MEASUREMENT OF THE UNIFIED GLARE RATING (UGR) BASED ON USING ILMD

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Abstract

Imaging luminance measuring devices (ILMD) are widely used in different fields of application. The assessment of glare caused by sun light and technical lighting installations for outdoor and indoor applications has meanwhile become reality. Measuring the discomfort glare for artificial indoor lighting installation is a fixed requirement of current standards.

The aim of this study is to develop a simple and very well suitable software algorithm to fulfil those requirements by using the ILMD measuring technique comfortably. This paper also includes a comparison of currently existing equations for the discomfort glare regarding their technical requirements to be met by the ILMD and also the validation of new ideas and methods for analysis and evaluation.

Keywords: Unified Glare Rating (UGR), Imaging Luminance Measuring Device (ILMD), discomfort glare

1 Introduction

Imaging luminance measuring devices (ILMD) are widely used in different fields of application. The first step in using an ILMD is to analyse the luminance 'as seen' in the image (ILMD Type I). In a further approach, not only the luminance information but also the position information of the measured luminance values and the relations to one another are necessary to extract relevant information for the application (ILMD Type II) (CIE Div.2 TC2-59, 2013). Therefore, the assessment of glare caused by artificial lighting installations for outdoor and indoor applications has meanwhile become reality.

Based on this knowledge, particular attention is now being paid on the determination of discomfort glare caused by artificial indoor lighting installations.
One of the difficulties in the evaluation of discomfort glare using ILMD is the identification of the glare source. The typical high dynamic and non-uniformity of the light sources and the influence of modulation and stray light effects make these issues a lot more complicate.
The Unified Glare Rating (UGR) formula for assessing the glare of indoor illumination is defined as (CIE, 1995):

$$UGR = 8 \cdot \log\left(\frac{0{,}25}{L_B} \cdot \sum_S \frac{L_S^2 \cdot \omega_S}{p_S^2}\right) \tag{1}$$

With the following symbols:
L_B Luminance of the environment
L_S Mean luminance of the glare sources
Ω_S Solid angle of the glare sources as seen
p_S Position index of the glare sources

2 Advantages of ILMD and its practical implementation

- Possible variation of the observer viewing direction
- Automated detection and manual glare source determination
- Simplified comparison of different parameter settings for discomfort glare equation (1)

This paper partly introduces a new software tool. Using this tool it becomes easy for virtual changing of the observers viewing direction and thus the position index of the light sources within the acquired luminance image. To do so, one needs to place a cross-hair at the desired position within the image (refer to 5.1). The placement depends on the ILMD's field of view (FoV) and direction respectively.

3 Identifying Glare Sources

For detecting the glare source in a luminance image several different image processing algorithms are available.
At first view they can be classified according to a spatially global or local scope of action. In a second approach they can be separated according to the mode of action. It is possible to use a luminance value or a luminance gradient as threshold.

- filtering by contrast threshold detection and afterwards modified luminance histogram analysis for a threshold luminance value (Wolf, 2004)
- defining area of interest for glare source detection (for example a task zone area)
- manually set one fix luminance threshold (for example the average luminance)
- manual definition of glare sources

All in all the results for classifying the glare sources and the derived luminances are depending on the imaging resolution of the ILMD. It must be comparable to the human eye. With current available ILMD this criteria can be fulfilled. However, the resolution of the human eye varies widely in the visual field and depends on various other factors, e. g. the adaptation level. This can be taken into account by local smoothing image processing functions if an appropriate model is available.

3.1 Contrast threshold detection

The proposed method for an automated filtering of the glare sources in the luminance image is using a local contrast threshold of $C_{log,th}$ = 0.25 (empirical value, see WOLF 2004). The local contrast is calculated as follows:

$$C_{loc(\vartheta_i,\varphi_j)} = \sqrt{\left(\frac{\partial L}{\partial \vartheta}\right)^2 + \left(\frac{\partial L}{\partial \varphi}\right)^2} \qquad (2)$$

with

$$\left(\frac{\partial L}{\partial \vartheta}\right) = \frac{L(\vartheta_{i+1},\varphi_j) - L(\vartheta_{i-1},\varphi_j)}{L(\vartheta_i,\varphi_j)} \qquad (3)$$

and

$$\left(\frac{\partial L}{\partial \varphi}\right) = \frac{L(\vartheta_i,\varphi_{j-1}) - L(\vartheta_i,\varphi_{j+1})}{L(\vartheta_i,\varphi_j)} \qquad (4)$$

Therefore an auxiliary image containing the local contrast is created step-wise by a horizontal and vertical gradient detection and contrast calculation following equation (3) and (4).

Afterwards the two images were squared and added for receiving an image that shows the spatial resolution of local contrasts (see figure 3) following equation (2) (Wolf, 2004).

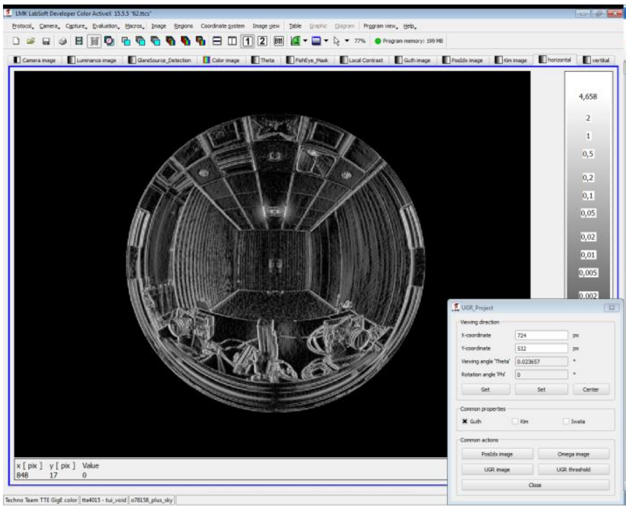

Figure 1 – Image of horizontal gradients

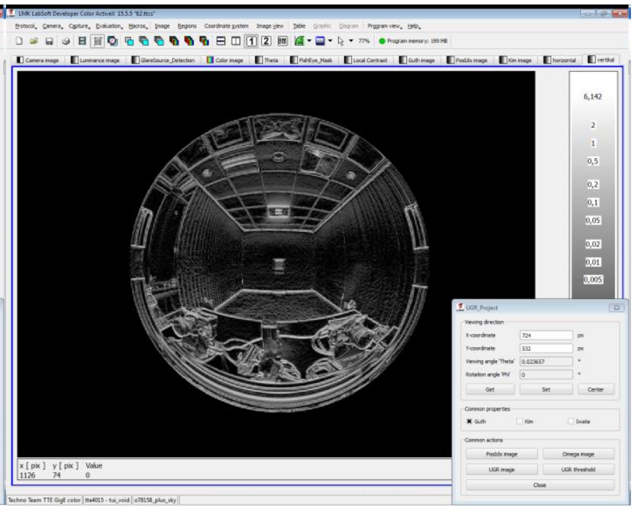

Figure 2 – Image of vertical gradients

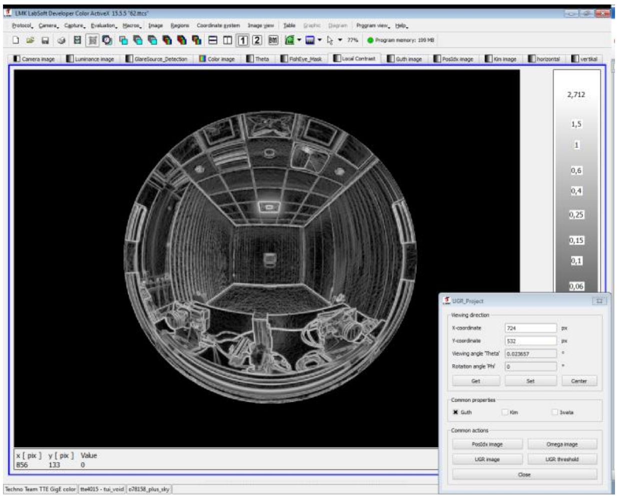

Figure 3 – Local contrast before binarization with a threshold of $C_{loc.th}$ = 0.25

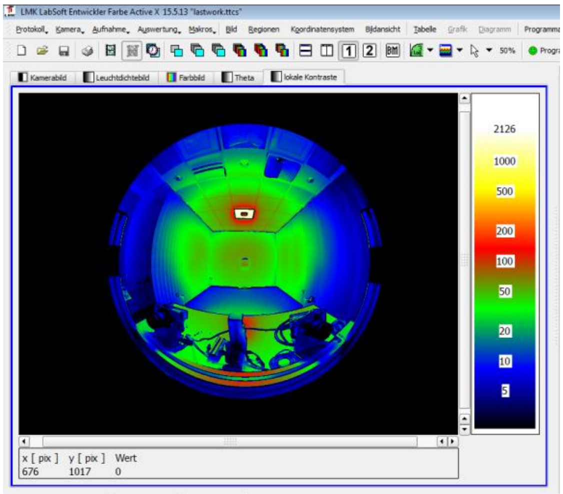

Figure 4 – Local contrast threshold ($C_{loc.th}$ = 0.25) filtered luminance image

Next, the received local contrast image is separated into two areas. The criteria for this separation is a local contrast threshold of $C_{loc.th} = 0.25$ for each pixel. The first area is set pixel-wise to '1' for all pixel < $C_{loc.th}$ and otherwise is set '0' for all pixel ≥ $C_{loc.th}$. The received binary mask image can be used for identifying those parts of the luminance image with local contrast above > $C_{loc.th}$ = 0.25 by multiplying with it (see figure 4).

3.2 Modified histogram analysis

For the local contrast threshold filtered luminance image a histogram is used to define a luminace threshold that classifies the glare sources and can also be used for identifying the background area. When applying the histogram to the image, the histogram has to be smoothed by a floating average over a sample of measurement values. A sample of 15 measurement values (±g=7 neighbours) is used following (Wolf, 2004).

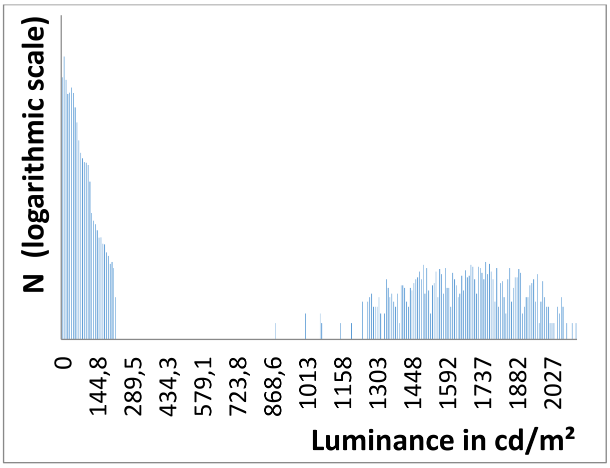

Figure *5* – Histogram for the luminance distribution

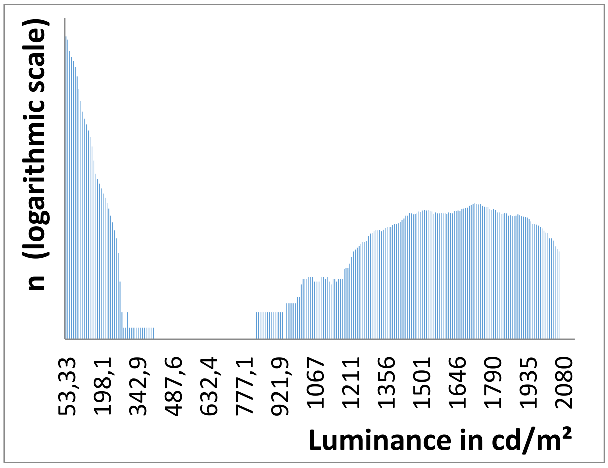

Figure 6 – Smoothed histogram(g=7) for the luminance distribution

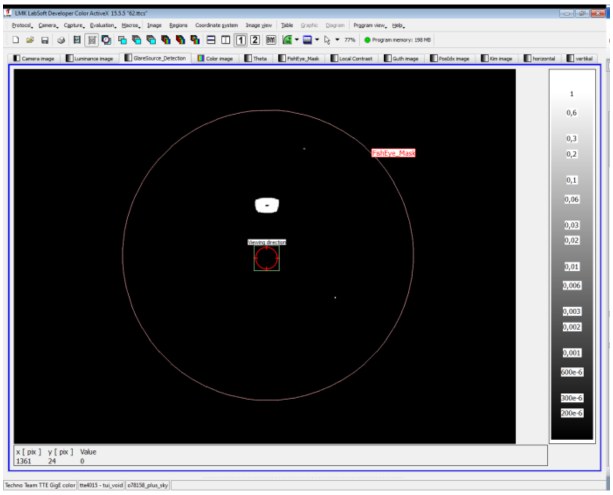

Figure 7 – Detection mask image for glare source

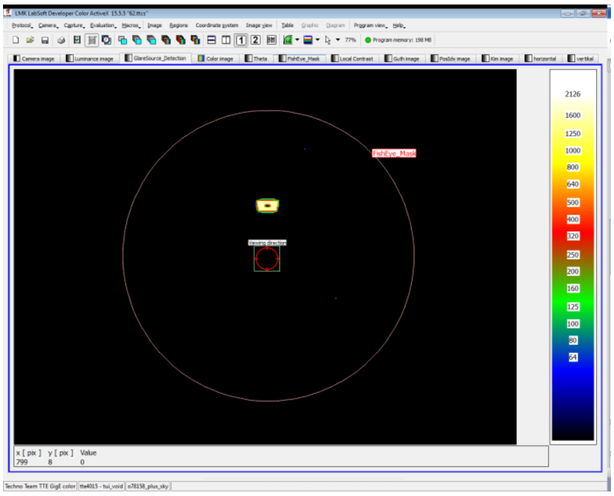

Figure 8 – Luminance image only containing detected glare sources

In the modified histogram (see figure 6) the first local luminance minimum $L_{loc,min}$ can be found significantly (comparing figure 5). Thus the criteria for classifying the glare sources $L_S > L_{loc,min}$ can be used by creating a binary mask image and multiplying it with the luminance image (see figure 7 and 8).

Conclusions: The proposed method for an automated filtering of the glare sources is using a local contrast threshold filtered luminance image and a modified histogram following the proposal of (Wolf, 2004). This algorithm shows reproducible results for a typical range of scenarios and a high transparency.

4 Determination of the adaptation level

As luminance for the level of adaptation the luminance of the environment L_B is used. Generally the algorithm uses the mean luminance of the luminance image without the glare sources for this purpose.
For this the binary mask image for detecting the glare source is inverted and afterwards multiplied with the luminance image (see figures 9 and 10).

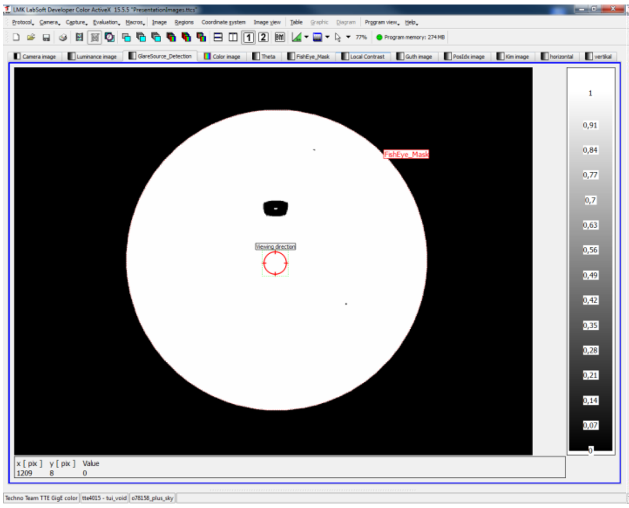

Figure 9 – Detection mask image for luminances of the background environment

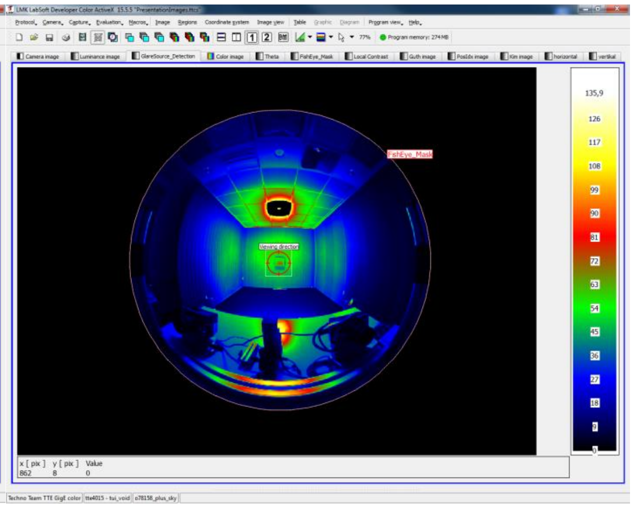

Figure 10 – Luminance image without glare sources

As result a luminance image without the glare source is derived. Using a statistic tool for all pixel values > 0 cd/m² allows to calculate the average luminance which is used as value for L_B in equation (1).

When using a lens type that realises a conformal projection an additional weighting of the pixel $L_{B(i,j)}$ by multiplying with the cosine of the viewing direction $\cos\vartheta_{(i,j)}$ is necessary, to avoid an overweight of the adaptation luminance level. The software tool does recognize this automatically when configuring the used ILMD in the settings for the algorithm.

Furthermore the measurement can be restricted and weighted according to a model for the adaptation. Such a model can be applied into a synthetic image. One idea is to use circular regions (area of interest - AOI) centered to the viewing direction and allocate weighting factors for the luminance to each circular AOI.

5 Modelling of the position index

The parameter p_S of equation (1) represent the position index. For calculating the position index more than one proposal is available. In general the position index is implemented according to Luckiesh and Guth (Luckiesh & Guth, 1949) above and also below the line of sight. Thus the guidance for the 1st quadrant was used similarly for the 2nd, 3rd, and 4th.
Nevertheless one can also choose Kim's guidance (Kim, W et al, 2011) for above and below the line of sight.
Alternatively for both rules the 1st and 2nd quadrant below the line of sight can be calculated with the position index for LED matrix sources according to Takahashi (Takahashi, H et al, 2007).

The figures 11 – 14 show calculated images containing the different equation for the position index. The images were synthesized for an equal-area projective fisheye lens.
This lens type has a circular 180° hemispheric field of view (FoV) and offers the possibility to readjust the real viewing direction of the lens virtually (see section 6). Therefore the orientation of the position index is calculated in real-time depending on the set viewing direction.

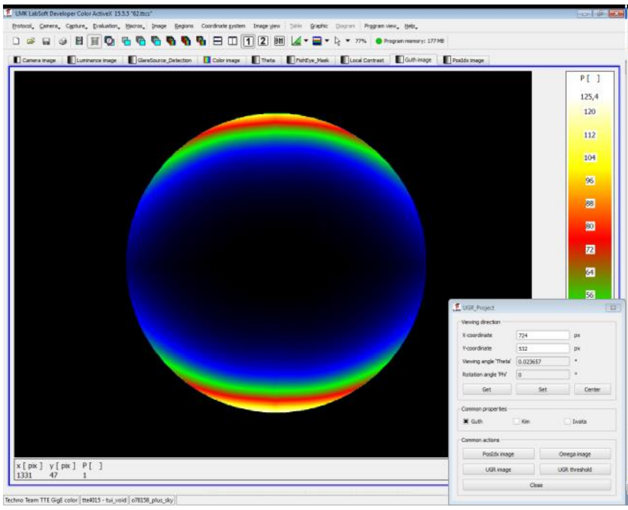

Figure 11 – Position Index following Luckiesh & Guth above and below the line of sight

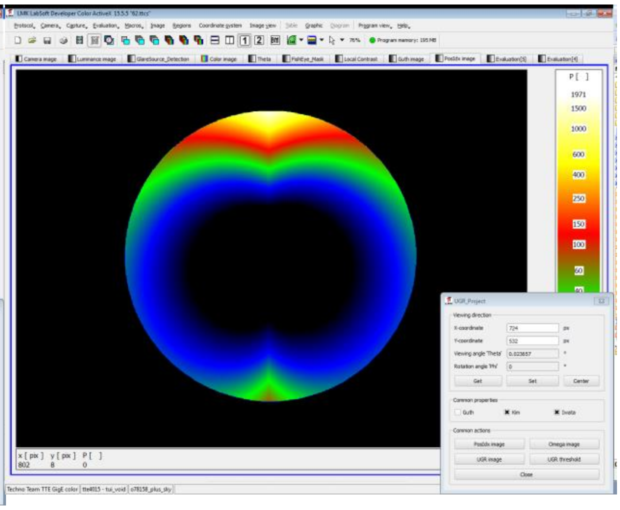

Figure 12 – Position Index following Kim W. above and below the line of sight

Theoretically an assignment of position indices to the glare source could be made pixel-wise. But generally the algorithm does detect one glare source as an area of adjacent pixel. Using statistical functions such as the so called area of interest (AOI) will be created for each source. For the definition of the position index for each AOI the coordinates ϑ,ϕ of the geometric centre will be used. Alternatively it is also possible to use the coordinates ϑ,ϕ of the photometric centre of the AOI. The photometric centre does additionally consider the inhomogeneity of the luminance when calculating the centre position of an AOI.

6 Virtual viewing direction

One advantage using an ILMD for analysis of glare scenarios is the possibility of simplified readjustment of the analysers viewing direction.

Many ILMD's field of view (FoV) does offer this possibility in a limited angular range. The limitations are due to the requirements of the used glare model. When using a circular 180° hemispheric lens for the UGR analysis - the viewing direction can roughly be shifted horizontally (pan) and vertically (tilt) at an amount of ±20°. A rotation of the FoV is not possible.

This does not only offer a correction of potential failures when adjusting the ILMD during the measurement. It does also allow an easy comparison of changes to the UGR for example considering the pupil movement of the observer. When using the software tool it is easy to change the observers viewing direction and thus the position index of the light sources within the acquired luminance image.

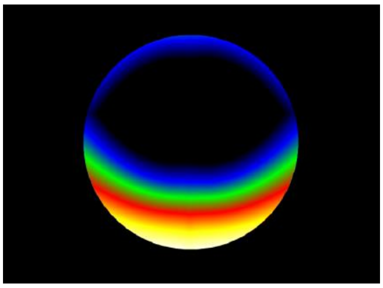

Figure 13 – Position Index following Luckiesh & Guth – shifted 20° upwards (tilt)

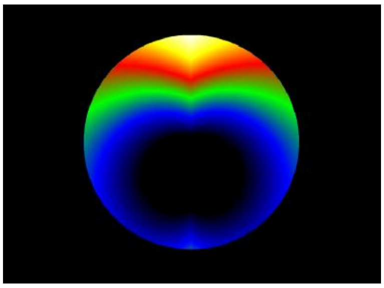

Figure 14 – Position Index following Kim W. – shifted 20° right (pan)

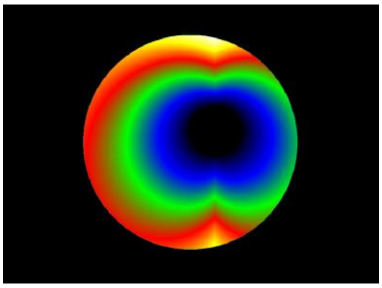

Figure 15 – Position Index following Kim W.– shifted 20° upwards (tilt) and right (pan)

7 Calculating the UGR

According to (CIE, 1995) the calculation of the UGR is performed by averaging and summarizing the luminance of each detected glare source (AOI). The average luminance, the overall solid angle of the glare source and the position index are used as in formula (1).

An additional optional method is to calculate the partial UGR quantity pixel-wise, for each as glare source classified pixel separately. That means the summation for the glare source luminance, solid angle and position index are made pixel-wise ($L_{S(i,j)}$, $\Omega_{S(i,j)}$, $p_{S(I,j)}$). Each classified pixel above the luminance threshold stands inside the algorithm for a single glare source.
The results will be presented as one UGR value and additionally separated into the partial quantities for each detected glare source.

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