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Optimizing the luminous environment using DiaLUX software at “Constantin and Elena” Elderly House – Study Case

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Abstract

The spatial and luminous optimization of the living environment of the elderly is now a major problem, reflecting the growing desire to meet their needs. It's common to design efficient lighting environments through the use of specialized design software, using standard parameters. The design of a lighting system for elderly today shakes up these habits. It modifies the design parameters and requires specific new parameters, meeting their specific needs. This non-hypothetical and different design process was tested here through a case study in a retirement home. It will develop a type of design based on contrast of luminance against illuminance ratio, leading to the development of a guide to good practice, thanks to which the CAD had to have a substantially better performance with DIALux Evo. Expanding even further the lighting design and accuracy of details, an original approach based on MATLAB functions are demonstrated.

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Keywords: Adapted environment; Elderly visual acuity; Lighting simulations; Luminance contrast; Retirement home's interior design

1. Introduction

The prevalence of visual pathologies increases with age. In fact, nearly 25% of over 75 years old suffer from a visual pathology [1]. In addition, according to OMS, 54% of people living in retirement homes have proven visual pathologies [2].

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Increasingly, this increasing prevalence is taken into account in the design of the built environment, but when this isn't the case, the environment becomes a source of handicap [3], increase the risk of falls. They are then multiplied by two in a situation of multiple pathologies [4]. It also becomes complicated to practice the acts of daily life autonomously and safely [5]. The finding is the same when it comes to moving, action sometimes requiring assistance when the elderly can't find their bearings, or poorly located in their environment [6]. Adapting the visual environment to the vision of the elderly is a necessity, which helps to prevent the risk of confusion, disorientation by improving their perception of their living environment. Physiological aging, such as a decrease in the diameter of the pupil, and pathological changes in the eye, such as cataracts, thus generate particular lighting needs in the elderly.

Quantity and quality of light, spatial optimization and contrasts are all singular parameters to take into account in their entirety in order to propose a lighting system adapted to their visual acuity and also comfortable [7]. It's then essential to design a luminous environment taking into consideration these particularities and specific needs. This will include improved lighting, between natural and artificial lighting, a better distribution of this lighting, between ambient lighting and additional lighting, a decrease in glare, alternating brightness and a suppression of light reflections, an amplification of contrasts, in particular with the help of colors or an increase in the contours of objects, an arrangement of spaces giving rise to a sense of security by reducing or even removing obstacles and offering spatial references, through a choice coating in line with the design of the lighting system [8].

As part of an interior design, the light design and its current applications can be optimized here by using specialized software. Considering here the new parameters inherent to the visual needs of the elderly, the use of this digital tool offers us the possibility of designing an adapted and intelligent luminous implantation [9].

2. The classical method limitations for interior lighting design

Our work on designing a lighting system adapted to the visual needs of the elderly is based on a case study in the *Constantin and Elena* retirement home, Iasi, Romania. It was chosen for its impersonal chromatic character and not adapted to the particular visual needs of the elderly occupying the premises. Indeed, the wall coverings are white and immaculate, thus presenting no contrasts or spatial references.

We have chosen to apply the classical methodology inherent to the use of the DIALux EVO 8 software, specialized in the design of interior lighting systems. This is a design work that matches the design of a lighting system intended for the average observer. But we have also added the new design parameters that will provide an appropriate lighting design for the elderly user with visual disturbances such as skirting boards, door frames and other structural architectural elements. Thanks to the integration of these new parameters of the modeling phase to the interpretation of the results, we are able to propose a design process differentiating the usual design systems.

Starting from the usual lighting design, the approach is very simple and without specific requirements. Based on EN 12464-1 and -2, the illuminance ratio, uniformity, glare limitation are calculated for the working plane. The results are presented in Fig.1, where the working plane in the pathway.



Fig. 1. The classical design for interior lighting system, with vertical illuminance in lux for the working plane.

There are some situation when this minimal requirements are extended. A typical situation is an exhibition hall, when the horizontal illuminance on the wall is relevant for visibility. In DIALux EVO is possible to obtain these results, as in Fig.2:

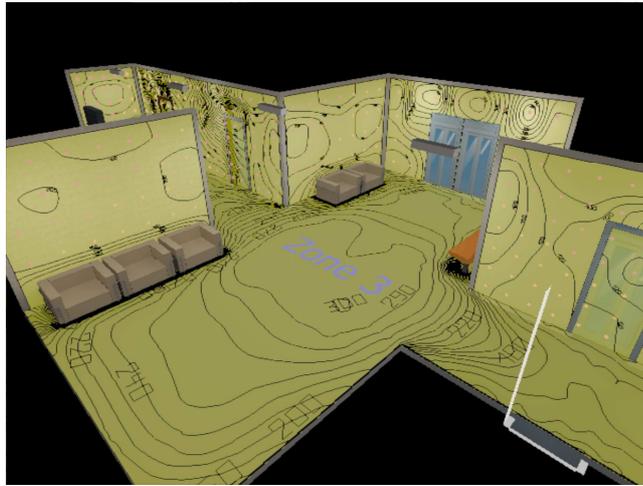


Fig. 2. The extended design for interior lighting system, including horizontal illuminance in lux for the walls.

For the study case, some supplementary visual task are necessary to be identify and study. One of them is the door visibility, seen as a pathway but also like an obstacle. In DIALux EVO is possible to introduce the door in the lighting simulation, with some particular parameters (material, texture, color) and to obtain some results, as in Fig.3.

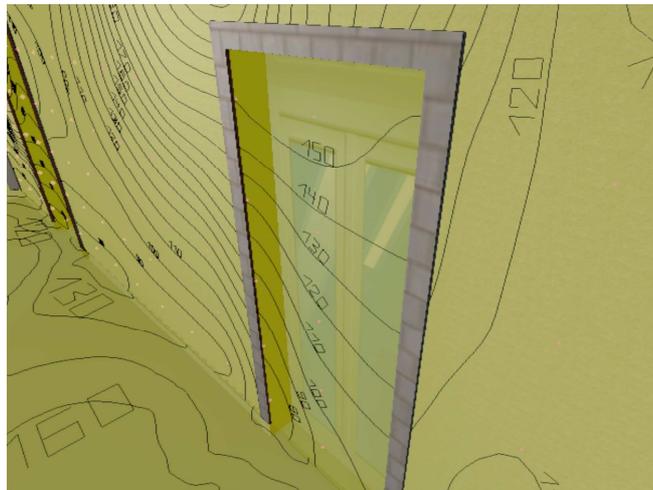


Fig. 3. Details about the horizontal illuminance on calculation object (door).

The main problem is the absence of the specific details from the door, because only some predefined doors are available, including the frame. To increase the fidelity of the simulations, particular objects could be created, using “extrusion body”, useful for our case. In Fig. 4 is presented such detail, scalable as in reality (working *m* or *mm* in respect with the real door):



Fig. 4. Building the frame of the door (with “extrusion object”) on the left, and illuminance in lux on the calculation object (right).

Even some results are available, also for luminance distribution (with average values, maximum and minimum values), the luminance contrast available for the frame of the door is difficult to be evaluated. Increasing the fineness of the calculation grid could be a solution, as presented in Fig.5:

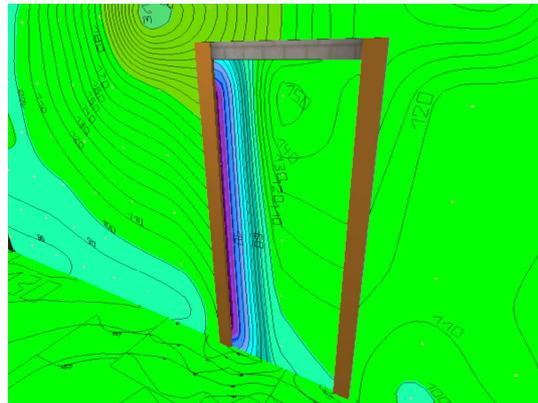


Fig. 5. The increasing the fineness of the calculation grid gives better resolution for illumination distribution, but no satisfactory information about the contrast of luminance.

In conclusion, luminance contrast is difficult to be evaluated, because DIALux EVO, as EN 12464, don't take in consideration different connected surfaces, when the luminance variance become important. Because the assessment of luminance contrast for different spatial object is important for elderly to avoid falling or injuries, an original approach for this kind of details is proposed, using MATLAB.

3. Luminance contrast assessment using MATLAB simulations

The main issue is to demonstrate the difference between the lighting design based on illuminance (as EN 12464) and the assessment of luminance, especially the contrast of luminance. The MATLAB model is built only for a detail from the interior of the building, respectively the frame of the door (or a step, stairs, handrail). The model is based on the frame profile, 15 cm deep, with a rounded edge with 4 cm radius, as in Fig.6:

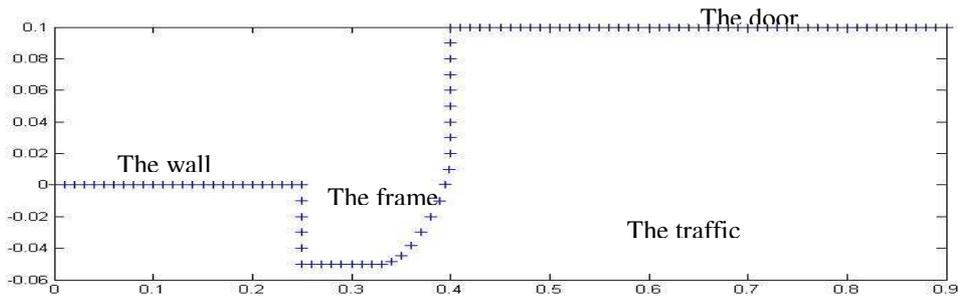


Fig. 6. The horizontal profile of the door frame, dimensions in *m*.

After this fast 2D validation, a 3D mesh-grid was generated, including reflexivity of the materials, as in Fig.7:

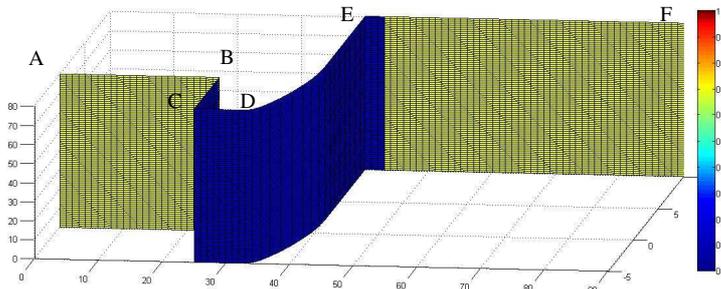


Fig. 7. The spatial model of the door frame (dimensions in *cm*), and the left corner is at (0, 0, 0), with color-map for materials reflexivity.

Using original MATLAB functions, illuminance ratio (lx) could be calculated. These functions are based on calculating the form factors between the various finite surfaces obtained from mesh-generation. The light flux with direct incidence from the source is then reflected between the various surfaces until it is considered complete attenuation. In order to maximize the visual effect of the luminance (to which the eye is sensitive) compared with illuminance ratio (to which the eye is indirect sensitive), a light source was impose with 3D symmetrical light intensity of 500 *cd*, situated at the coordinates ($x= 2.60$; $y= -0.9$; $z= 0.4$), related on Fig.6 and Fig.7. The results relative to illuminance ratio are displayed with MATLAB function *surf*, as in Fig. 8:

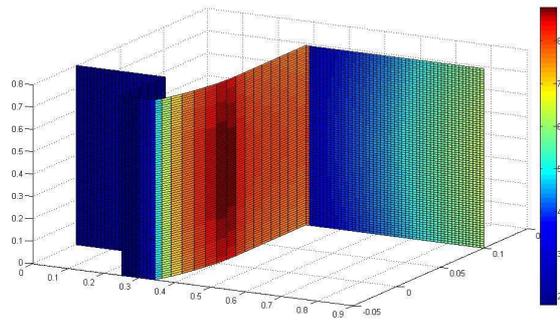


Fig. 8. The illuminance ratio (lx) obtained from a source with spherical light intensity of 500 *cd*, situated at the coordinates in *m* ($x= 2.60$; $y= -0.9$; $z= 0.4$).

These illuminance map is easy to be accepted, due to the incident angle of the lighting that is close to normal for DE region from Fig. 7 and tangential for EF region. To highlight the differences between the lighting design based on illuminance ratio and lighting design based on luminance contrast, the illuminance variance on the longitudinal (horizontal) profile of the door is extracted in Fig. 9:

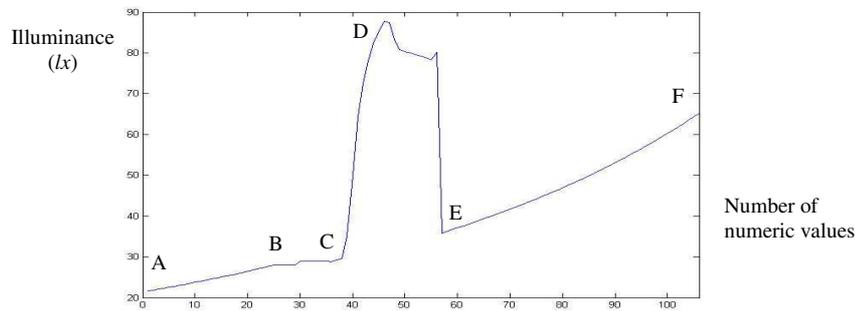


Fig. 9. The illuminance variance (lx) on the median line of the frame model (as in Fig.7), plotted for the elements (40, 1:106) from the total matrix of illuminance.

The next step, luminance assessment, is presented in Fig. 10, assuming that the surfaces of the door and wall are perfect diffuse (Lambertian):

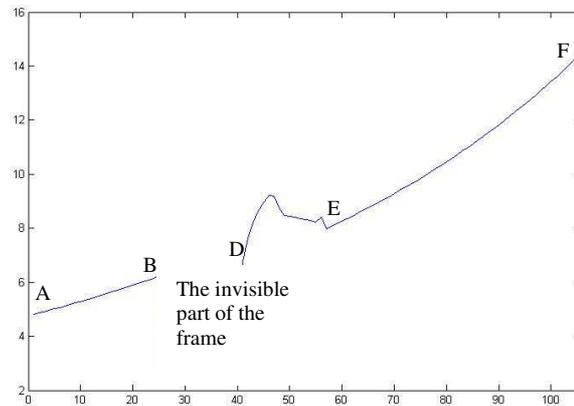


Fig. 10. The luminance variance (lx) on the median line of the frame model (as in Fig.7), plotted for the elements (40, 1:106) from the total matrix of illuminance (as Fig.8).

We notice that the differences between Fig.9 and Fig.10 are huge, concluding that the peak in illuminance is not mandatory to be present as luminance. In fact, the luminance contrast between the frame and the door is very poor, much less than 0.7, which is the threshold for visibility. This could be observed in Fig. 11, generated for the luminance ratio. The comparison between Fig.10 and Fig.11 gives a supplementary argument: even if the frame is well illuminated (zone DE in Fig.9), lighting incidence being optimal, close to normal (as a particular case), the luminance will be lower, due the color and reflectivity of the paintings. The result is sensitive to the particular lighting scene, a different light distribution could generate total different luminance contrast. This observation make the DIALux simulation more important. The possibility to build models in details generates more accurate assessment of the pathway visibility.

4. Discussion

The results obtained here show that it's possible to obtain lighting solutions adapted to the needs of elderly users through the use of light design software usually used for applications intended for the average observer. The comfort and quality of life of the elderly are among the main concerns of our European societies, for example in France [10], these results will constitute a guide of good practice, in adequacy with the expected and desires of the users but also of the policies in force [11].

This guide to unheard of good practices can be made available to the authorities to facilitate its development and deployment in retirement homes as a first step. Indeed, it will be possible for the future to be considered and reworked to match the needs and expectations of a home life.

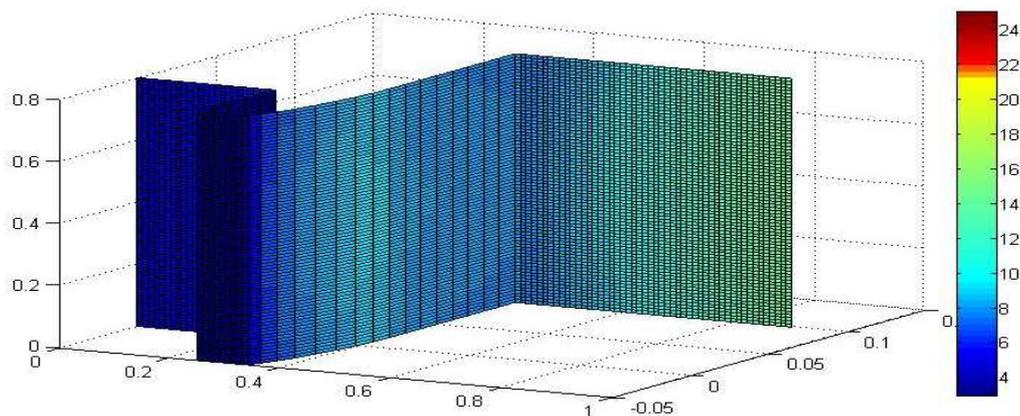


Fig. 11. The luminance map (cd/m^2) for the illuminance ratio from Fig.8, revealing the poor luminance contrast and lower visibility for the door frame.

Contrary to the usual practices of architects, our new approach of DIALux and MATLAB makes possible the modeling of a prototype of the final space and also the quantitative evaluation of the luminous characteristics, and in particular the contrast of luminance, major characteristic in the discrimination of the environment [12][13].

The difference between lighting design based on illumination level and luminance contrast can be schematized as follows:

Classical design based on illumination level:

- Visual activities and visual tasks for the room are determined
- Establish working plans and the necessary lighting level
- Lighting design with consideration of aesthetic and visual comfort
- Check the illumination pattern on the working plane

Design by luminance and by luminance contrast:

- Design the complete configuration for the illumination level
- Continue checking the visibility threshold for access ways
- The extreme limits position of the observer is established (there may be also elderly people who move autonomously but in the trolley)
- Directions and travel flows (arrival / departure, left or right)
- Obstacles and boundaries of the pathways (railings, stairs, doors, windows)
- Set design elements that generate luminance contrast
- Perform the luminaires solutions and check the visibility threshold
- Luminous contrast is enhanced by design details and additional light sources in the day, night or twilight hypothesis, or even emergency evacuation.

This approach is thus of great use for the designer, in order to understand the complexity of the light design, correlated to the particular needs of elderly users. It's also useful for the investors, as well as the authorities in order to be able to improve the living conditions of the elderly.

5. Conclusion

Thanks to our differentiating approach to the use of DIALux interior lighting system design software, we are able to design lighting systems adapted to the visual needs of elderly users, here based on the study of retirement home “Constantin and Elena” from Iași, Romania. The integration of new parameters allows us to extract luminance contrast from the conventional design approach. By shaping digital design systems, it's possible to develop specific installations. It also justifies the immediate interventions necessary to optimize the building to improve the visual comfort of the elderly, thus constituting a model for many other retirement homes.

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