Camera Radiance Correction in Lightning Imaging Experiment

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Keywords: image correction; radiance calibration; radiance correction

Abstract. The camera radiance correction methods was designed and implemented to improve the pixel optical response features and eliminate the difference of the optical response. Otherwise the camera space correction and distortion correction method was designed and implemented to ensure the seamless splicing of the image. After correction of camera images，in each corner point coordinates deviation average at 0.168226, far less than the requirements of the deviation (0.5 pixels).

Introduction

The calibration in lightning imaging experiments and data acquisition processing system of verification system is mainly composed of two parts which are the testing console and the receiving and processing of test data. In the testing system the equipment which accept the control and management are high-speed camera, two-dimensional random pointing device, laser, variable attenuator, high precision triangle chopper, zoom beam expanding optical system, integrating sphere, a projector and a halogen lamp. It requires calibration and correction of amplitude and the brightness of the camera in order to ensure the effectof shooting lightning.

The defect test of camera element

The standard for judging the defect pixels is: If the value of pixel response is above or below the mean value of 25%, then the pixel is distinguished as defect; The standard for judging the cluster defect pixels is: If the number of defect pixels which are adjacent or connected to each other is bigger than or equal to 4，then it is determinated that there exists a cluster defect pixel. The test procedure is as follows:

(1) Perform the connection of the testing system and the preset of instruments；

(2) Adjust the testing system and apply the working voltage to testing system to make the instrument is in normal working condition;

(3) Collect F images in the condition without light and calculate the average signal output of the camera according to the formula V_{od}:

$$V_{od} = \frac{1}{M}\sum_{i=1}^{M} V_{odi}$$

In the formula above，

V_{od}： The average signal output of the camera in the condition without light;

M：The number of pixel of photosensitive surface;

V_{odi}： The average signal output of the camera pixel i in the condition without light;

(4) Label the pixels which meet the formula as defective ones and the total number is recorded as N_d;

$$V_{odi} \le xV_{od} \text{或} V_{odi} \ge yV_{od}$$

the value of x and y is set to 25%.

(5) Regulate the light intensity to be uniform so that the camera is in half saturated output and collect F images; calculate the average signal output of the camera according to the formula V_o

$$V_o = \frac{1}{M}\sum_{i=1}^{M} V_{oi}$$

In the formula above,

V_o： The average signal output of the camera;

V_{oi}： The average signal output of the camera pixel i;

M：The number of pixel of photosensitive surface after eliminating the defect pixels which meet formula 3.10.

(6) Label the pixels which meet the formula 3.12 as defective ones and the total number is recorded as N_e;

$$V_{odi} \le xV_{od} \text{ or } V_{odi} \ge yV_{od}$$

the value of x and y is set to 25%.

(7) The total number of defect pixels is $N_d + N_e$;

(8) If the number of defect pixels which are adjacent or connected to each other is bigger than or equal to 4， then it is determinated that there exists a cluster defect pixel.

Camera radiance calibration

After the spatial calibration of the camera is completed and obtaining images of different cameras, it ensures that a fixed point on the diffuse reflective screen at the same pixel position in the image sequence taken by the four cameras in time division in a group of four camera and ensures the continuity of the position on the time axis. However because of the influence of the camera and the lens focal plane, it cannot be guaranteed to get the same luminance value in the image of different cameras even if the brightness value of the point on the diffuse reflecting screen is constant. It is necessary to calibrate the brightness of different camera to make it easy to follow transient point source extracted using background subtraction algorithm method. Assuming the camera resolution is only 3 * 3 pixels, as shown in Figure 1, after the spatial calibration and correction, A1 and A2 are two images obtained by the camera:

Therefore, the luminance value of the camera image is need to be corrected to obtain a number of mapping tables, so that the same point in the different camera imaging and after the operation of the mapping table, different images have the same luminance value of the diffuse reflection on the screen. Supposing the camera's resolution is $W*H$, pixel for p^i_{index}, $index = 1,...,W*H$, i is the camera number. The step of calibration for brightness of A1 camera is:

199	201	202
200	212	211
198	210	211

200	201	200
201	213	211
200	211	214

Fig.1. Luminance value differences schematic of different camera

1)For camera A1, integrating sphere imaging to obtain images I_1;

2)Correct the coordinate system of I_1 using space correction method to obtain images I_1';

3) Get pixels p_1^1, according to the radiance meter values, calibration values can be obtained at a luminance value p_1^1;

4) Repeat Step 3, get all the maps of p_{index}^2;

5) Adjust the brightness of the integrating sphere, repeat steps 3 and 4, and obtain the mapping table of different brightness values of p_{index}^2.

Each pixel of camera A1 has a mapping table. After the above experiments for A1, the same way can be used for A2, A3, A4, B1, B2, B3, and B4. No matter what is on the diffuse reflection screen, different cameras on the same pixel have the same luminance value, which ensures the brightness uniformity.

Camera radiance correction

Due to the requirement of using eight cameras to shoot the same target object, it is necessary to carry out uniform radiance calibration for these eight cameras. In this paper, the absolute radiance calibration method and relative radiance calibration method are combined for radiance calibration.

The steps of the calibration method for the combination of absolute radiance and the relative radiance are as follows:

1) Absolute radiance calibration：

a. Place the adjustable power lighting equipment inside the integrating sphere;

b. Set the value of the output power（P0 ~ P3）of 4 illumination devices;

c. Set the output power of lighting equipment to be P0 ~ P3 and shoot 1000 images. Calculate the average value of the 1000 image and calculate the average DN value at each illumination element;

d. Merge the output power of equipment and the average DN value per pixel and determine the standard response line (through the coordinate origin), written as:

$$y = k_{ab}x + b_{ab}$$

Through testing，determine $k = 104.21$.

2) Relative radiance correction of other elements:

For any other element i except 0, the gradation values of the pixel were measured as at the output power value (the exposure amount is used during the test) $P_0, P_1, ..., P_n (2 \le n \le 4096)$. If the gray value of pixel i is G, then the corrected gray value G' of element i is calculated as follows:

a. Locate the gray value range of G, which is to say determine the interval $[G_j, G_{j+1}](0 \le j \le 4094)$, so that $G_j \le G < G_{j+1}$;

b. Calculate the corresponding output power value P of G,

$$P = \frac{(G - G_j)}{G_{j+1} - G_j}(P_{j+1} - P_j) + P_j$$

c. Calculate correction value G' of i,

$$G' = k_{ab}P$$

Correct the image acquisition of 1 # and 2 # which are two Photon Focus industrial cameras at different exposure levels following the above method. The calibration results are as follows:

After calculation, the non-linearity of camera 1# before the correction was 1.862 and the value turns to be 0.221 after correction. The non-uniformity of the

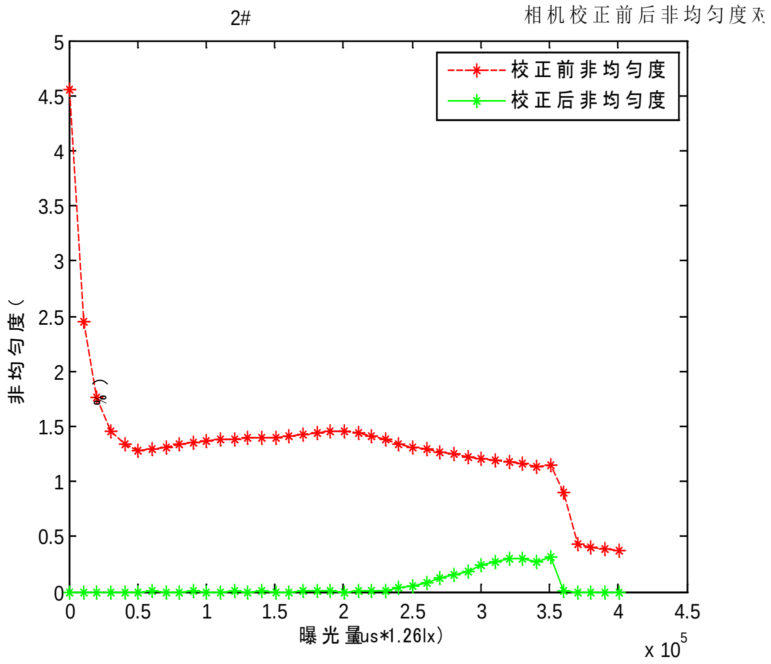

Fig.2. non-uniformity comparison of camera 1# before and after correction

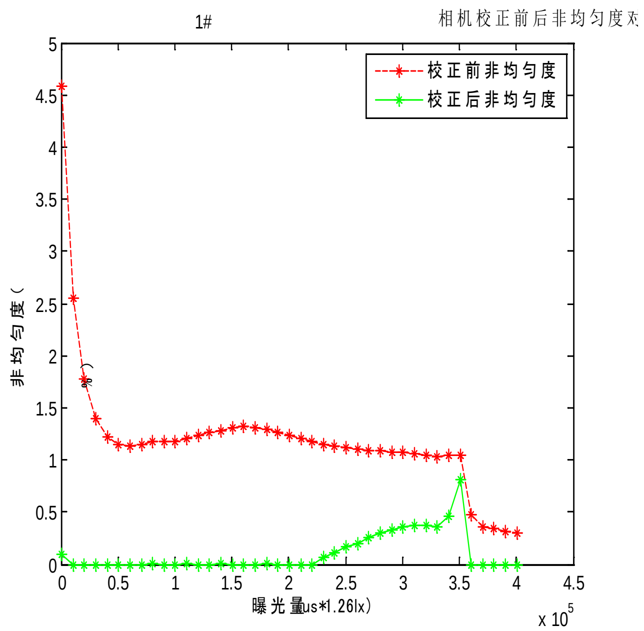

Fig.3. non-uniformity comparison of camera 2# before and after correction

image before and after correction is shown in Figure 2. The mean of the non-uniformity before correction is 1.205% and the value is 0.105% after correction.

After calculation, the non-linearity of camera 2# before the correction was 1.771 and the value turns to be 0.031 after correction. The non-uniformity of the image before and after correction is shown in Figure 3. The mean of the non-uniformity before correction is 1.342% and the value is 0.059% after correction.

Conclusion

The radiance calibration is used to establish the number of digital signals measured by sensors and the corresponding radiation energy and convert the digital values of images to physical values. Determine a judgment which can make a direct comparison of the standard object, the target scene quantitative analysis, and better recognition of the target. Correction can be greatly improved through experiments using non-uniformity correction and relative absolute radiance calibration method. A camera pixel radiance calibration method to enhance the response characteristics like light elements and eliminate differences in response elements like light is designed and implemented. A camera calibration method to ensure image seamless and spatial distortion correction is designed and implemented. The mean deviation of each corner position of the camera image coordinates after correction reaches 0.168226 which is far less than the required offset value (0.5 pixels).

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