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Luminance Contrast Assessment for Elderly Visual Comfort Using Imaging Measurements

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Abstract

The visual perception of the elderly is today question carrying major issues. In a growing context of aging, it's important to pay attention to optimizing their light environments. This is especially true in a situation of visual impairment, impacting their visual comfort. It's therefore necessary to adapt the quantity and the quality of light, but especially the luminance contrast levels. Then using digital imaging, it's possible to measure and identify existing levels, which will subsequently optimize these levels of luminance contrast and therefore the light environment. With the identification of the weaknesses of the luminous environment via digital imaging and a rich geriatric and medical literature, we are able to compensate the effects of visual pathologies inherent to the age and giving daily visual comfort.

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Keywords: Contrast of luminance; Elderly visual comfort; Luminance map; Visual pathologies; Camera calibration.

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1. Introduction

Today, people over 60 years old are becoming increasingly important in the demographic, social and economic dynamics. For good reason, if at the beginning of the years 2000, they represented 11% of the world population, in 2050 they will represent 22%, going from 605 million to 2 billion during the same period [1].

This context of aging is accompanied by new issues, particularly related to their quality of life and their health. They concern especially the evolution of the senses, and more particularly the vision. Raising new questions around the notion of visual comfort, inherent to their visual perception, it's important not to minimize the consequences of this sensory evolution in the elderly [2]. Indeed, they can affect their physical, emotional and social well-being, thus reducing their quality of life [3]. But if aging isn't a disease, it can sometimes be accompanied by a development of multiple visual pathologies, resulting for example in a decrease in perceived light, a change in color perception, an increased sensitivity to glare, diminished perception of contrasts or visual acuity disorders [4][5][6]. The most common being cataract, AMD and glaucoma. They affect respectively 20% [7], 30% [8] and 10% [9] over 75 years. These are pathologies that today are widely considered in the medical and geriatric literature [10][11][12].

But if the demographic characteristics and the direct physical consequences are identified, the observation is different when one looks at the determining factors contributing to compensate the effects of these pathologies, factors often minimized. This is especially true when, as here, we question the visual comfort of these elderly and the constituents of their visual environment. Indeed, today established recommendations for designing a comfortable visual environment are designed to meet the needs of an average observer, not specifically the needs of the elderly [13]. If we correlate the results of these recommendations with the geriatric and medical literature, we find that these recommendations aren't adapted to their needs, especially for elderly with visual pathologies. In comparison with the established recommendations, these pathologies cause the need to use more light, better quality, but especially to increase the levels of contrasts so that they become sufficient [14]. These are the levels of luminance contrast required to discriminate the elements that make up the environment, enabling the elderly to perform their daily activities. But to propose levels of luminance contrasts adapted to these particular needs inherent to the age, one must then be able to measure them.

2. The method for quantitative approach for luminance contrast

The most effective way to measure luminance contrast levels is the use of digital imaging. This method makes it possible to simplify the measurement of luminance contrast levels, because in fact, the measurement of luminance itself is nowadays uncommon. Digital imaging makes it possible to correct this problem and thus to propose an effective and objective response. It allows providing imperceptible results by the eye. And this is just as true for the average observer as for the elderly, because of the constant pupillary adaptation.

Digital imagery then makes it possible to develop luminance maps of the visual field. They make it possible to identify the weaknesses and strengths of the visual environment concerned, as well as the levels of luminance contrasts of each element. For an optimal discrimination of these elements by the elderly, the threshold contrast of luminance between two juxtaposed surfaces must be equal to 0.7 (or greater) [6][15].

Considering this threshold of luminance contrast, we expect the number of detectable thresholds to be somewhat limited. This is quickly found, if we accept that maximum luminance is obtained for the gray value (encoded by a byte) of 255, as in Table 1. So, if we consider a total white surface (gray=255), the have a visible adjacency contour, the next gray level must be 178. The maximum detectable thresholds will be 14, but normally could be considered close to 10, due the poor relevance of the values close to zero.

Table 1. Numeric values for luminance contrast levels in a grayscale image, to obtain visible threshold

Level (1 to 7)	0	1	2	3	4	5	6	7
Luminance (Gray Levels)	255	178	124	86	60	42	29	20
Level (8 to 14)	8	9	10	11	12	13	14	
Luminance (Gray Levels)	14	9	6	4	2	1	0	

An immediate question arises as to the real impact on the usual observer. To answer, it must consider the optoelectronic conversion function (*OCF*) for camera (Nikon D5300), obtained by the authors experimentally in the laboratory *LAPLACE*, Paul Sabatier University, Toulouse. For our *OCF* and an arbitrary exposure parameters (time, F number and ISO) the global conversion function of the camera is available in Fig.1:

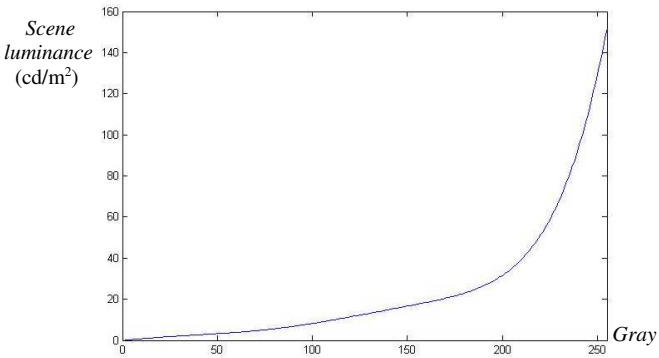
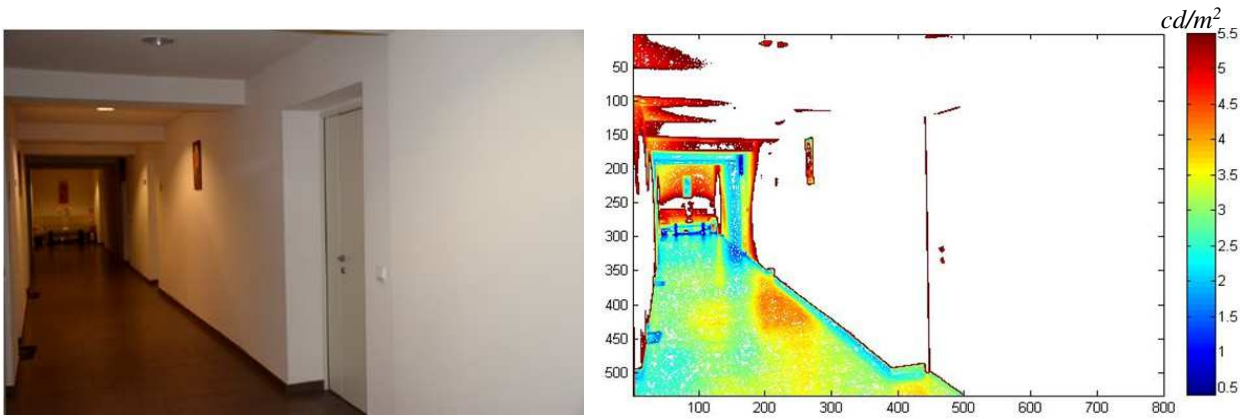


Fig. 1. Nikon D5300 optical conversion function (*OCF*): Luminance (*cd/m*^{2}) – Gray levels for an arbitrary exposure parameters

In Fig.1, the lower luminance are converted with a linear function, but for higher luminance (greater than 20 *cd/m*^{2}) the conversion is obviously nonlinear, giving the possibility to obtain relevant gray levels even for high values of luminance. It results that the number of thresholds of the luminance contrast that can be highlighted is much higher, but the contrast has to be calculated with actual values of the luminance of the scene and not in the values of the gray level. The conclusions are the same even if the image are obtained on two bytes, with increased gray resolution.

3. Scene analysis

The method of quantitative analysis based on luminance maps requires a progressive approach to investigating the details relevant to the movement of the elderly people. A case study was developed at the elderly nursing home in Iasi, Romania. The building is relatively new, with a high degree of comfort, demonstrating the increased attention the municipality gives to these old people. Paintings are generally white, subordinated to hygienic criteria. This criterion, in addition to its advantages, generates possible disadvantages. The first scene (Fig.2.a) is a common corridor with access to various functions. Quantitative analysis begins with a first exposure of DSLR camera and



a) b)

Fig. 2. a) Photo of interior scene and b) the first luminance map (*cd/m*^{2})

image conversion in luminance values, based on OCF as in Fig.1, affected by exposure time, F number and ISO settings. The luminance map is obtained by plotting lines of equal luminance between minimum values (usually zero) and maximum (but not equal to the maximum luminance of the image, because, as a rule, the maximum value is generated by a non-masked luminaire).

For the average observer, the scene is visually pleasing. This is less important, as quantitative interpretation is sought. The first map of the luminaries (Fig.2, b) highlights the obvious contrast between the floor and the walls, but

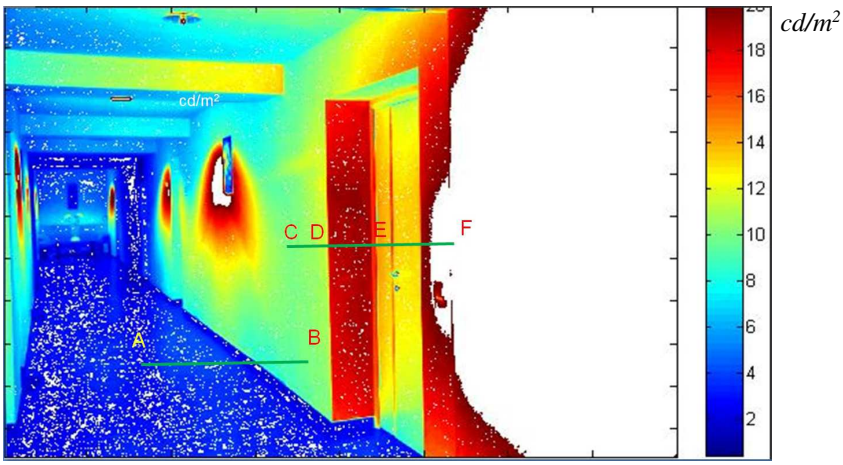


Fig. 3. The second luminance map for the scene from Fig.2.a), with extended plotted luminance values (0 ÷ 20 *cd/m*²)

it is obvious that many values of the luminance are not displayed: white area on the right part of the map. To correct this, a second luminance map is generated, for values in a lager domain (0 ÷ 20 *cd/m*²) as in Fig.3:

The color map has no other significance, opposite to "false colors" representation, as in DIALux. Starting from the image (Fig.2.a), the contrast between the dark floor and the white wall is positive. Extracting the data from luminance map, particular contrast could be calculated. For the floor-wall contrast we have A-B line, and for the door visibility we have C-D-E-F line. The luminance variance on these zones are illustrated in Fig.4:

A fast evaluation for every detail is possible. Luminance contrast (LC) for the floor – wall transition, with luminance in *cd/m*², is:

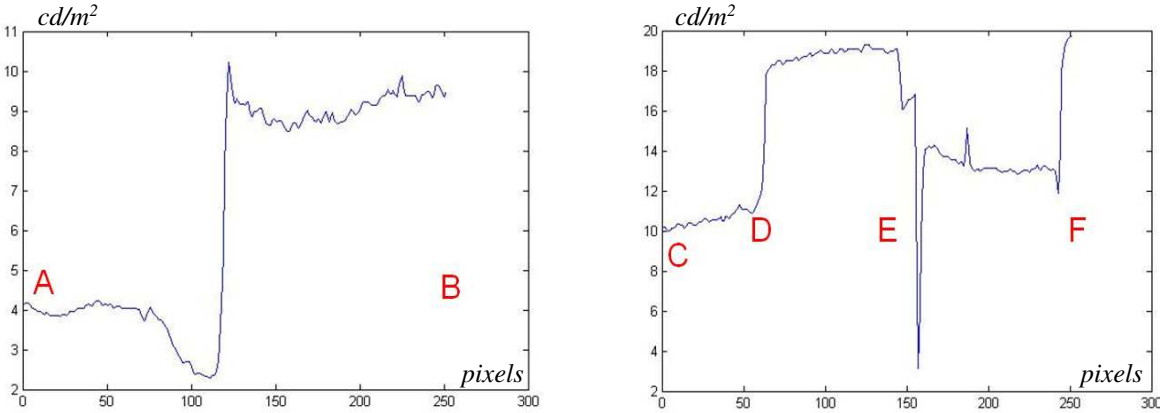
$$LC_{AB} = \frac{L_B - L_A}{L_A} = \frac{9-4}{4} = 1.2 > 0.7 \quad 1)$$

So the visibility is certain. The situation for the white wall to the door frame, with luminance in *cd/m*²:

$$LC_{CE} = \frac{L_{DE} - L_{CD}}{L_{CD}} = \frac{18-10}{10} = 0.8 > 0.7 \quad (2)$$

The visibility is possible, but the threshold is close. Any supplementary depreciation of the elderly's vision will affect the perception of the frame. The next luminance contrast is between the frame and the door itself, D – E – F, Fig.3.

$$LC_{DF} = \frac{L_{DE} - L_{EF}}{L_{EF}} = \frac{18-13}{13} = 0.38 < 0.7 \quad (3)$$

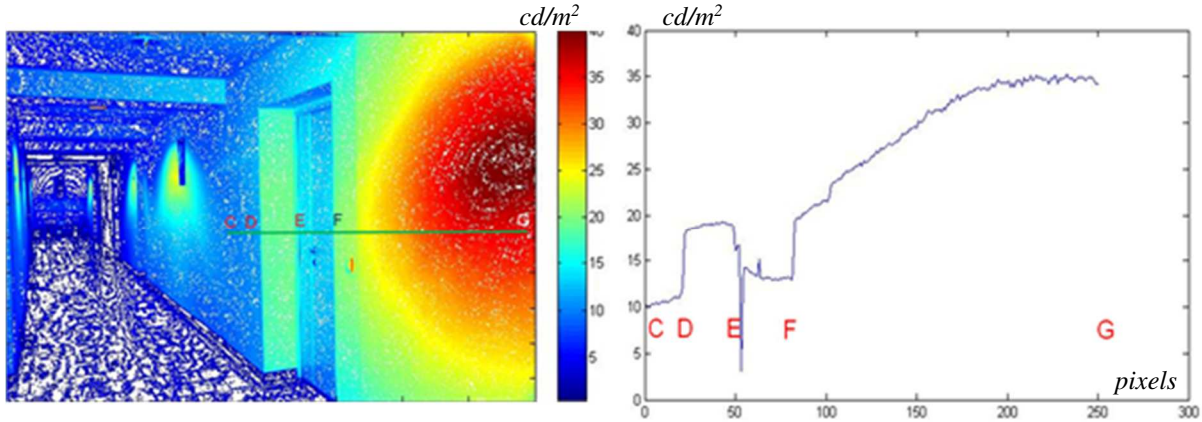


a) b)

Fig. 4. The luminance variation for luminance map from Fig.3 (*cd/m*^{2}): a) Luminance contrast (variation) for floor-wall; b) Luminance contrast (variation) for the door frame.

Here, the situation is problematic, because *the door is invisible*. For a normal observer, it is not obvious, but remember what happened if a clean glass door is close, with no other signaling: in short time, the door will be struck by someone! Here the situation is similar, and even if a serious accident is not possible, the visual discomfort is significant.

This local demonstration is enough to argue the utility of the method, so there is the possibility of examining all other paths. You can even deepen the previous scene if you look at an even broader range of luminance, as in Fig.5:



a) b)

Fig. 5. The third luminance map for the scene from Fig.2.a, with maximum extended luminance values (0 ÷ 40 *cd/m*^{2}): a) the position of line of vision visibility investigation C-D-E-F-G; b) the luminance variation on horizontal position of vision, for the door frame and wall.

The new available data reveal the effect of the closest luminaire on the wall, with a continuous increase of luminance (F to G, Fig.5.a and b). The effect is difficult to estimate, but the contrast with the door became important, and it is possible to have a total invisible door, due the possible glare from the wall.

4. Discussion

By employing digital imaging here to analyze and measure luminance contrast levels allows us to provide results not perceptible to the human eye, thus producing objective results, both qualitative and quantitative. Quantitative because one is able to deploy the parameters that will determine the criteria attached to an optimal lighting environment. Using the results defined by these parameters, we can determine the transformations to be performed

in this environment to provide visual comfort, here adapted to the needs of the elderly. That's why it's also a qualitative method. It identifies the determining factors that will allow elderly in this environment to regain the ability to practice their daily activities, in a better quality of life context, through quality lighting.

The major challenge conveyed by this method is the ability to propose a light design that is no longer only the result of the formatting of the established norms, but the result of a consideration of the needs correlated with the weaknesses and strengths of the existing environment. It's thus much more than the result of a calculation of luminous efficiency. Based on this method, it's therefore possible to optimize the necessary interventions to transform a living environment, and thus to design an optimized interior space between relief and spatial landmarks. For the analyzed scene, the immediate and inexpensive intervention must change the paintings for the door frame, and even the total white of the door could be modify, with some decorative picture. The second step, more complex, is to redesign the lighting system, in order to avoid the high values of luminance on the wall.

5. Conclusion

Aging is often accompanied by visual pathologies, impacting the visual comfort of the elderly. For the usual lighting design the assessment of the visibility on the pathways for elderly is not solved, and for an average observer the lighting environment could be acceptable. But thanks to this method of qualitative and quantitative imaging, combining analysis of luminance contrast levels and visual needs considerations, we are able to identify the weaknesses of an existing environment and then proceed with its optimization. Supplementary sources of contrast could be added, using paintings or decorative objects in connection with light sources. It's then possible to design luminous environments offering reliefs and spatial landmarks.

This method makes it possible to obtain a personalized response, adapted to the individualities of the elderly, to their visual comfort, thus enabling them to keep their daily activities.

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