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COMPARISON OF THE FISHEYE CAMERA METHOD WITH GONIOPHOTOMETERS FOR MEASURING RELATIVE ANGULAR INTENSITY DISTRIBUTIONS OF LIGHT SOURCES

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Abstract

1. Motivation, specific objective

Angular intensity distributions of light sources are traditionally measured using goniophotometers. Usually, goniophotometers are expensive to obtain and resource intensive to operate, due to requirements of a dedicated laboratory and the time consuming nature of the measurements.

In addition to other applications, such as lighting design, angular intensity distribution data are used for spatial corrections to increase accuracy of luminous flux measurements with integrating spheres. Because goniometric measurements are so laborious, many laboratories omit the spatial correction altogether, increasing their measurement uncertainty by up to a few percent, depending on the integrating sphere and the light source under test.

Previously, the fisheye camera method was developed to enable faster and more cost-effective measurements of angular intensity distributions of light sources. Using the fisheye camera method, such angular distribution is obtained in a matter of seconds from a fisheye camera image captured through a port of an integrating sphere, while the sphere is illuminated by the lamp under test. The method was reported in CIE 2017 Midterm Meeting in Jeju, where doubts were presented about the wide applicability of the method and its comparability with traditional goniophotometers.

In this study, the performance of the method is confirmed. The fisheye camera method is validated by measuring six LED lamps in eight integrating spheres of various configurations, and by comparing the obtained angular data with that measured using five goniophotometers of different types.

2. Methods

In the fisheye camera method, after capturing an image of the lamp under test, the image is processed to diminish the impact of the imaging hardware and integrating sphere imperfections, including the structural elements of the sphere, such as port baffles and non-uniform coating. This processed image and the intrinsic parameters of the camera are then used to map the intensity values of the processed image to the three-dimensional coordinates on the sphere surface. After subtracting the diffuse light level signal, the remaining intensity value of each point in the sphere reconstruction is proportional to the luminous intensity of the lamp in the direction of that point.

The integrating spheres used in the study ranged in diameter from 1.5 m to 4.0 m. The coating reflectance of the spheres ranged from 80% to 98%. The angular data obtained using the fisheye camera method was compared with the data measured using five goniophotometers. For the study, two near-field, two far-field, and a robot goniophotometer were employed. The closeness scores, which range from 0 to 100 and describe the similarity of any two distributions (0 total mismatch, 100 perfect match), were calculated for all the camera-obtained data and the respective data of each goniophotometer. To see the deviations between the goniophotometers, the closeness scores were also calculated for each goniophotometer dataset in comparison with the datasets of the other four goniophotometers.

The effect of the deviations in the angular distributions obtained using the two methods on the spatial correction factors was tested by using the spatial responsivity map, or spatial responsivity distribution function (SRDF), of one of the spheres.

3. Results

On average, the closeness scores for angular intensity distributions measured using the fisheye camera method were 94.6 when compared with the goniometric data. The average closeness score when comparing each goniophotometer dataset with the results of the other four goniophotometers was 96.6. The range of the average closeness scores for the fisheye camera method in the eight integrating spheres was from 92.1 to 96.2. The mean closeness scores for the goniophotometrically obtained data ranged from 96.0 to 97.0 when compared with the other four goniophotometers.

The main discrepancies between the results stemmed from two integrating spheres, which had large, view-obstructing elements in front of the camera. The mean closeness scores for those spheres were 92.1 and 93.2. The two spheres were particularly problematic when measuring lamps which were not rotationally uniform about their optical axis, as the data missing from the view of the camera could not be replaced using values from the unobstructed azimuth angles of the sphere.

When calculating spatial correction factors using the distributions obtained with the fisheye camera method and the five goniophotometers, the average difference between the methods was 0.05%.

4. Conclusions

The fisheye camera method for quick and cost-effective angular intensity distribution measurements was validated by measuring the angular distributions of six LED lamps in eight integrating spheres. The results were then compared with those obtained using five goniophotometers. The average closeness score calculated for the fisheye camera method when comparing with the respective goniophotometric data was 94.6. The mean closeness score cross-calculated for the five goniophotometers was 96.6. The most significant sources of uncertainty for the fisheye camera method are large sphere elements close to the camera port.

When combined with the spatial responsivity map of the integrating sphere, the method is an easy and a convenient way to decrease measurement uncertainty caused by the spatial non-uniformity of the integrating sphere.