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Rapid measurement of the Size-of-Source Effect by using an Iris aperture

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Summary: The source size effect (SSE) is a systematic error in thermography cameras, where the measured radiance temperature varies with object size. The SSE is measured by capturing deviations in the camera's response across defined object sizes. These methods must ensure that the calculated differences are distinguishable from of measurement uncertainty and that any thermal effects unrelated to the measurement process are minimized. This often requires considerable effort, especially when the number of points to collect increases. This paper proposes an alternative method using an iris aperture for continuous SSE measurement, which yields results comparable to those of the conventional discrete method, while providing three times more data points and reducing measurement time by 98 %.

Keywords: Infrared thermography, Size-of-Source Effect, Iris aperture

Introduction

As with pyrometers, the accuracy of temperature measurements with thermography cameras depends not only on the emissivity of the objects to be measured, but also on their size, among other factors. This is known as the Size-of-Source Effect (SSE), and the associated deviations can exceed the uncertainty reported by manufacturers [1]. To study this systematic error and its causes—such as diffraction, scattering, and sensor signal digitization—a proposed method of measurement must be precise enough to clearly represent the behavior of the sensor-optical system under test [2]. Since the SSE is often represented as differences in measured quantities, the reported values can easily be contaminated by side effects, such as thermal drift due to heat convection. This complication increases the complexity of experimental setup and the effort required to measure the SSE. This paper presents a rapid method for measuring the SSE of a thermal imaging camera using an Iris aperture.

Measurement of the Size-of-Source Effect

The SSE evaluation is typically performed by recording the deviation of the measured radiance temperature of an object observed by the camera as the object size changes. To do this, the traditional approach, referred to as the discrete approach, positions a series of circular apertures, each with a different diameter, in front of a black body surface (BBS) with a known radiance temperature. These apertures are changed from smallest to largest, with a waiting period, of 2 min in this paper, between each change so that the thermal behavior stabilizes after the positioning of the apertures. The present paper proposes an alternative that uses an Iris aperture, which will be referred to as the continuous approach. It consists of capturing a sequence of frames to measure the change in temperature as the BBS is enlarged by hand sliding the pin lever of an Iris aperture, which adjusts the diameter of the circumference formed by the leaves. The Iris was mounted on a 3D-printed bracket, which was attached to a stainless steel plate (see Fig. 1). This bracket was designed for smooth insertion, but with sufficient stiffness to restrict the displacement of Iris while the circumference is being adjusted. The stainless steel plate was coated on the front with a high-emissivity reference paint, whereas the back side was left untreated to minimize heating up on the black surface.

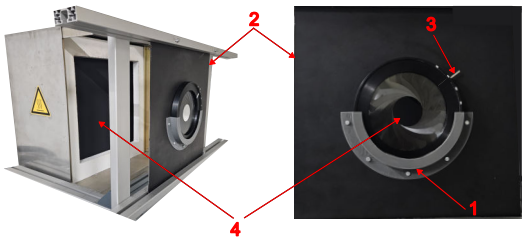

Fig. 1: Experimental set-up. The 3D printed mounting bracket (1) is attached to the high emissivity coated metal sheet plate (2) by means of conventional screws. The Iris aperture (3) is then placed into the mounting bracket and the size of the observed black body surface (4) is adjusted by moving the pin lever.

Results

The SSE was evaluated using the discrete and continuous approaches for a cooled midwave infrared camera, with a frame rate of 200 Hz for

both measurements. A relative diameter $d_{\text{rel,i}}$ in % is determined as

$$d_{\text{rel,i}} = d_{\text{px,i}} \cdot 100 / V_{\text{res}} \quad (1)$$

with $d_{\text{px,i}}$ the diameter of the circle in thermogram number i, determined with an image processing algorithm, and V_{res} the vertical resolution of the camera. The SSE is evaluated through the calculated temperature deviations

$$\Delta\theta_j = \theta_j - \theta_{\text{ref}} \quad (2)$$

where θ_j is the mean value obtained over a concentric circular region of interest (ROI), with a radius of 5 px, in an averaged thermogram j. In the discrete approach, for each diameter, this thermogram j was obtained by averaging 50 consecutive frames. In the continuous approach, for a set of predefined values of $d_{\text{rel,j}}$, all thermograms in the frame sequence with similar diameters $d_{\text{rel,i}}$, within a tolerance range of $\pm$ 0.5 %, were grouped together. Each set, with at least 20 members, was averaged pixel by pixel, resulting in thermogram j. Then θ_{ref} corresponds to the value obtained at the largest circle for each measurement.

The temporal evolution of d_{rel} and the measured radiance temperature θ is presented in Fig. 2-a). The contraction of the observed BBS is reflected in a reduction of the measured temperature, as well as the opposite, which is congruent with the well known behaviour of the SSE. The temperature deviations are presented in Fig. 2-b). It can be observed that both curves overlap, except for the point enclosed by the red circle, which deviates slightly from the trend observed in the other points of both curves. Notwithstanding, the superposition of the curves suggest that, the SSE of the optical system (camera and optical objective) was reproduced well enough by both approaches.

Table 1 lists the time spent performing each measurement and the number of points obtained with each approach. The use of the Iris aperture made it possible to collect 3 times more measured points, at a cost of 2 % of the time spent for the continuous measurement. This improves significantly the resolution of the resulting curves, facilitating a more accurate interpretation of the measured SSE and related phenomena. However, it requires 6 more times disk storage capacity.

Summary and Outlook

This paper has presented the use of an Iris aperture to measure the Size-of-Source Effect of a thermography camera. The size of the object is adjusted by sliding the pin lever of the Iris aperture. The temporal evolution of the measured temperature decreases as the observed diameter is reduced. Both this method and the traditional method provide the same relationship between these variables, but an improvement in the resolution of the curve was achieved, along with a notable reduction in measurement time ($> 98\%$) by using the Iris aperture. However, this came at the cost of requiring 10 times more disk space. In future work, the Iris aperture will be automated so as to provide a more uniform and reproducible variation in the diameter.

Tab. 1: Summary statistics of the measurements

Approach	Discrete	Continuous
Total measurement time in s	1020	18
Number of samples obtained	8	29
Required storage disk space in MB	163	1120

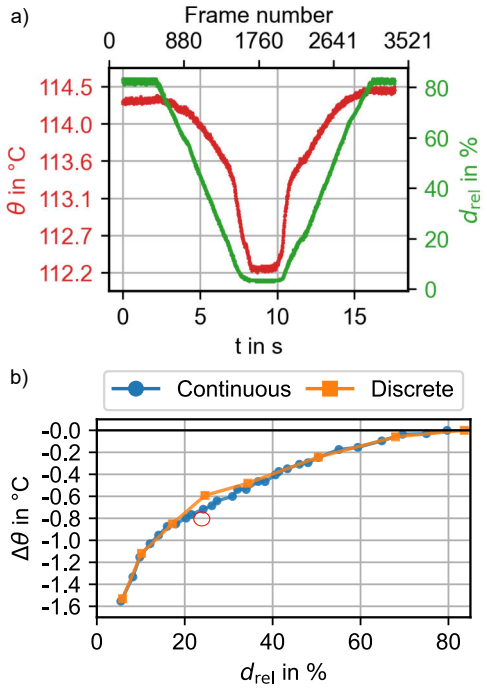

Fig. 2: Measured Size-of-Source Effect. a) Time series of the temporal evolution of the measured radiance temperature and b) the calculated temperature deviations.

Acknowledgments

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