VIDEOGRAPHY APPLICATION TO INDOOR ENVIRONMENT

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ABSTRACT

In recent years, the availability of video-cameras with CCD-type sensors (Charge Coupled Device) has given considerable impulse to the use of videography system for all applications requiring photometric measurements, above all the luminance evaluation. With reference to the measurement of luminance in a built-up environment, this method is particularly interesting because it allows the instantaneous capture of an image, thereby obtaining luminance values relating to different points of measurement.

In this paper, a brief description of this acquisition system is reported and then a report on the procedure adopted for its calibration with a zoom and a fish-eye lens is presented. Finally, with reference to an office application, a case study on videoluminancemeter potentiality features in the built environment is reported; the results are compared with values obtained using a traditional luminancemeter, and the potentiality of video-camera in the assessment of Italian standard prescription is shown too.

1. INTRODUCTION

In recent years, the availability of video-cameras with CCD-type sensors (Charge Coupled Device) has given considerable impulse to the use of videography system for all those applications requiring photometric measurements, above all the luminance evaluation; some examples of videography application, also said videoluminancemeter, regard mobile measuring systems for the evaluation of road lighting system performance, availability of daylighting data, definition of the photometric properties of lighting apparatus, etc... [1-6].

With reference to the measurement of luminance in a built-up environment, this method is particularly interesting because it allows the instantaneous capture of an image, thereby obtaining luminance values relating to different points of measurement. This in turn leads to the evaluation of luminance distribution and lighting levels of the built environment surfaces; this feature can be conveniently applied for a verification of prescribed standards and the assessment of lighting performance and user comfort.

The Lighting Technology Laboratory at DETEC – University of Naples Federico II, Italy – set up a measuring system based on the use of a video-camera.

In this paper, we give a brief description of this acquisition system and subsequently a report on the procedure adopted for its calibration with a zoom and a fish-eye lens. The calibration procedure concerns essentially spectral response and the overall transfer function relating to the passage from a radiation input to a numerical output in which the luminance values are expressed.

Finally we report, with reference to an office application, a case study on CCD potentiality features in the built environment; the results are compared with values obtained using a traditional luminancemeter, and the potentiality of CCD in the assessment of Italian standard prescription is shown too.

2. THE VIDEOGRAPHIC SYSTEM

This method of measurement consists of the instantaneous capturing of an image by means of an appropriate lens. The image is then acquired by the video-camera sensor; point by point the intensity of light projected onto the sensor is transduced into a proportional electric signal and subsequently, by means of an A/D converter, the computer-processed image is obtained.

The utilised video-camera is an industrial B/W telecamera [7], fitted with separate head, and an electronic shutter of 1/60th to 1/10.000th of a second, whose sensory element is a CCD 2/3" sensor with 756 (H) × 581 (V) pixel matrix.

The video-camera has a dynamic range of 50 dB, and the radiometric sensitivity has been set at $\gamma = 1$; the Automatic Gain Control (AGC), that is to say the automatic regulation of the quantity of incoming light, was deliberately disenabled so as...
to keep the input/output relationship at a constant level for whatever range of measured values.

The optic interface consists of a zoom (focal length is 50 mm) with manually-regulated lens aperture from f/3.5 to f/22 and a fish-eye lens (focal length is 16 mm) with manually-regulated lens aperture from f/2.8 to f/22; the lens are provided with an appropriate ring-adapter between the photographic optic with a bayonet-mount and the video-camera with a C-mount; the optical interface is completed by an appropriate photopic filter. For both lenses during calibration, the focal length is kept constant while lens aperture is manually changed.

The measuring chain is also equipped with an appropriate size digitalisation-card (i.e. a 256 grey scale image capture and display board, 1024*1024*8 bit) inside a PC, and with the software for the analysis and processing of the image.

3. CALIBRATION OF THE VIDEOGRAPHIC SYSTEM

Neglecting problems related to video-camera modulation transfer function, and other influences such as cross talking between pixel rows and local variation of pixel sensitivity, the calibration of the measuring system concerns [8-12] essentially spectral response and the overall transfer function related to the passage from a radiation input to a numerical output in which the values of luminance are expressed.

As far as the spectral response of the acquisition system is concerned, in the first instance the lens was fitted with a CVI photopic filter in order to match the spectral response of a standard CIE observer. An experimental apparatus (Fig. 1) was set up [11-13] by which the spectral video-camera sensitivity has been verified: the obtained spectral sensitivity curves regarding zoom and fish-eye lens are reported in Figs. 2a and 2b. In these figures for the zoom lens (Fig. 2a) and for the fish-eye lens (Fig. 2b), the relative sensitivity of the video-camera is reported as a function of the wavelength \(\lambda\), compared with the standard CIE curve.

The “on-axis” video-camera calibration was accomplished by setting up the photometric bench as shown in Fig. 3. A 120 mm sample target was placed at one end of the photometric bench (1.2 m length), situated inside a room in which efforts were made to keep reflections to a minimum, while on the other end, a reference lamp with luminous intensity of 290 cd was placed on runners, and powered by a constant supply (30,568 V - 5,903 A) from a DC unit. Along opposite sides of the photometric bench, the following were arranged: a precision luminancemeter (with a measuring angle of 1°) connected to a data acquisition system, and the video-camera connected to an appropriately-configured personal computer.

Fig. 1: Experimental apparatus for spectral response
The calibration was carried out [13, 14] by varying the distance of the test lamp with respect to the target, while both the luminancemeter and the telecamera were focused on its central zone; once the desired luminance value had been reached, the image filmed by the telecamera was captured and digitalised (provided the sensor had not reached saturation point), thereby connecting the corresponding greyness level to the luminance value measured by the luminancemeter. This procedure was carried out both for zoom and fisheye lens varying lens aperture; the results are displayed in Figs. 4a and 4b. As can be seen from the resultant experimental data, the relationship between the scale of greyness and luminance is non-linear, for any of the lens apertures; with very close approximation, the data are interpolated from a second order polynomial function.

In Figs. 5a and 5b, the calibration data are rearranged considering, for each lens aperture, the minimum and maximum luminance values detectable by the video-camera; for example, for both the utilised lenses, points C and D represent, respectively, the maximum and the minimum luminance value detectable by the video-camera with a lens aperture equal to f/22. This representation can help the video-camera users in selecting the suitable lens aperture when a measurement is claimed in a certain range of luminance.

![Fig. 2a: Comparison of CIE and zoom lens spectral response curves](image1)

![Fig. 2b: Comparison of CIE and fisheye lens spectral response curves](image2)
Legend
A Computer (PC – Pentium 120 MHz, HD 1 Gb, with image capture board)  H Data acquisition unit
B CC Power supply  I Color video monitor
C A/D Converter  L Keyboard  M Target
D B/W CCD Video-camera  R Graduated guide-rail  T Dark curtain
E Movable crossbar  
F Standard lamp (power: 100 W)  
G Luminancemeter  
(angular measurement field: 1°)

Fig. 3: Experimental set-up for videoluminancemeter calibration

Fig. 4a: Calibration curves for zoom lens
Fig. 4b: Calibration curves for fish-eye lens

Fig. 5a: Zoom lens measurement range

Fig. 5b: Fish-eye lens measurement range
4. APPLICATION OF THE VIDEO-CAMERA

The CCD camera peculiarity of mapping luminance distribution in interior and its capability to perform photometric measurement have been investigated by a field test referred to an office application. The analysed office (Fig. 6) is lighted by six ceiling surface mounted luminaries with fluorescent lamps; a VDT type task was then set up to explore videoluminancemeter application in interior.

![Fig. 6: The analysed office](image)

The author’s intention was the assessment of the UNI 10380 Italian standard [15] prescription for visual task as reported in Table 1. The UNI 10380 (“Lighting – Interior lighting with artificial light”) reports various prescriptions for the interior lighting, such as those related to minimum recommended illuminance values for different applications, illuminance uniformity, glare limitation, colour temperature, colour rendering index and luminance distribution; about the last topic, luminance of visual task and luminance of surroundings should be balanced, so the luminance ratio values should not exceed the limit values as indicated in Table 1.

The measurement was carried out by videoluminancemeter, fitted with the fish-eye lens in order to enlarge the field of view, and by a traditional luminancemeter in order to perform the appropriate comparison; both instruments were located considering the actual position of a VDT’s operator.

In Fig. 7, considering the image acquired by the video-camera, both instrument measurements are reported (in particular the videoluminancemeter ones are in brackets); the result comparison suggests that the mean square deviation is about ± 8.5%, and this confirms the ± 10% value proposed in the technical literature as accuracy limit that affects this type of instrumentation [16].

A further investigation was carried out for standard prescription verification as reported in Table 1; this was accomplished by performing a luminance mapping (Fig. 8) and then its elaboration in terms of ratios between visual task and surroundings. A mapping of luminance ratios is reported in Fig. 9 to verify items 1-4 of standard (as in Table 1), while Figs. 10 and 11 report videoluminancemeter verification of items 5 and 6 (as in Table 1). It can be quickly inferred that all prescriptions are respected.

Finally, with reference to the evaluation of reflecting glare on a VDT’s screen due to the lighting source, as reported in Fig. 12, the luminance mapping permits to check that the luminance reflected on the screen, limited to the value of 420 cd/m², not exceeds the limit value of 500 cd/m² as suggested by prescriptions.

<table>
<thead>
<tr>
<th>Type of work place</th>
<th>Luminance ratio limit values</th>
<th>X</th>
<th>Y</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Between visual task and contiguous dark surfaces</td>
<td></td>
<td>3/1</td>
<td>3/1</td>
<td>5/1</td>
</tr>
<tr>
<td>2 Between visual task and contiguous light surfaces</td>
<td></td>
<td>1/3</td>
<td>1/3</td>
<td>1/5</td>
</tr>
<tr>
<td>3 Between visual task and far dark surfaces</td>
<td></td>
<td>10/1</td>
<td>20/1</td>
<td></td>
</tr>
<tr>
<td>4 Between visual task and far light surfaces</td>
<td></td>
<td>1/10</td>
<td>1/20</td>
<td></td>
</tr>
<tr>
<td>5 Between lighting source (luminaries, fenestration, etc.) and surroundings</td>
<td>20/1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 In the entire field of view</td>
<td></td>
<td>40/1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- X = places where it is possible to control the reflections in the entire field of view;
- Y = places where it is possible to control the reflections only near the visual task;
- Z = places where it is not possible to control the reflections.

Table 1: UNI 10380 (Italian standard) – Luminance ratio limit values for indoor application
Fig. 7: Single point measurements

Fig. 8: Luminance mapping

Fig. 9: Luminance ratio curves of visual task and surroundings

Fig. 10: Luminance ratio curves of light sources and surroundings

Fig. 11: Luminance ratio curves in the entire field of view

Fig. 12: Luminance mapping on a VDT’s screen – Reflected glare assessment
5. CONCLUSIONS

The “in-situ” evaluation of videoluminancemeter performance confirms that this instrument has high potentiality for a wide application in the assessment of “quality” of lighting in any indoor environment. In fact, it allows an accurate and quick image acquisition, and consequently a luminance mapping of indoor environment.

The setting up of this instrument has been performed for the evaluation of the quality of lighting in terms of luminance, luminance ratios or visual comfort indexes. Considering a videoluminancemeter with a suitable lens in order to match the visual field of an observer, the image acquired by the instrument can be assumed as “what the eye sees” and then the successively performed measurement conveniently gives useful information by means of evaluation of luminance, luminance ratios and glare indexes. On the contrary, the application of traditional luminancemeter, with a measuring angle of 1°, leads to an heavy and continuous repetition of measurement. The use of this sort of measuring system necessitates a more complex preliminary calibration process, since it is necessary to take a great number of parameters into consideration (lens aperture, type of lens, etc…), all of them influence the system’s performance.

ACKNOWLEDGEMENTS

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15. UNI 10380 Italian Standard, Illuminazione di interni con luce artificiale, UNI (1994).