LUMINANCE ANALYSERS - WHAT THEY ARE AND HOW DO THEY WORK

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ABSTRACT

With luminance cameras it is possible to measure the luminance distribution of a scene as well as its geometrical properties if the camera is appropriately calibrated.

Devices capable of mostly automatic photo diagnostics of complex luminance scenes based on photometric and geometrical values are called "Luminance Analysers".

The fundamental construction and functionality are discussed in this paper as well as the results of a sample application.

ZUSAMMENFASSUNG

Mit Leuchtdichtemesskameras können sowohl Leuchtdichteverteilungen einer Szene als auch ihre geometrischen Eigenschaften bestimmt werden, wenn die Kamera entsprechend kalibriert wurde.

Geräte, die in der Lage sind, eine komplexe Leuchtdichteszene ausgehend von deren photometrischen und geometrischen Eigenschaften weitgehend automatisch zu analysieren werden Leuchtdichte-Analysatoren genannt.

Der grundsätzliche Aufbau und Funktionsweise als auch die Ergebnisse einer beispielhaften Anwendung werden in diesem Artikel dargestellt.

Keywords: luminance, image resolved measurement, glare rating, Luminance Analyser

1. INTRODUCTION

With luminance cameras it is possible to measure the luminance distribution of a scene as well as its geometrical properties if the camera is appropriately calibrated.

Both applications were published in the past. Berutto, Fischbach etc. have described the measurement of luminance using CCD cameras [1-3]. The field of geometrical measurement using image resolved sensors is also commonly known, mainly without any relation to lighting measurement.

The resolute exploitation of the possibilities to measure photometrical and geometrical (photogrammetrical) values at the same time with the same equipment in conjunction with special evaluation routines brings a new quality in determination of classification numbers of illumination facilities.

Devices capable of mostly automatic photo diagnostics of complex luminance scenes based on photometric and photogrammetric values are called "Luminance Analysers" [5-7].

2. FUNDAMENTAL CONSTRUCTION AND FUNCTIONALITY

A Luminance Analyser developed and implemented at our department consists of a photometrical and geometrical calibrated CCD camera, a portable PC equipped with an image processing board (frame grabber) and a motor control unit, and the necessary software (figure 1). This device can measure luminances with a very high spatial resolution and with a large solid angle.

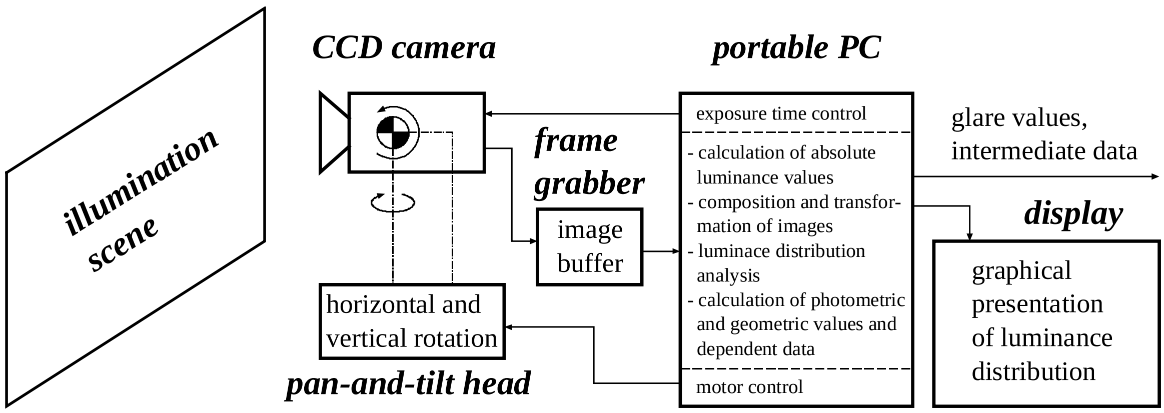

Figure 1: Principle of the Luminance Analyser

This was achieved with a telephoto lens and a CCD camera mounted on a pan-and-tilt head (figure 2). This 2-axis camera mount allows the camera to be rotated around the horizontal and one vertical axis with accurately defined angles. Together with the distortion correction of the camera, a target luminance image is composed from a multitude of high-resolution images taken at various camera orientations.

The camera and its CCD chip are optimised for accurately measuring luminances. This includes the spectral (V(λ)-)correction, shading correction, the compensation of dark current and temperature-drift, as well as the absolute calibration of the system.

The composite high-resolution luminance image is the starting point of the real luminance analysis. Through spatial calibration pixel coordinates are directly related to polar angles subtended by the pixel relative to a defined line of sight.

Therefore, all luminance and geometric properties of a scene can be calculated. For instance, the direct and indirect luminance at the camera position in any plane can be determinated, as well as average luminances and luminance ratios.

The next step of the luminance analysis is the classification of the image. For each part of the image a decision is made whether it belongs to a luminaire or the background, to any window or wall or similar groupings depending on the task to be performed.

The realised Luminance Analyser was designed for measurements of glare indices, so it is important to know if a point is part of a light source or not. The criteria used is a luminance threshold. If the luminance of an object area is higher then the threshold luminance then it is part of a light source, otherwise it belongs to the background.

After the classification a numerical list of all contiguous light source areas is generated. Such a contiguous area is now called "luminance object". For each luminance object a number of values can be calculated based on measured luminance and geometry, for instance:

– Average luminance
– Angles relating the source location to the line of sight
– Position index
– Solid angle of the source
– Illuminance on the observer's eye (glare illuminance) caused by this light source.

It can be seen that all the values are required for calculating glare values.

The following glare ratings have been implemented: Daylight glare index (DGI), threshold increment (TI), Contrast Reduction Index (CRI) and unified glare rating (UGR). Different glare ratings such as discomfort glare rating (DGR) and visual comfort probability (VCP) can be added easily as needed.

Figure 2: View of the measurement head

3. SAMPLE APPLICATION

Practical measurements of UGR-values were done on interior lighting systems in order to evaluate the Luminance Analyser. The readings obtained were compared to values derived with different methodologies. In the following a short summary about this will be given, for further details please refer to [4].

These investigations were done in rooms with uniform reflectance's on the walls, the floor and the ceiling. The URG formula values were obtained by applying the UGR formula on conventional measured data. The UGR table is part of the luminaire documentation and ignores the real observers position. Table 1 shows the taken results.

		Calculation	Luminance Analyser
No.	URG formula	UGR table	Measured UGR value
1	< 10	21,2	5,00 i.e. < 10
2	< 10	21,2	-8,13 i.e. < 10
3	20,0	21,2	20,77
4	24,5	21,2	25,31
5	19,2	21,1	19,22
6	19,6	21,5	19,65
7	< 10	15,1	7,55 i.e. < 10
8	13,1	13,5	14,40
9	16,1	13,5	9,14 (15,26)
10	13,4	12,4	14,40

Table 1: Comparison of calculated and measured glare ratings in test rooms

As it can be seen there is a very good consistency between the UGR formula value and the measured glare rating. The only remarkable difference occurs in case no. 9 (16,1 vs. 9,14).

There are parts of luminaires outside the range of the position factor, and therefore ignored by the evaluation routines of the Luminance Analyser. For this reason a modification of the software was done. The measured URG value by the Luminance Analyser in this case is now 15,26, all other situations in the upper table are not affected by the modification.

CONCLUSIONS

The Luminance Analyser illustrated above can be used for glare assessment in complex environments. The device improves over traditional glare measurements by its automated procedure and short measurement cycles (a 180 degree field will take about 45 minutes by a single operator).

All parameters required for a detailed analysis can be taken effortlessly compared to individual measurements. Since the device is very portable, it can be used to take field measurements of illuminance distributions, luminance, glare indices etc. It is anticipated that the Luminance Analyser will become the preferred method of the evaluation and assessment of lighting installations.

Other interesting applications of the principle of pixel resolved luminance measurements can be seen in lighting laboratories where it can revolutionise the design of goniophotometers by creating a new breed of near-field goniophotometers, as well as much improved devices for measuring the spatial distribution of luminous intensity, illuminance and reflectance.

Yet another very topical application is the image resolved measurement of colour values [8].

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