will perceive the environment.

A three dimensional pseudocolor visualization provides a dramatically more detailed analysis than traditional point-by-point methods drawing from a much larger dataset as luminance is known for all surfaces, not just the ones with calculation points present.

Radiosity based software programs provide the added advantage of yielding a fully interactive 3D model after one calculation. The computer display can be adjusted such that any surface can be seen using navigation techniques such as Orbit, Pan, Rotate and Walk. Interactive walk-through capabilities provide both designer and client with a visualization of the complete model to more fully understand the results. The identification of overlighted areas which do not comply with the required limits established by the CIE is then more accurate and quite easy.

3. TEST CASES

To demonstrate the effectiveness of pseudocolor analysis we have constructed two models in the AGi32 software. In the first model, a small commercial facility (restaurant) containing a parking lot, the limits of the vertical illuminance on surrounding properties were considered as indicated in the 3rd and 4th columns of Table 1. This model is most applicable to shopping centers, stadiums and gas stations, usually located in E3 and E4 environmental zones, where the values of E_v must be maintained within reasonable limits during pre-curfew and post-curfew periods.

In a second model the luminance levels of a building façade was tested, considering the limits of column 5 of Table 1. This is a typical case of illuminated buildings in urban areas where the lighting design has to take into account the reflectance of the material used for the building construction in order to maintain the luminance levels within the allowable limits.

4. RESULTS

Figures 1a-1c shows the rendered pseudocolor images of the commercial facility where the maximum limit of 10 lx was set with vertical planes at an average distance of 15 meters from the lighting installation property line. It can be noticed the difference between the images where the lighting fixtures have been replaced from cutoff type (Fig 1a) to semicutoff (Fig 1b) and non cutoff (Fig 1c). The pseudocolor analysis clearly shows areas with illuminace values of 10 lx and above incident on the surfaces of concern.

The results of the pseudocolor analysis for the building façade using linear and power law scales are shown in Figures 2a-2d considering the maximum limit of 25 cd/m^2 as required by buildings located in a E4 environmental zone. It can be observed that in the case of Figs. 2a and 2b there are some red spots indicating areas of the façade where the luminance values exceed the maximum permitted, indicating the use of oversized floodlights for the reflectance of the material used in the building façade. Figures 2c and 2d show the same design considering the floodlights with reduced power ratings.

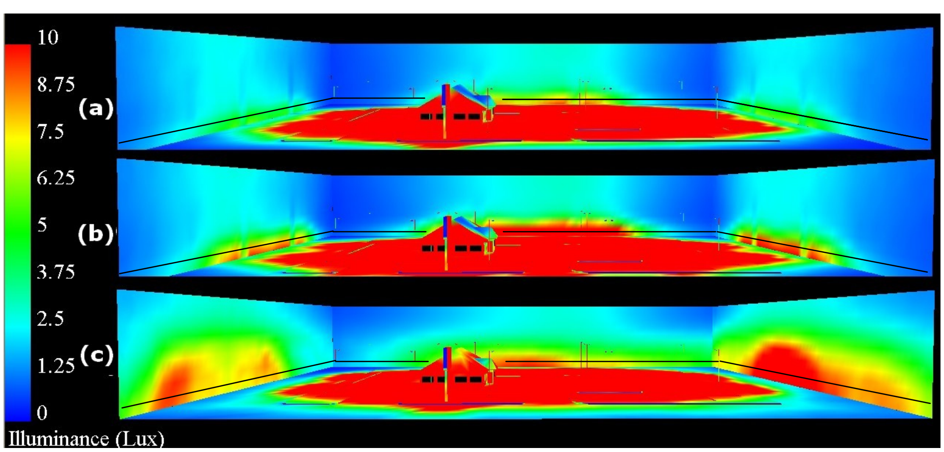


Figure 1

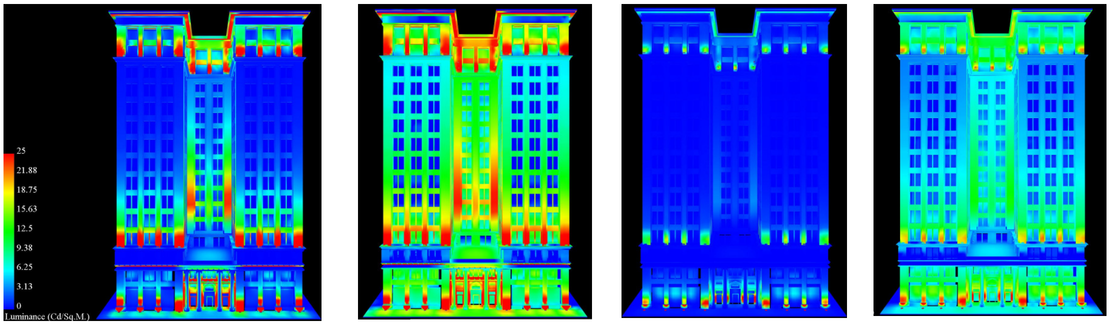
Vertical Illuminance

(a) Cutoff luminaires

(b) Semicutoff luminaires

(c) Non Cutoff luminaires

(black lines indicate level 2m above ground)



(a) (b) (c) (d)

Figure 2 – Façade Luminance : (a) Full, Linear Scale; (b) Full, Power Law Scale; (c) Reduced, Linear Scale; (d) Reduced, Power Law Scale

5. CONCLUSIONS

The pseudocolor analysis proposed in this paper can be considered as a powerful and expeditious tool to architects and lighting designers to verify the compliance of their design work, at the design stage, with the applicable ordinances and standards providing more environmental friendly lighting design and reducing energy waste. Most modern lighting software containing render modules offer the possibility of generating relevant pseudocolor rendered images to prove that the design does not violate the predefined restrictions for obtrusive lighting.

6. REFERENCES

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