21NRM01 HiDyn

{HiDyn}

D3: Report on the relevance of existing quality indices and the need for new ones, specific to HDR imaging luminance measurement systems, for glare and obtrusive light assessment.

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Deliverable Cover Sheet

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Glossary

ILMD	Imaging Luminance Measurement Devices
HDR	High-dynamic-range
LDR	Low-dynamic-range
FOV	Field Of View
SPD	Spectral power distribution

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1 Abstract

In this report the relevance of the of existing quality indices described in CIE 244:2021 to calculate glare metrics is evaluated.

Some of the indices are almost not relevant for the glare metrics as metrics apply typically a logarithmic function on the luminance. However, indices related to the linearity, shutter and aperture repeatability, light modulation, size of source and smear have a high impact on the glare metrics, and such influences should be minimized during the acquisition of the HDR images.

2 Scope

This report evaluates the relevance of existing quality indices described in CIE 244:2021 to calculate glare metrics. The evaluation is based on the experience of the participants of the HiDyn project and the measurements conducted in the framework of the project. The project team also suggests an additional, new quality index.

3 Existing quality indices in CIE 244:2021 and their relevance for measuring glare

3.1 Initial adjustment index, f_{adj}

This index describes the deviation of the luminance measured by the ILMD from the reference. The relevance of this index for glare measurement is low. While absolute luminance is important for the calculation of glare metrics, the instrument's calibration factor will correct the deviation.

3.2 General $V(\lambda)$ mismatch index, f'_1

This index describes the variation of the luminous responsivity of the ILMD to the spectral power distribution (SPD) of the sources to be measured. The larger the difference of the SPD between measurement and calibration, the larger is the error committed in the measurements. Since the sources in the scene might have different SPDs, the committed error is different for the different sources in the field of view. This error can be corrected if the SPD of the sources to be measured is known, but in many cases they are unknown. A low f'_1 minimize this error. The relevance of this index for measuring glare strongly depends on the nature of the SPD measured in relation to the calibration SPD. In general, the impact is lesser if the measured light source has a broader emission spectrum (e.g. daylight) compared to spiky emitters (e.g. fluorescent lamps).

3.3 UV response, f_{UV}

This index describes the responsivity of the photometer to the UV radiation, that ideally should be null. It might affect to the glare evaluation through an error in the measurement of luminance, in an analogue way as f'_1. The relevance of this index for measuring glare is low in an LED-lighting scenario as the UV content for these light sources is low. The relevance of this index for measuring glare is moderate when the glare source is the sun or other light sources with a significant amount of UV emitted.

3.4 IR response, f_{IR}

This index describes the responsivity of the photometer to the IR radiation, that ideally should be null. It might affect to the glare evaluation through an error in the measurement of luminance, in an analogue way as f'_1. The relevance of this index for measuring glare is low in an LED-lighting scenario as LEDs typically don’t emit IR radiation. The relevancy of this index for measuring glare is moderate when the glare source emits a significant amount of IR (e.g., the sun or Xenon-lamps).

3.5 Detection limit, $f_{3,0}$

This index describes the detection limit of the instrument, that is, the lowest luminance able to measure. This might be important for the measurement of the background luminance in dark environments (outdoors), although in general this limit is typically lower than the stray light produced by the brightest sources in the scene. Therefore, the relevancy of this index for measuring glare is regarded as slight for outdoor night applications, not relevant for indoor or daylight applications.

3.6 Linearity using a fix measurement range, $f_{3,1}$, and Linearity using range change, $f_{3,2}$

This index describes the linearity of the ILMD. A low linearity will affect at great extent the value of the ration between the luminance of the brightest source and that of the background, which can have an important impact in the calculation of the glare indices. The relevancy of this index for measuring glare is high.

3.7 Temperature dependence index, $f_{6,T}$

This index describes the dependence of the luminance responsivity on the temperature. For field measurements, where the temperatures might be very different to those during the adjustment, the relevancy of this index for measuring glare is slight, as it has been proven in practice.

3.8 Humidity test index, $f_{6,H}$

This index describes the dependence of the luminance responsivity on the humidity. For field measurements, where the humidity might be very different to those during the adjustment, the relevancy of this index for measuring glare is slight, as it has been proven in practice.

3.9 Modulated light, f_7

This index describes the influence of the modulated light at various frequencies, compared to the response to a constant illumination. In the case of imaging measurement systems, this effect will depend on the integration time. The larger the integration time, more cycles are averaged, decreasing the error. Most importantly the shortest integration time should cover several cycles – for high intensity light sources the usage of neutral density filters is necessary. The relevancy of this index for measurement of glare is high.

3.10 Polarization response, f_8

This index describes the dependence of the responsivity on the polarization of the light. In glare measurements the only polarized light comes from specular reflections in surfaces. We assume the relevancy of this index for measuring glare is moderate.

3.11 Range change, f_{11}

This index describes the deviations obtained when using different measurement ranges. In the case of imaging measurement systems, the integration times used during the measurement is equivalent to the measurement range. It is not directly evaluable according to the definition of this index, and we consider that its relevancy is minor. Note that when an HDR algorithm is applied, only the more adequate integration times (those optimizing the SNR) are used.

3.12 Focusing distance, f_{12}

This index describes the deviations of the test distance to the focus distance. Since the objects in the glare measurement are usually far, and the error due to this effect decreases with the distance, we assume that the relevancy of this index for glare assessment is minor.

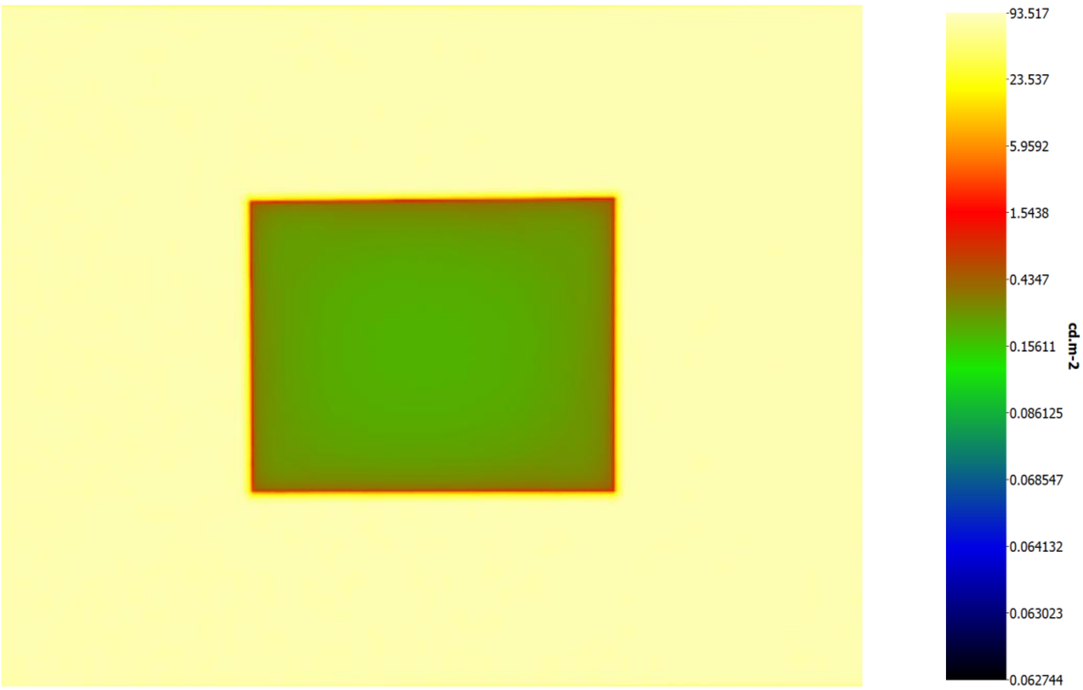
3.13 Responsivity uniformity for flat field, $f_{2,1}$, and responsivity uniformity for spots, $f_{2,2}$

These indices describe the dependence of the luminance responsivity on the position of the field of view. Its impact is similar to the effect spectral mismatch, f'_1 (both effects can be corrected but requiring additional methods and devices not always available). The relevancy of these indices for measuring glare is slight. From experience, it was observed that a relative deviation of 10% in terms of luminance results in relative deviation of the glare index of about less than 1%.

3.14 Effect of surrounding field, $f_{2,3}$

This index describes the effect of the surrounding filed (out of the FOV) on luminance measurements. Since glare evaluation need to include the complete field, with all surrounding sources, the relevancy of this index for measuring glare can be regarded as small.

An example of the effect of the dark and light components in the index value by obtaining an HDR and LDR images is shown below:

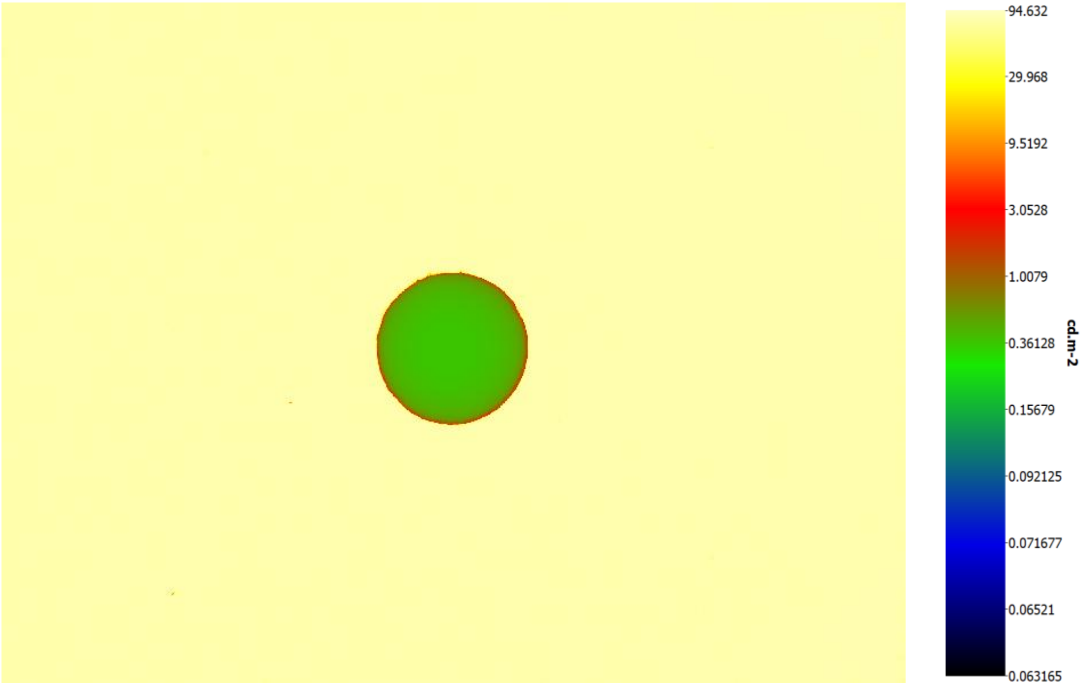


Region/Image	HDR	LDR 1	LDR 2	LDR 3	LDR 4	LDR 5	LDR 6
Dark region / cd/m²	0.2254	2.1439	0.7335	0.3616	0.249	0.2211	0.2254
Light region / cd/m²	85.315	84.584	85.695	85.580	85.407	85.3151	Saturated
Lowest dark / cd/m²				0.2211			
$f_{2,3}$	0.26%	2.53%	0.86%	0.42%	0.29%	0.26%	-
$f_{2,3}$ (using the lowest dark value)	0.26%	0.26%	0.26%	0.26%	0.26%	0.26%	-

Note: The HDR image was generated by merging the individual LDR ones (LDR1 to LDR10)

3.15 Stray light influence for negative contrast, $f_{2,4}$

The effect due to internal stray light limits the ability of the instrument to evaluate simultaneously very different luminances within the scene, and those luminance measurements are involved in the calculation of the glare rating. Therefore, this index, as the Edge function index or Size-of-effect index (which are closely related to internal stray light too), should be highly relevant for evaluation of glare. However, this index evaluates a specific condition which is far from common in outdoor or indoor lighting, and we might decrease its relevancy level to "slight".
An example of the effect of the dark and light components in the index value by obtaining an HDR and LDR images is shown below:



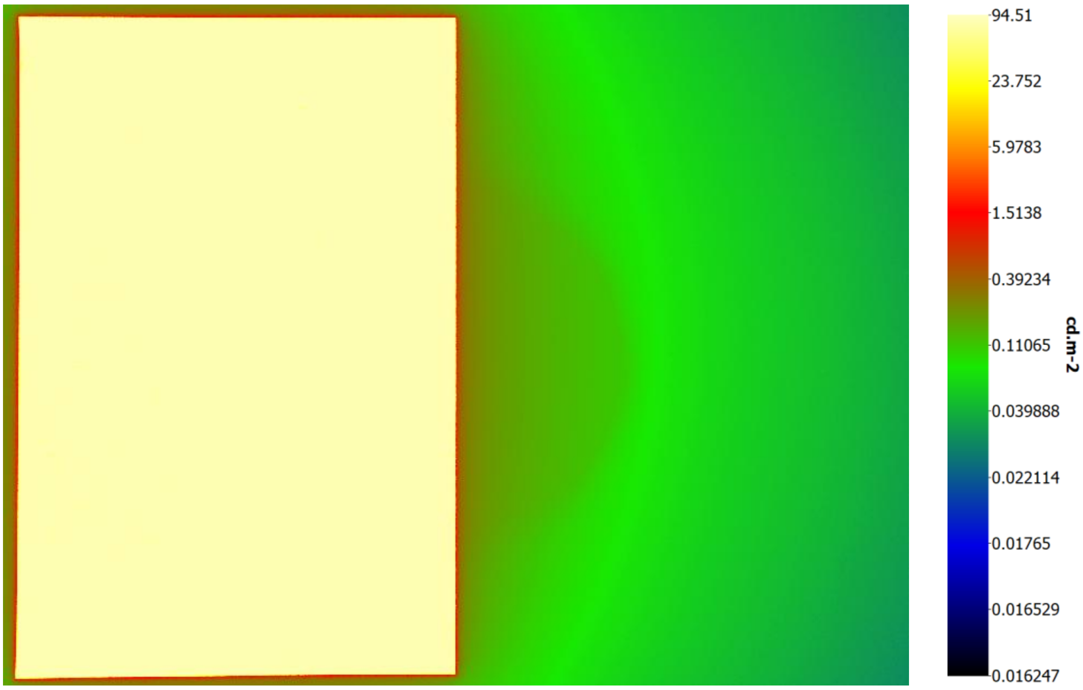
Region/Image	HDR	LDR 1	LDR 2	LDR 3	LDR 4	LDR 5	LDR 6
Dark region / cd/m²	0.4018	0.3994	0.3747	0.5052	0.9467	3.233	12.6184
Light region / cd/m²	85.669	85.669	85.699	85.886	86.299	87.479	91.288
Lowest dark / cd/m²				0.3747			
$f_{2,4}$	0.47%	0.47%	0.44%	0.59%	1.10%	3.70%	13.82%
$f_{2,4}$ **(using the lowest dark value)**	0.44%	0.44%	0.44%	0.44%	0.43%	0.43%	0.41%

Note: The HDR image was generated by merging the individual LDR ones (LDR1 to LDR10)

Edge function, $f_{2,5}$

As $f_{2,4}$, this index is larger when the effect due to internal stray light is larger. The effect that it quantifies is related to a situation with a large luminaire on a dark background. We might say that this index is relevant for those situations with large and uniform luminaires, where the measurement of the luminance background is important. However, for indoor applications typically the influence is minor.

An example of the effect of the dark and light components in the index value by obtaining an HDR and LDR images is shown below:



Region/Image	HDR	LDR 1	LDR 2	LDR 3	LDR 4	LDR 5	LDR 6
Dark region / cd/m²	0.0667	0.07646	0.1056	0.1451	0.5030	0.0667	0.0687
Light region / cd/m²	85.295	85.295	85.422	85.335	33.243	Saturated	Saturated
Lowest dark / cd/m²				0.06625			
$f_{2,5}$	0.08%	0.09%	0.12%	0.17%	1.51%	-	-
$f_{2,5}$ **(using the lowest dark value)**	0.08%	0.08%	0.08%	0.08%	0.20%	-	-

Note: The HDR image was generated by merging the individual LDR ones (LDR1 to LDR10)

3.16 Size-of-Source Effect, $f_{2,9}$

This index describes the variation of measured luminance when differently sized sources with the same luminance are measured. It is related again with the internal stray light, as a result that by the effect of diffraction an object point is not a point anymore in the image, but a spread point (PSF, point spread function). It might produce an error when the luminous responsivity is characterized, since it might depend on the size of the source (the area of the reference must be done large enough for avoiding this variation). This impact has its effect when measuring sources not large enough, which impacts on the calculation of the glare rating. Therefore, the relevancy of this index for measuring glare is high, especially for small glare sources.

3.17 Influence of smear, $f_{2,6}$

This index describes the smear, which is source of error by leakage observed only in CCD sensors and only when the integration time is comparable to the readout time (very low integration time). The more practical solution to avoid this error is to avoid those low integration times in acquisitions. If the smear is high in the device, we would need to use neutral filters in more conditions, to avoid short integration times. We might say that the relevancy of this index for measuring glare is high, although only relevant for CCDs.

3.18 Shutter repeatability, $f_{2,7}$, and Aperture repeatability, , $f_{2,8}$

These two indices affect the repeatability of consecutive acquisitions. This error must be avoided averaging by a number of repetitions large enough to keep the average constant enough. The consequence is an increase in the measurement time. Therefore, the relevance of these indices is high.

4 Additional, new suggested quality index

Achievable dynamic range (HDR indices)

We define ground-truth luminance (L_{GT}) to the luminance obtained when the light source is not surrounded by other light sources producing internal stray sight which might affect its measurement. We define modified luminance (L_m) to the luminance obtained when the light source is surrounded by other light sources producing internal stray light which affects its measurement.

By comparing the reference **R** with $\mathbf{F'_{1:7}}$, it is possible to describe the relation between the decades of the ground-truth luminance (L_{GT}) in the scene and the decades of the modified luminance (L_m) by each measurement system.

This relation depends on the number of decades, since the less decades are to be measured, the lower is the impact of the stray light to reduce the dynamic range of the acquisitions. We define the relative reduction of decades, ΔD, as:

$$\Delta D = \frac{|\Delta \log_{10}(L_{\mathrm{GT}}) - \Delta \log_{10}(L_{\mathrm{m}})|}{\Delta \log_{10}(L_{\mathrm{m}})}, \quad (1)$$

where $\Delta \log_{10}(L)$ denotes the number of decades within a given range, and this is calculated as the difference between the decimal logarithms of minimum and maximum luminances within the range, as:

$$\Delta \log_{10}(L) = \log_{10}(L_{\mathrm{max}}) - \log_{10}(L_{\mathrm{min}}) \quad (2)$$

The relative reduction of decades, ΔD, depends on the number of decades. We have tested that it increases exponentially with respect the number of decades, and can be empirically modelled as:

$$\Delta D = f_{\mathrm{HDR,1}} \cdot 10^{D_{\mathrm{GT}} f_{\mathrm{HDR,2}}}, \quad (3)$$

where:

- D_{GT} denotes the GT number of decades and is calculated as:

$$D_{\mathrm{GT}} = \Delta \log_{10}(L_{\mathrm{GT}}) \tag{4}$$

- $f_{\mathrm{HDR},1}$ and $f_{\mathrm{HDR},2}$ are empirical parameters.

Both $f_{\mathrm{HDR},1}$ and $f_{\mathrm{HDR},2}$ are empirical parameters whose values are determining by fitting the Eq. (3) to the experimental data obtained for ΔD at different values of D_{GT}.

The calculation of ΔD through Eq. (1) can be applied to any other luminance distribution, as long the GT is known. However, the result can depend strongly on this distribution for a given imaging system. For instance, ΔD would increase toward lower distances between the brightest and the dimmest sources, or with the size of the brightest source. We propose here to restrict the calculation of $f_{\mathrm{HDR},1}$ and $f_{\mathrm{HDR},2}$ to the hexagonal distribution defined by **R**, with:

- The dimmest light source always at the center.
- Light sources of identical sizes.
- Light sources small with respect to the complete image.
- Light sources large with respect to the pixel.
- For all sources, the same distance to the dimmest source (between 1/4 and 1/3 of the largest side of the image).

These restrictions must minimize the variation of the obtained $f_{\mathrm{HDR},1}$ and $f_{\mathrm{HDR},2}$ with slightly different luminance distributions.

5 Summary of impact on glare metrics

Quality index		Impact on glare metric (-minor +slight ++moderate +++strong)	
		Indoor/Outdoor daylight	Outdoor night
f_{adj}	Initial adjustment	-	-
f'_1	Spectral mismatch	+	+
f_{UV}	UV response	-	-
f_{IR}	IR response	+	-
$f_{3,0}$	Detection limit	-	+
$f_{3,1}$	Linearity using a fix measurement range	+++	+++
$f_{3,2}$	Linearity using range change	+++	+++
$f_{6,T}$	Temperature dependence	-	+
$f_{6,H}$	Humidity test index	-	+
f_7	Modulated light	+++	+++
f_8	Polarization response	-	-
f_{11}	Range change	-	-
f_{12}	Focusing distance	-	-
$f_{2,1}$	Responsivity uniformity for flat field	+	+
$f_{2,2}$	Responsivity uniformity for spots	+	+
$f_{2,3}$	Effect of surrounding field	-	+
$f_{2,4}$	Stray light influence for negative contrast	-	+
$f_{2,5}$	Edge function	-	+
$f_{2,6}$	Influence of smear	+++	+++
$f_{2,7}$	Shutter repeatability	+++	+++
$f_{2,8}$	Aperture repeatability	+++	+++
$f_{2,9}$	Size-of-Source Effect	+++	++
ΔD	Reduction of decades	+	+++