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AN AUTOMATED GONIOPHOTOMETER FOR LUMINAIRE CHARACTERIZATION

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Abstract: This paper describes the design and construction of an automated goniophotometer. It consists of an optical-photometric system mounted on a positioning system, and its purpose is defined as luminaire characterization. The proposed model is based on the use of two mirrors in order to reduce the total size of the system. This original configuration is possible due to a motion control system which improves the general performances of the goniphotometer. The prototype has been tested and the results show higher accuracy and lower time to characterize a luminaire than other commercial solutions. *Copyright © 2002 IFAC.*

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1. INTRODUCTION

During the last year, quality assurance has spread to almost all productive sectors. Illumination industry, especially, is in a transition period where part of the laws and regulations amplifying the actual certification requirements have already been applied.

The certification of luminaires requires using a goniophotometer. So far, the certification of luminaires has been made with goniophotometers reproducing the methodologies proposed in the CIE (Commission Internationale de L'Éclairage) regulations. In those regulations the CIE proposes a series of structures which can be used to characterize luminaires. In general, it consists of measuring the luminous flux in different points of a virtual sphere with a certain radius and whose center is the luminaire. With those data it is possible to draw up a map of the luminous flux or of any other magnitude of interest.

The mentioned procedure involves some problems. First of all, the installations based on the CIE proposal run, to a great extent, manually: the luminaire is placed, the photometer is set in the required position, the measure is taken and the process is repeated. In addition to the inaccuracy inherent to this procedure, characterizing a luminaire takes a long time, and even more if we bear in mind that the CIE states a format for that information (CIE, 1993). Secondly, the radius of the virtual sphere used to take the measures depends on the size of the luminaire. In general, the radius obtained when applying the limits stated in the regulations is ten times the biggest dimension of the luminaire. Thus, to characterize 1.5 m luminaires (a fluorescent tube size which is becoming more and more regular), regulations state that the distance from the sensor to the luminaire must be, at least, 15 m.

This paper describes the development of a goniophotometer allowing the automatic luminaire characterization. First of all, some of the CIE proposals regarding goniophotometer characteristics, and the consequent restrictions in their design, are summed up. After that we describe the mechanical structure of the system, an innovation with regard to the CIE regulations and which allows to substantially reduce the goniophotometer size. Later we describe the control system, considering both hardware and functionality. Finally conclusions are presented.

2. PROBLEM STATEMENT

Luminous flux can be obtained mainly via three different methodologies (CIE, 1989): with a photometric sphere, using the measure of illuminance distribution, or using the measure of luminous intensity distribution.

2.1. LUMINOUS FLUX CALCULATION USING PHOTOMETRIC SPHERE.

A photometric sphere measures luminous flux comparing the luminous source with other standard sources. This technique is appropriate to characterizes sources whose flux varies sharply ('flash' lights), as well as to measure luminous flux as a function of time (CIE, 1989). This technique, however, it is not recommended to calculate the efficiency of luminaires whose luminous flux distributions in luminaire and lamp are considerably different.

2.2. LUMINOUS FLUX CALCULATION USING THE MEASURE OF ILLUMINANCE DISTRIBUTION.

To measure illuminance distribution it is used a goniophotometer describing a spherical surface around the luminous source. The luminous flux is obtained by integrating the illuminance measure along all the surface. It is not possible, however, getting the direct measure of another property quite often used to characterize light sources: luminous intensity distribution. The mentioned measure can be obtained, however, with a reasonable margin of error making some adaptations. Another possibility consists of using a goniophotometer with the capability to measure luminous intensity.

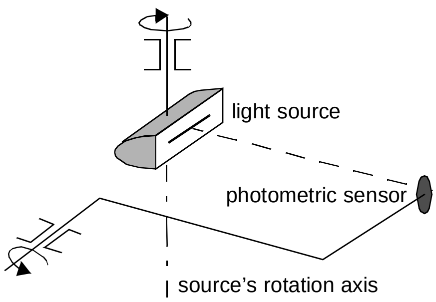

Fig 1. Goniophotometer with source rotation around the vertical axis.

The minimum distance between the luminous source and the optical-photometric system can be as small as allowed by mechanical restrictions. Angular resolution in polar and azimuthal axes must be better than 0.1º. The different configurations for such a goniophotometer attend to the shape of the relative movement of the photometer with regard to the light source. Those configurations can be (CIE, 1989):

1. With a fixed luminous source.
2. With the source moving only around the vertical axis (figure 1).
3. With the source moving around the vertical axis and with the lamp center displacing (figure 2). Luminous flux can be affected by the movement of the material within the luminous source.

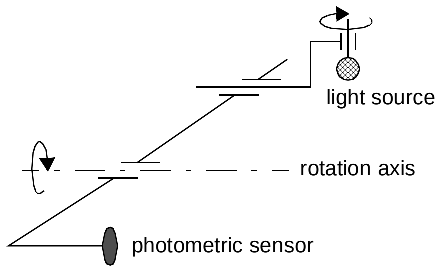

Fig 2. Goniophotometer with displacement of the source center.

2.3. LUMINOUS FLUX CALCULATION USING THE MEASURE OF LUMINOUS INTENSITY DISTRIBUTION.

If we use a goniophotometer able to characterize a luminous source's luminous intensity distribution, its luminous flux is immediately obtained. The problem with this kind of measures is that the optical-photometric system must be placed at a distance at least five times the biggest luminous source's dimension (photometric distance limit). This fact compels to build a positioning system with a considerable size which can be reduced using reflecting mirrors. Configurations recommended by the CIE (CIE, 1987) are:

1. Turning the luminous source (figure 3). It is inadvisable to get accurate measures, because auxiliary detectors are required and because not all the kind of luminous sources can be used.

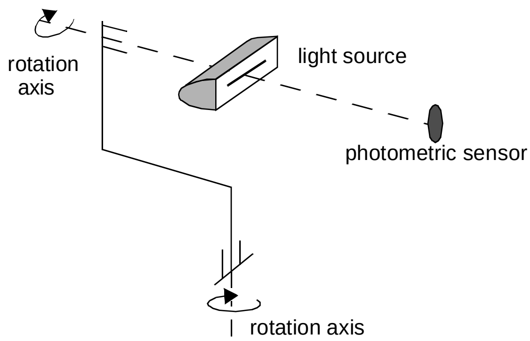

Fig 3. Turn of the luminous source.

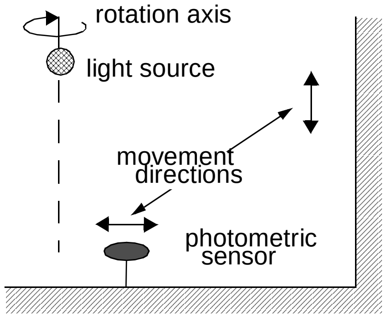

Fig 4. Goniophotometer with movement of the optical-photometric system.

2. Moving the optical-photometric system, or placing a sufficient number of photometric sensors in fixed positions (figures 1, 2 and 4).
3. Moving an auxiliary mirror (figure 5). It is appropriate to measure all kind of luminaires if the photometric distance limit is respected.

3. THE AUTOMATED GONIOPHOTOMETER

The adopted solution is based on the configuration explained in figure 5. With that structure, the photometric sensor should be moved away 20 m for luminaires with 0.5 m of equivalent radius (*R*), in order to comply with angle (ϕ) and photometric distance limit specifications. To diminish that distance a mirror system reducing the final installation volume is used (figure 7)

3.1.MECHANICAL STRUCTURE.

The system is configured as an arc turning around the luminaire's holding arm, designed in such a way that the center of the luminaire is placed just in the arc's

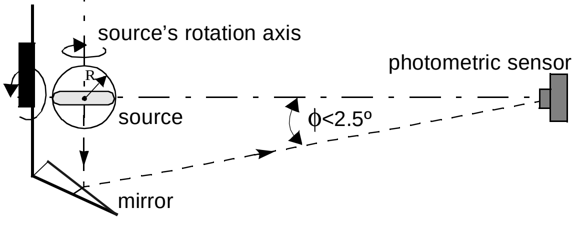

Fig 5. Goniophotometer with turning mirror.

Fig 6. Automated goniophotometer (auxiliary mirror not shown).

rotation axis (see figure 6). In one of the arc's ends is placed the photometer, and in the other one, a mirror. In front of the arc's rotation axis is placed another mirror. The luminaire's holding arm turns also around its vertical axis, in such a way that coordinating the movements of the two rotation axes and the photometer data acquisition, the result is a series of measures in a virtual sphere around the luminaire. The radiation coming from the luminaire is reflected by the arc mirror towards the second mirror, which finally forwards it to the photometer. This allows the system dimensions to be more reduced, since the mirrors 'fold' the cone made up by the luminaire's radiation.

As it has been previously said, there is a relation between the luminaire size and distance the photometer has to be placed at to get valid measures. According to this, the size of the machine is determined by the dimensions of the luminaire to be characterized. The structure has been built to characterized luminaires with a main axis of up to 0.7 m, and it can be installed on a plant of 3 m width, 5.5 m length and 3 m high. The elements have been made in steal and the total weight of the machine is around 450 kg..

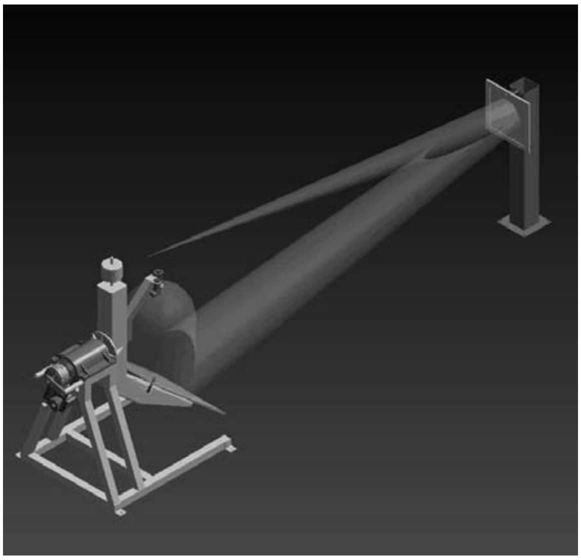

Fig 7. A general scheme of the automated goniofotometer.

3.2. CONTROL SYSTEM.

The control system is in charge of coordinating the mechanical structure movements with the optical-photometric system's data acquisition, of generating the appropriate position and speed commands to optimize a working index (maximum speed for a determined uncertainty limit in the measures), and of calculating photometric magnitudes to show them to the operator through an output device with a certain format. The different nature of the mentioned tasks involves, quite often in robotics, the design of a hierarchical control architecture based on the following modules: supervisor and low level control..

The aforesaid division is made according to the nature of the controlled variables. Specifically, the supervisor module is in charge of solving high level questions, such as validating the computer control system integrity or managing the data input and output actions. It synchronizes, as well, the motion control and sensor data registration processes.

Low control level translates positioning orders into articular position and speed references, which are applied servocontrol techniques. To be exact, the actual position is compared with the desired one, and the actuation is obtained via a PIDVF (*Proportional, Integral, Derivative, Velocity Feedback and Velocity Feed Forward*) algorithm. To get the parameters involved in the algorithm, it is necessary to know the dynamic variables of the mechanical positioning system, such as the centre of mass and the inertial tensors.

Figure 8 shows the block diagram for the control system, which can be divided into three subsystems:

1. Optical-photometric subsystem: it gets the analogical signal provided by the photometric sensor which, once amplified and sampled, is processed to get the required optical magnitudes
2. Mechanical control subsystem: it comprises the mechanical system, the low level control and the motion control. On one hand the mechanical system's motors provide the low level control - which gives the actuation- with the resolver and thermoswitch signals. And on the other hand, the low level control translate the resolver signal into an encoder signal which is transmitted, as well as a series of status signal, to the motion control. This last control generates the orders to execute the tasks the user requests.

High level control subsystem: it is divided into a data acquisition block, a data interpretation block and a user interface block. Taking the signals provided by the mechanical control subsystem and the optical magnitudes, this third subsystem makes a record of positions and optical measures. It also recovers all the errors that may have been produced in the inferior subsystems. The data interpretation block uses the models of the optical system and of the mechanism to process the measures taken. Considering the processed measures, the user interface block generates reports and makes the graphical representation of the magnitudes of interest. Finally, this module sets forth the task to be carried out

4. CONTROL ELECTRONICS.

The system is divided into a workstation and the goniophotometer. From the functional point of view, we can find the motion control blocks and the data acquisition blocks.

Within the motion control, we have used industrial servocontrollers and AC brushless motors (one per each degree of freedom), which provide a constant torque. Motors are controlled and synchronized using a 32 bits floating point DSP.

The data acquisition consists of a photometer, an amplifier and a 12 bits A/D converter..

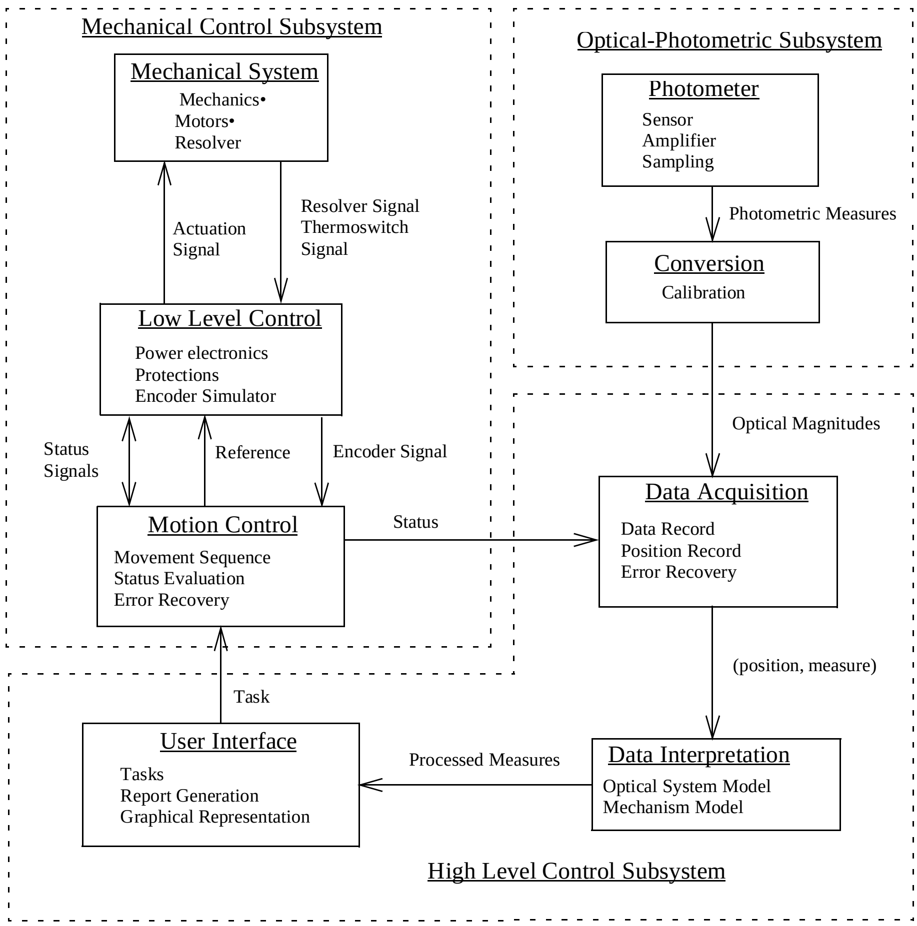

Fig 8. Block diagram of the system.

5. EXPERIMENTS AND CONCLUSIONS.

According to the preliminary results, the developed configuration for the goniophotometer has improved its performance when compared with other commercial solutions. Measures are more accurate and, despite that fact, the time needed to characterize a luminaire is under four minutes, versus the seven minutes taken by the fastest goniophotometer (which is based on a number of measures four times smaller than the one of the developed goniophotometer). In those timings, the time required to elaborate reports is not being considered. If we also considered that item, the system proposed in this paper would be even faster, since it automatically generates reports. These reports can be complemented with a graphic representation.

A specific software for representations has been developed. The Fig 9 shows one of the most usual plots: the isocandle curve (in this case, a commercial luminaire with two fluorescent tubes). This curve is generated by connecting with lines the equal luminous intensity points of the collected data . A reference system of meridians (*beta*) and parallels (*alpha*) is

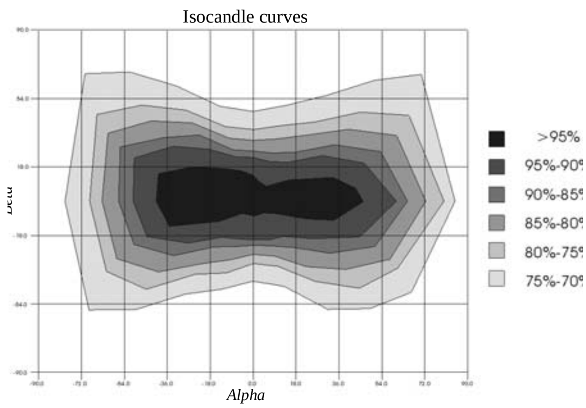

Fig 9. An example of isocandle curve.

used. The parallel 0º is made acoording to the horizontal plane that contains the direction of the beam of light and meridian 0º with his perpendicular plane.

Finally, the characteristics of the system could be summarized as follows:

1. Smaller measuring time.

2. More accuracy without auxiliary sensors.
3. The material within the luminous source is not affected by the movement of the goniophotometer.
4. Direct and simultaneous acquisition of several photometric magnitudes.
5. Automated report generation.
6. Automated measuring, without human intervention during the procedure.

6. ACKNOWLEDGMENTS

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