Manual

glare analysis

LMK

LabSoft AddON

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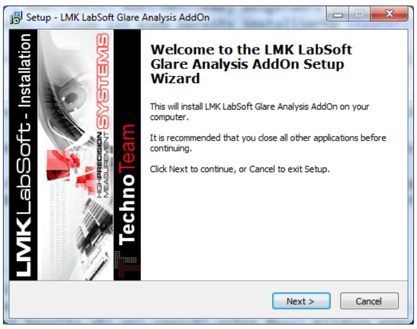
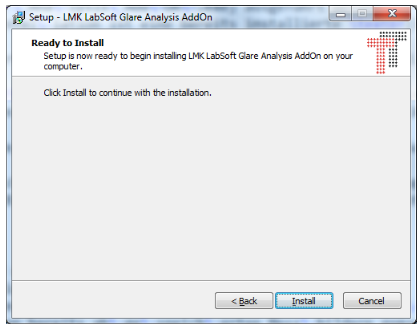
1 Starting the program and the main dialog

1.1 Installation

To install the new menu item for the AddOn **Glare analysis** run the **LMK_LabSoft_Glare_Analysis_AddOn.exe** installer. Prerequisite for the installation of the AddOn is an already installed **LMK LabSoft** standard version 16.11.21 or later.





The installation program **LMK_LabSoft_Glare_Analysis_AddOn.exe** is located either on the data carrier delivered with the delivery of the **LMK** system or can be downloaded from the **TECHNOTEAM**-Webserver.:

http://www2.technoteam.de/LMK_LabSoft/

After successfully finished installation the addon can be found in the **LMK LabSoft** menu „MACROS | GLARE ANALYSIS | GLARE ANALYSIS“.

1.2 Selecting the LMK and the lens

The AddOn is made for an interactive use of the **LMK**. But nevertheless the analysis of earlier captured and stored images can be done. At the start the AddOn checks the **LMK LabSoft** for an active **LMK** connection. If there is a camera connection, the necessary angular calibration data will be loaded. For this the file **geo.ini** is required. The file is located in the camera calibration data in the subfolder of the selected lens.
Alternatively, the user can start the AddOn without active camera connection. In this case, the AddOn asks for the location of the **geo.ini** file on the hard disk, If the file does not exist, the AddOn will terminate with a hint.
Often a lens with a field of view (FOV) **Theta** $\geq$ 120°is used for determining the glare value. For this reason, the use of such lens is presupposed below. In exceptional cases, the use of another lens is pointed out.

1.3 Start of the program

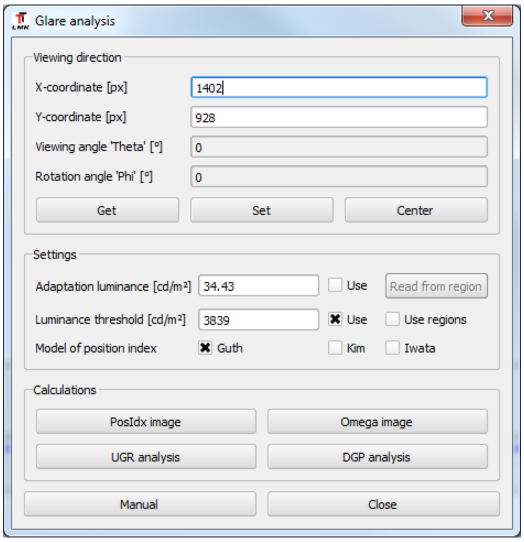
When starting the AddOn, the required geometric information for the used lens is loaded in the background (see section 1.2 on page 4).
The **Theta** image which is displayed in the **LMK LabSoft** shows the opening angle **Theta** of the selected lens in degrees [°]. The position of the optical axis of the lens is expressed by a cross-hair region labeled **Viewing direction** in the luminance image of the **LMK LabSoft**.
The **Glare analysis** works only for luminance images which are displayed in the **Luminance image** tab of the **LMK LabSoft**. If a stored evaluation image is to be evaluated with the AddOn, it must be loaded or copied into the **Luminance image** tab.

1.4 Structure of the main dialog

All the necessary control elements and input fields for the **Glare analysis** are thematically grouped into operating groups in the main dialog. The functions of the individual groups and the operation of the dialog are explained in the following chapters.

- Viewing direction
- Settings
- Calculations

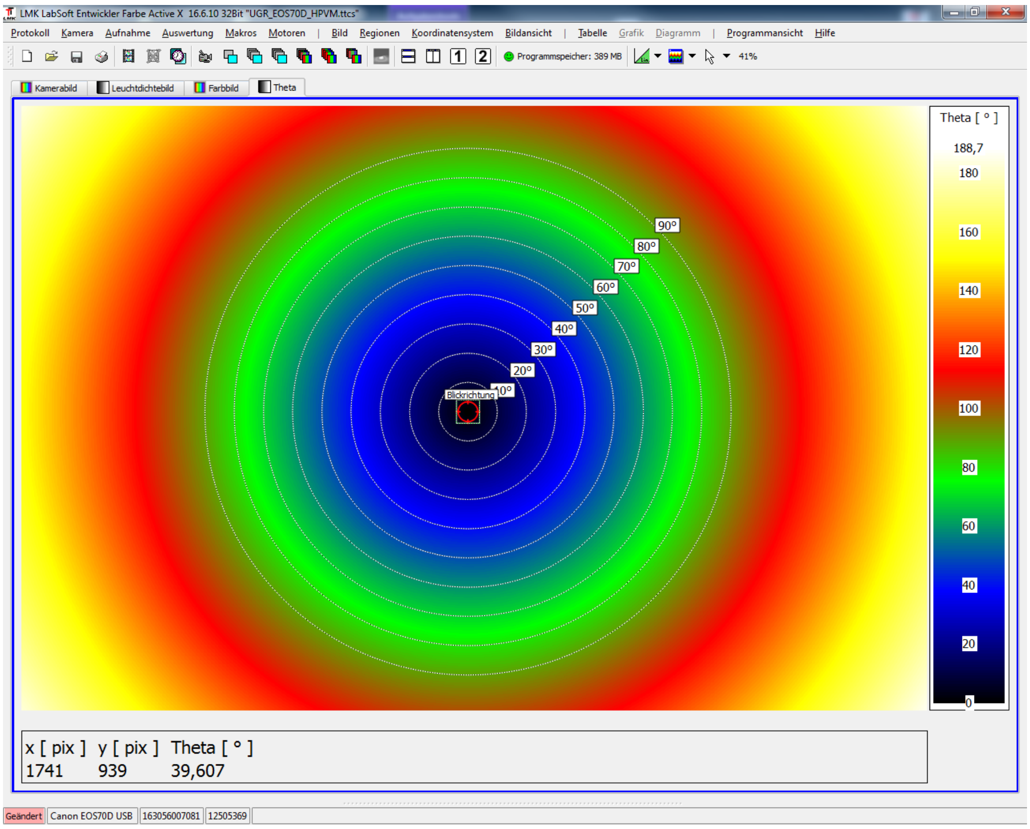
Cross-functionalities are indicated by means of text references in the corresponding chapters and sections.



1.5 Functionality of the Theta image

The calculated **Theta** image shows the relationship between the viewing direction of the lens and the image area. This gives the user an overview of the image coordinates (x, y) and the corresponding image field angle **Theta** in degrees [°]. The representation is a polar angle coordinate system.

Pixel-by-pixel values of the image field angle **Theta** are shown in the status line while moving the cursor over the image. For better orientation, circular regions with a distance of 10° half the field angle **Theta** and the position of the optical axis are indicated.



1.6 Control button: Manual

The control button **Manual** opens the manual of the **Glare analysis**. An installed program for opening and reading PDF files is required for opening. The PDF file of the manual is located in the installation path of the **LabSoft** in the subdirectory:

.../Macros/Glare_Analysis/doc.

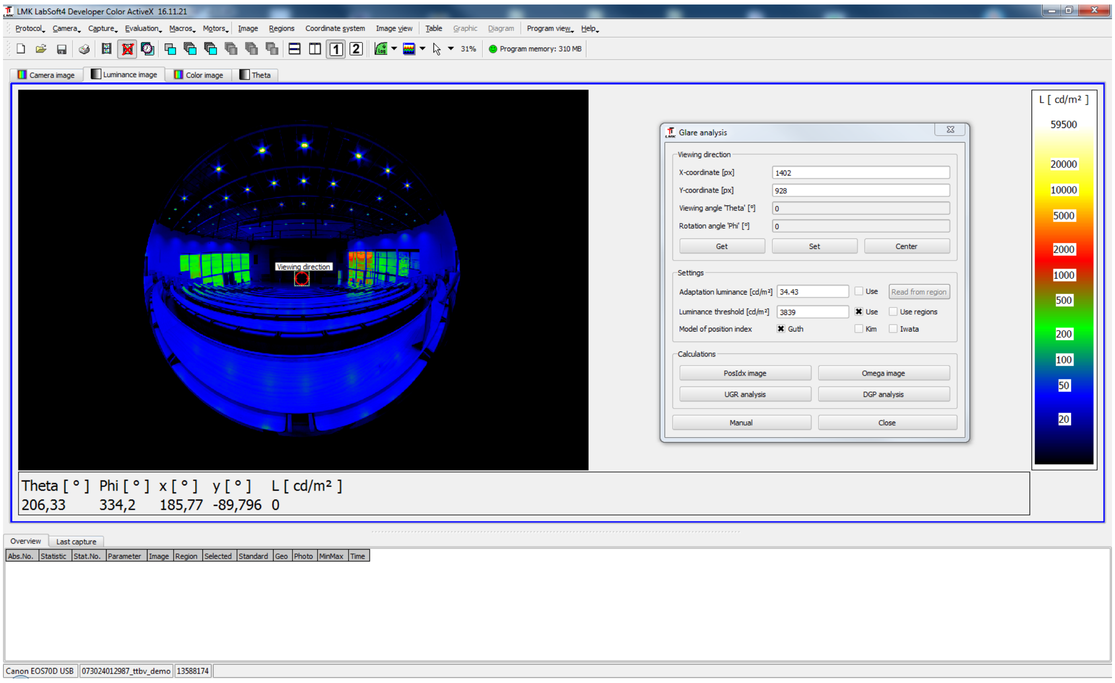
1.7 Control button: Close

The control button **Close** closes the Addon. When the **Glare analysis** is ended, the current settings of the main dialog are saved for the following parameters.:

- Set coordinates in the operating group **Viewing direction**
- Input field with value for the adaptation luminance
- **Use** option of the adaptation luminance
- Input field with value for the threshold luminance
- **Use** option of the threshold luminance
- Model used for the position index

2 Viewing direction

The position of the optical axis is set and displayed in the operating group **Viewing direction**. The adjusted optical axis of the lens is displayed with the crosshair area in the **Luminance image**. The underlying coordinate system are angular coordinates in polar representation. The rotation angle Phi is orientated counter-clockwise and begins / ends at 0° and 360°, respectively, at the right side of the image. Therefore 90° are on top, 180° at the left side, and 270° at the bottom of the image. All angular relations, the position indication of the glare sources, the determination of the position index and many more are dependent on the position of the **Viewing direction** in the **Luminance image**.



The input fields **X-coordinate [px]** and **Y-coordinate [px]** give the position of the **Viewing direction** in pixel coordinates. The image pixel coordinates can be changed to adjust the position of the **Viewing direction** in the **Luminance image**. In order to accept a change of these two input fields and also the representation of the optical axis in the **Luminance image**, **Set** must be pressed.
In addition, it is possible to adjust the **Viewing direction** with the cursor directly in the **Luminance image**. In order to accept this change in the main dialog, the **Get** button must be pressed. In the two text fields **Viewing angle 'Theta' [°]** and **Rotation angle 'Phi' [°]** the corresponding polar angle coordinates to the set image pixel coordinates are displayed .

Functional overview of the control buttons:

- **Get**: Read and adopt the current coordinates of the **Viewing direction** into the main dialog.

- **Set**: Draws the crosshair according to the input fields **X-coordinate [px]** and **Y-coordinate [px]** in the **Luminance image**.

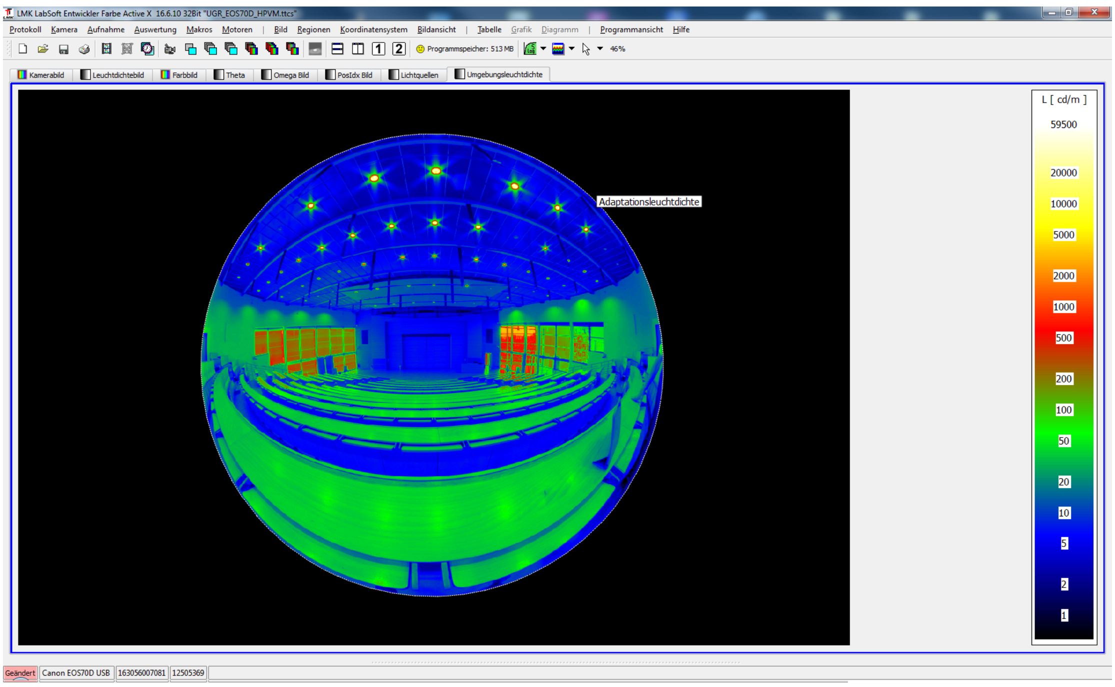
- **Center**: Set the crosshair **Viewing direction** in the **Luminance image** to the position of the optical axis of the LMK system.

3 Settings

In this operating group, the control buttons and input fields for important input values are accommodated. These are the Adaptation luminance [cd/m^2], the Threshold luminance [cd/m^2] and the model for the position index. The Adaptation luminance and the Threshold luminance can be automatically determined by the AddOn during execution. However, it is additionally possible to enter manual specifications via the input fields.

3.1 Adaptation luminance

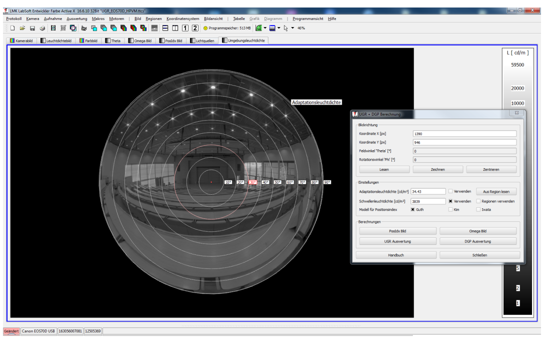
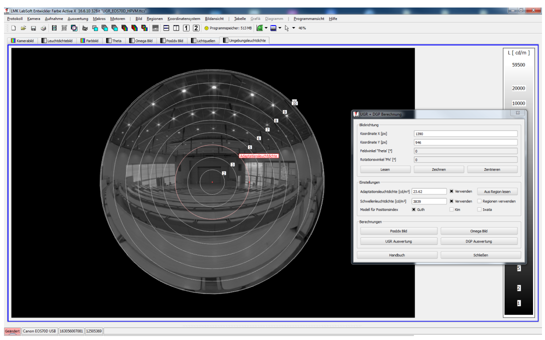
The Adaptation luminance serves as a number for the state of adaptation of the observer. The glare effect caused by a lighting situation is decisively dependent on the adaptation state of the human eye. The Adaptation luminance displayed in the dialog has two different meanings when executing the **Glare analysis**.
When determining the **UGR** value, the Adaptation luminance is equal to the Ambient luminance in the **UGR** calculation formula. The Ambient luminance is defined as the mean luminance of the entire measuring range or the field of view. Where active light sources are not taken into account. Once the evaluation is started with the control button **UGR analysis**, a luminance value is defined as a Threshold value by means of an automated method 3.2.1. Afterwards the image areas [px] of the passive ambience and the active light sources are classified with this value. In the following, this process is referred to as glare source detection. The Adaptation luminance is derived from the image areas [px] which are classified as ambience.



The user can also specify the Adaptation luminance in the input field manually. Turning on the **Use** option in the same line suppresses the automatic re-determination when running the analysis again.
Alternatively the user can specify another measuring area by creating a new or modification of the existing region in the **Ambient light** image (created during the initial execution). Then the mean luminance of the changed measuring region is taken over as Adaptation luminance when pressing the command button **Use regions**. In this case as well, the automatic re-determination is suppressed when the analysis is executed again and the selected measuring region in the **Ambient light** image will be renamed into **Adaptation luminance** for documentation. The **Use** option will automatically be activated by pressing the command button **Use region**. The luminance value displayed in the input field **Adaptation luminance [cd/m^2]** will also be displayed in the **UGR table** for documentation.

CAUTION: In the case of the above mentioned actions, the active light sources are also not taken into account for determining the Adaptation luminance!

In the second meaning, the Adaptation luminance serves as input for the vertical illuminance Ev[lx] at the eye of the observer. This number is used as a measure for the adaptation state of the observing eye for the **Glare analysis** on daylight impact according to the DGP method. For this purpose, the mean luminance of the selected region is multiplied by the size of the measuring field [sr]. The calculated vertical illuminance Ev [lx] is given in the **DGP table** instead of the mean luminance. Even in this application, the automatically defined measuring region for the adaptation can be subsequently changed in the **Ambient light** image.

3.2 Threshold luminance

On the basis of the Threshold luminance [cd/m^2], a classification of two luminance measuring ranges is carried out. Image pixel [px] with a luminance value greater than the Threshold luminance are considered as a light or as a glare source, respectively. Image pixel [px] with a lower luminance value are assigned to the passive ambiance. With the image pixel [px] of the ambiance the Adaptation luminace will be determined (see section 3.1).

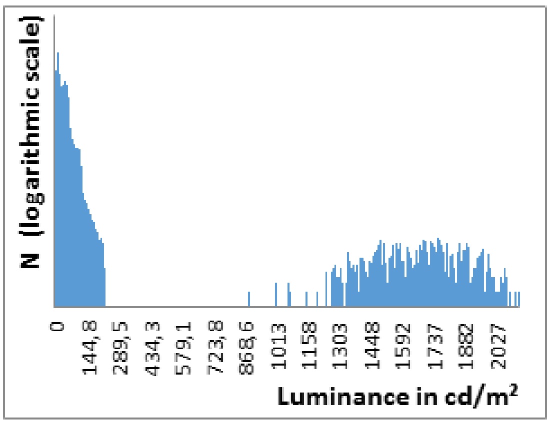
The Threshold luminance is determined in an automated process according to Wolf (see sections 3.2.1 and 3.2.2). The result of the automatic glare source detection is displayed in the image **Light sources** (created during the initial execution).
The user can influence the result of the automatic classification by changing the regions in this image. When the option **Use regions** is set, current measuring regions in the **Light sources** image are used for the UGR and DGP analysis. Alternatively, the user can manually specify a Threshold luminance in the input field **Threshold luminance [cd/m^2]**. By activating the option **Use** in the same line, the Threshold luminance displayed in the input field is used for the determination of active light sources. The result is also drawn into the image **Light sources**. The automatic re-determination of the light sources is deactivated in both cases.

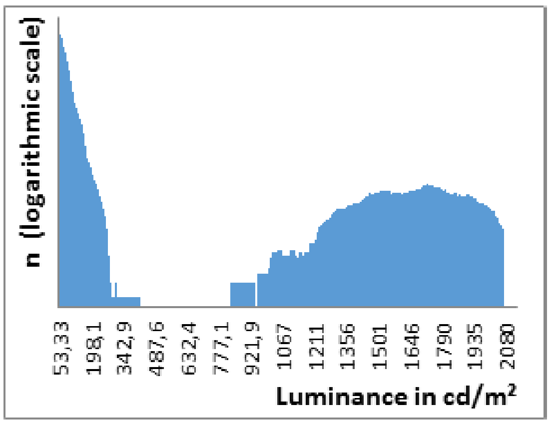
3.2.1 Modified histogram

The method for determining the Threshold luminance is based on the histogram of the luminance in the image [px]. In this so called luminance histogram you can usually see two clusters. One for the ambient luminances and a second for the luminances of the light sources. The value for the Threshold luminance can be somewhere between.

In reality, there are no homogenous environments and the local luminance distributions of the light sources can be very inhomogeneous. As a result, two very strongly pronounced maxima rarely result in a luminance histogram. There is a distribution of their maxima, separated by more or less pronounced local minima.

In order to optimize this local minimum in the luminance histogram for the determination of the threshold luminance, the histogram is modified in two steps.
The first step is a local filtering of the source luminance image using a threshold contrast (see section 3.2.2). In the second step, the luminance histogram of the filtered source image is then smoothed with the aid of a sliding mean value (g = 7). As a result, all less pronounced local minima and maxima are suppressed.





Thus the modified and smoothed luminance histogram serves to determine the threshold luminance. It is located at the beginning of the first local minimum following the global maximum in the direction of increasing luminances. The basic idea behind is that most of the image pixel [px] are representing ambient luminance values and furthermore that light sources have always greater luminance values than the ambience.

This method also works if several light sources with different luminance values are presented in the source image.

3.2.2 Local contrast threshold

A much better separation of the light source and ambient pixel can be achieved by using a modified histogram. For this purpose, image pixel which have a high gradient in the histogram are not taken into account. Pixel with a high gradient G(x, y) are located at edges of objects, for example at the edges of the light sources.

For the application of the modified histogram for determining a Threshold luminance the method is adapted in such a way that instead of the gradient G(x, y), a contrast of a pixel and its minimum neighborhood is used. The minimum neighborhood is defined as (x_{i-1},y_j) (x_{i+1},y_j) (x_i,y_{j-1}) and (x_i,y_{j+1}).
The contrast determined is called the local contrast C_{loc} and is calculated as follows:

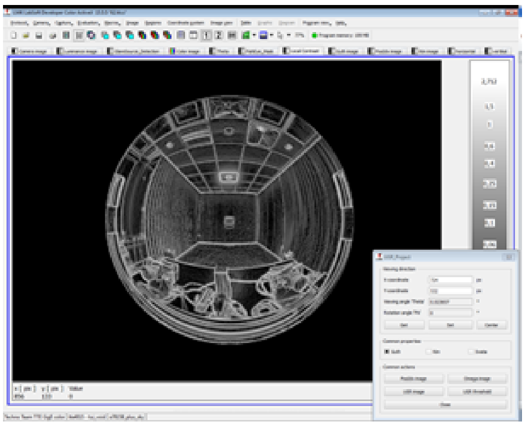
$$C_{\text{loc}}(x_{\text{i}}, y_{\text{j}}) = \sqrt{\left(\frac{\partial L}{\partial x}\right)^2 + \left(\frac{\partial L}{\partial y}\right)^2}$$

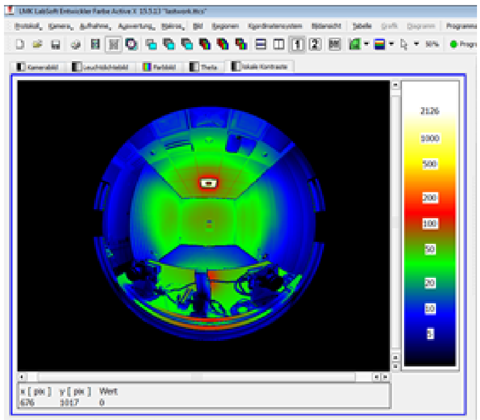
with

$$\frac{\partial L}{\partial x} = \frac{L\left(x_{\text{i}+1},y_{\text{j}}\right)-L\left(x_{\text{i-1}},y_{\text{j}}\right)}{L\left(x_{\text{i}},y_{\text{j}}\right)}$$

$$\frac{\partial L}{\partial y} = \frac{L\left(x_{\text{i}},y_{\text{j-1}}\right)-L\left(x_{\text{i}},y_{\text{j}+1}\right)}{L\left(x_{\text{i}},y_{\text{j}}\right)}$$

A limit of $C_{loc,th} = 0.25$ was empirically determined and set for the local contrast C_{loc}. Image pixel with a local contrast C_{loc} above that limit are not included in the histogram.





3.3 Modell of the Position index

Three different models for the Position index are available for the analysis of psychological glare by artificial or daylight. The Position index has the function to weight the image of the glare source on the human retina according to its position. The viewing angle under which the light source is observed is decisive. The larger the viewing angle, the more we perceive the light source peripherally. This reduces the glare of that light source for the observer.

Simply spoken the Position index is a perception model of our retina. In the central retinal field *fovea centralis*, the density of light-sensitive receivers is significantly higher than in the outer regions.

In the measurement standard for the **UGR**, the Position index defined by Luckiesh and Guth is prescribed for the determination of the UGR value. Turning on the option **Guth** in the main dialog activates it. For the calculation of the **DGP** value, Wienhold proposes in his work the use of the Position index defined by Kim for the half sphere above and by Iwata for the half sphere below the line of sight. This means the measuring ranges of 0° - 180° above and of 180° - 360° below the viewing direction. By activating the options **Kim** and **Iwata**, these models can be activated for the analysis.
The definition of the Position index by Iwata was only made for the lower half-sphere (180° - 360°). The model by Luckiesh and Guth and the model by Kim can be combined with the Iwata model.

CAUTION: The option **Iwata** can not be activated individually!

When running the analysis of the **UGR** or the **DGP** value the selected model type of the Position index is displayed for documentation in the respective evaluation table. Additionally each model type can be calculated and displayed as an image **PosIdx** in LabSoft.

4 Calculations

In this operating group, the control buttons **UGR analysis** and **DGP analysis** for determining the respective glare numbers can be found. By pressing each of the control buttons, the result for the glare is calculated and displayed in a table together with additional informations. The additional informations are used to interpret the determined glare index. A detailed explanation of the evaluation tables can be found in the following chapter (5).

4.1 PosIdx image

Using the control button **PosIdx image** allows to create an image of the Position index according to recent settings in the user dialog. The relevant parameters for the Position index are the model used (see section 3.3) and the position of the virtual direction of view (see section 2). The displayed image **PosIdx image** is used for the calculation of the UGR or DGP glare indices.
It is not absolutely necessary to display a **PosIdx image** for the calculation. If no image was pre-calculated, the program automatically processes the needed Position indices as background operation.

CAUTION: If the settings for the Position index are changed, the new settings are only displayed after recalculation of the **PosIdx** Image, or are not used until deleting the currently displayed image!

4.2 Omega image

Using the control button **Omega image**, it is possible to generate an image for the solid angle. The so called **Omega image** displays the solid angle increments per pixel and thus will be used for the processing of the UGR or DGP glare indices. The presented solid angle image depends on the selected camera-lens combination (see section 1.2).
It is not absolutely necessary to display an **Omega image** for the calculation. If no image was pre-calculated, the program automatically processes the needed solid angle increments as background operation.

4.3 UGR analysis

Using the **UGR analysis** control button, the calculation of the UGR index is carried out. For this purpose, the following intermediate steps will be done:

- Automatic determination of the Threshold luminance. If not set otherwise in the dialog!

- Automatic determination of glare sources.

- Automatic determination of the adaptation luminance. If not set otherwise in the dialog!

- Determination of the Position index of the glare sources.

- Determination of the Solid angle of the light sources.

- Processing of the UGR index and auxiliary information.

- Create and display an evaluation table.

The step-by-step processed parameters and measuremed values are used in the following formula according to CIE publication 117 for the calculation of the UGR index:

$$UGR = 8 \cdot \log \left(\frac{0{,}25}{L_u} \cdot \sum_i \frac{L_i^2 \cdot \omega_i}{p_i^2} \right)$$

with:

- L_u mean luminance of the surroundings without glare sources

- L_i mean luminance of the glare source

- ω_i solid angle of the glare source, determined by pixel-wise summation

- p_i Position index of the glare source, determined for the x,y image coordinates of the photometric center of gravity

4.4 DGP analysis

Using the **DGP analysis** control button, the calculation of the DGP index is carried out. For this purpose, the following intermediate steps will be done:

- Automatic determination of the Threshold luminance. If not set otherwise in the dialog!
- Automatic determination of glare sources.

- Automatic determination of the adaptation luminance. If not set otherwise in the dialog!

- Determination of the Position index of the glare sources.

- Determination of the Solid angle of the light sources.
- Processing of the UGR index and auxiliary information.
- Create and display an evaluation table.

The step-by-step processed parameters and measuremed values are used in the following formula according to the publication by WIENOLD and CHRISTOFFERSEN using the **EvalGlare**-software tool for Radiance:

$$DGP = 5,87 \cdot 10^{-5} \cdot E_v + 9,18 \cdot 10^{-2} \cdot \log\left(1 + \sum_i \frac{L_{s,i}^2 \cdot \omega_{s,i}}{E_v^{1,87} \cdot p_i^2}\right) + 0,16$$

with:

- E_v vertical illuminance at the observers eye - determined as the product of the mean luminance and the solid angle of the ambiance. The ambiance area taken into account can be defined in the **Ambient light** image by adjusting the region **Adaptation luminance**.
- L_i mean luminance of the glare source
- ω_i solid angle of the glare source, determined by pixel-wise summation
- p_i Position index of the glare source, determined for the x,y image coordinates of the photometric center of gravity

5 Evaluation table

The control button **UGR analysis** or **DGP analysis** carries out the calculation of the UGR or DGP index. The respective result is displayed in the **UGR table** or the **DGP table** together with auxiliary results. The additional information can be used to interpret the calculated glare index.:

- **Number**: Provides information about the number of glare sources detected.
- **Type PosIdx**: Displays the model of Position index used for the analysis.
- **Adaptation**: Displays the Adaptation level. For the UGR analysis this value is specified in [cd/m^2]. For the DGP analysis this value is used and specified in the DGP table in [lux].
- **Threshold**: Shows the Threshold luminance used to classify the glare sources.
- **Measure values**: In the first 4 lines, the auxiliary values for each individual glare source are named. The last line indicates the type of the processed glare index.
- **Sum**: The last line shows the integral result of the glare analysis.
- **LQ1 ...**: Individual auxiliary photometric and geometric values are processed and displayed for each detected glare source [LQ] in a separate column. The count of columns depends on how much glare sources are available.