Mathematical Model for a Calibration of Multiple-View Thermal Camera

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Abstract— **This paper presents a new method for the non-overlap laceration camera calibration. The equipment used in the experiment is multi-thermal camera equipment, and three cameras are looking in different directions at a certain angle. Also, there is no tipping point between the cameras and therefore cannot use the existing camera-calibration method. The method presented in this paper computes the angle mathematically in the equipment, through which the relationship between each camera is identified and the pre-processing process is completed to proceed with the calibration.**

***Keywords*— calibration; thermal camer; multiple-view; rotation; translation**

I. Introduction

In the field of computer vision, technology and research to replace or help human vision, such as technology for robot and factory automation, are being developed and researched a lot. [1-2], While human beings are working to understand and recognize information, the human eye accounts for more than 70% of the roles of accepting information around them. The goal of the computer vision field is to get machines to recognize and judge objects, such as objects, landscapes, etc. on behalf of human eyes. Human beings may always be inconsistent in their judgment through sight, depending on the circumstances surrounding them. However, machines have the advantage of being able to maintain consistency in judgment unless physical defects occur. Thus, computer vision and video processing technology are increasingly taking up a larger share in the areas of defect detection, object recognition, and medical imaging. [3] When humans recognize scenes through vision, the need for technology to acquire or restore three-dimensional coordinate information in the field of computer vision is growing. The procedure to quantitatively define the relationship between the coordinates to which the three-dimensional object belongs and the two-dimensional coordinates in the projected image plane by obtaining variables that quantitatively represent the environmental factors affecting the performance of the camera, is called camera calibration. Camera calibration is to obtain parameters for geometric factors caused by the internal and external environment of the camera when the points (or zero inverse) in the three-dimensional space are projected to the two-dimensional image plane. Parameters consisting of elements defining internal factors or internal characteristics of a camera are called internal parameters and parameters consisting of elements defining characteristics are called external parameters. The external parameters represent the relative position of the camera compared to the real three-dimensional coordinate system and can be expressed in a rotation (R) and displacement (T) matrix. And the internal parameters can be expressed as a projection matrix. The internal parameters are marked with A and the external parameters with $[R|T]$. The relationship between the three-dimensional coordinates and the two-dimensional coordinates can be expressed as equation (1).

$$s\begin{pmatrix} x \\ y \\ 1 \end{pmatrix} = A[R|T]\begin{pmatrix} X_W \\ Y_W \\ Z_W \\ 1 \end{pmatrix} \tag{1}$$

s is a constant and is intended for scaling factor representation. The internal parameters consist of a focus distance (Focal length, f), a skew coefficient (Skew coefficient), a principal point ((x_p, y_p)). In matrix A (equation (1)), which constitutes an internal parameter, the asymmetric coefficient may be fixed at zero. The focal distance is the distance between the camera lens (optical center) and the image sensor, and the center point is located at the center of the lens where the image sensor is projection. And the asymmetric coefficient indicates the degree to which the vertical axis (y axis) of the image sensor is tilted. If there is no tilt, the asymmetric coefficient is zero. expressed in rotation and variation as elements for calculating external parameters. If one camera is used, the rotation represents the angle of rotation between the three-dimensional real-world coordinate system and the camera-accelerated coordinate system, and if the stereo camera is used, the relative angle of rotation between the cameras used. And in stereo cameras, the displacement value can be expressed as the distance between the optical centers of the two cameras. Thus, the external parameters indicate the relative position between the camera and the real coordinate system, and this is suitable to express the relative perspective of a three-dimensional object or scene. In order to obtain the absolute root value, an inference internal parameter is required, which can be expressed by equation (2).

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$$z = \frac{bf}{d} \tag{2}$$

z is the distance between the camera and the three-dimensional object target, b, f, d represents the distance between the two cameras, the focal distance, and the Disparity. In depth camera systems with multiple cameras, normalized coordinates can be used to solve the problem of different focal distances (or different focal distances even for the same camera). [4] The real world coordinate system is the coordinate system used to express the position of a three-dimensional object and the camera coordinate system is the coordinate system used by the camera to express one or two-dimensional space inside. The coordinate system of the actual image used before presenting to the pixel coordinate system when projected to the two-dimensional image coordinate system after being converted from a real coordinate system to a camera coordinate system is called a film coordinate system. [5] In image processing, the film coordinate system is oxidized to the pixel coordinate system to operate the pixel unit of the image. In this paper, we proceed with calibration using camera equipment that is not overlapping. Because there are no overlap parts, external and internal parameters cannot be obtained in the conventional way, and mathematical models are used to obtain information for calibration.

II. PROPOSED MODEL

In this paper, a structural mathematical method for carrying out three lacerated camera calibrations in un-overlap state is presented

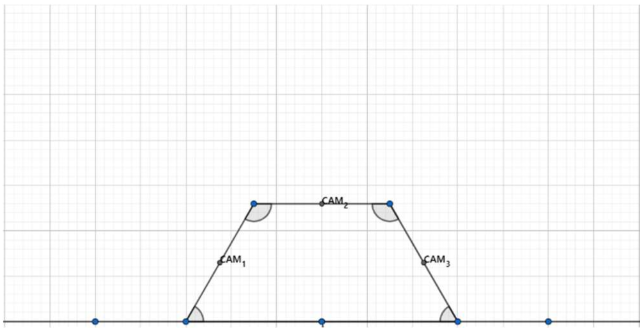

Fig.1 Schematic camera equipment

Currently, the laceration camera equipment has the same structure as Figure 1, and each laceration camera has a constant angle and is looking in different directions. Because the above equipment does not overlap, the existing calibration method cannot be used. The following methods are presented:

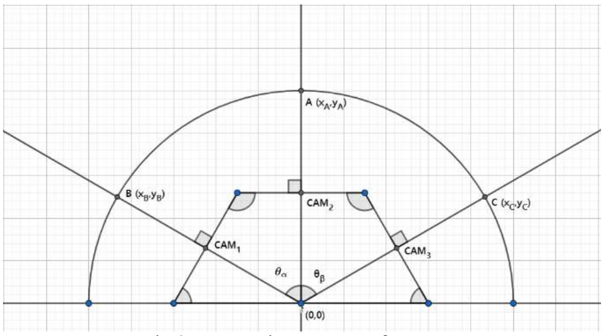

Fig.2 Geometric structure of cameras

Set the origin and draw a half circle based on the origin as shown in Figure 2. In CAM1,2,3, a straight line was set so that it was perpendicular to the origin and passed through the half circle. Each point through the half circle was set TO $(x_A, y_A), (x_B, y_B), (x_C, y_C)$.

$$\begin{pmatrix} x_A \\ y_A \end{pmatrix} = \begin{pmatrix} \cos\theta_\alpha & \sin\theta_\alpha \\ -\sin\theta_\alpha & \cos\theta_\alpha \end{pmatrix} \begin{pmatrix} x_B \\ y_B \end{pmatrix} \tag{1}$$

$$\begin{pmatrix} x_A \\ y_A \end{pmatrix} = \begin{pmatrix} \cos\theta_\beta & -\sin\theta_\beta \\ \sin\theta_\beta & \cos\theta_\beta \end{pmatrix} \begin{pmatrix} x_C \\ y_C \end{pmatrix} \tag{2}$$

The relationship between point A and point B is expressed as Equation (1). Rotation of point B to the clockwise as much as θ_α becomes point A, and in the same way, the relationship between point A and point C can be expressed as Equation(2), and the direction is converted counterclockwise. If we solve the equations above,

$$\begin{pmatrix} x_A \\ y_A \end{pmatrix} = \begin{pmatrix} x_B \cos\theta_\alpha + y_B \sin\theta_\alpha \\ -x_B \sin\theta_\alpha + y_B \cos\theta_\alpha \end{pmatrix}, \tag{3}$$

$$\begin{pmatrix} x_A \\ y_A \end{pmatrix} = \begin{pmatrix} x_C \cos\theta_\beta - y_C \sin\theta_\beta \\ x_C \sin\theta_\beta + y_C \cos\theta_\beta \end{pmatrix}. \tag{4}$$

Assuming coordinates of the origin is (0,0), (x_A, y_A) becomes $(0, y_A)$ and we you rearrange equations (3) and (4.)

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$$x_B \cos\theta_\alpha + y_B \sin\theta_\alpha = 0 \tag{5}$$

$$x_C \cos\theta_\beta - y_C \sin\theta_\beta = 0 \tag{6}$$

Equations (5) and (6) can be rearranged by setting $x_A = 0$.

$$x_B \cos\theta_\alpha = -\, y_B \sin\theta_\alpha \tag{7}$$

$$x_C \cos\theta_\beta = y_C \sin\theta_\beta \tag{8}$$

$$\cos\theta_\alpha = \frac{-\,y_B \sin\theta_\alpha}{x_B} \tag{9}$$

$$\cos\theta_\beta = \frac{y_C \sin\theta_\beta}{x_C} \tag{10}$$

Equations (7-10) show the estimation of relative rotations between cameras, $\theta_\alpha, \theta_\beta$, that are the most important factors that determine relative orientations of viewpoints. The above equations give evidence of θ_α, θ_β, and the relative location relationship of CAM1,2,3 using θ_α, θ_β. It is judged that the direction of view from each camera and the internal and external parameters can be predicted using the structure of half circle as shown in Figure 2.

III. Conclusion

This paper presents a new method for the non-overlap laceration camera calibration. Because there is no Overlap, the existing calibration method cannot be used. Calculate the angle mathematically on the equipment and use it to find out the relationship between each camera and complete the pretreatment process to proceed with the calibration. Future work will focus on estimating the external and the internal parameters of the camera.

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