International Journal of Science and Research (IJSR)
ISSN: 2319-7064
ResearchGate Impact Factor (2018): 0.28 | SJIF (2018): 7.426

Research and Realization of Binocular Camera Calibration based on Open CV

Yongchao Wang[1], Dong Guo[2]

Tianjin Key Laboratory of Information Sensing and Intelligent Control, Tianjin Polytechnic Normal University, Tianjin 300222, China

Abstract: ***Based on the analysis of the transformation relationship between image pixel coordinate system, image physical coordinate system, camera coordinate system and world coordinate system, the imaging model of binocular camera is established. The model takes the distortion coefficient into account comprehensively and realizes the fast and accurate calibration of the binocular camera platform.***

Keywords: Camera imaging model; Distortion coefficient; Camera calibration

1. Introduction

Computer vision is widely used in industry, military, people's livelihood and other fields, and plays an indispensable role in human production and life. Binocular stereo vision is an important branch of computer vision. Binocular stereo vision system can be roughly divided into image acquisition, camera calibration, image calibration, stereo matching, depth calculation, in which the camera calibration is the basis of binocular stereo vision system, the precision and speed determines the precision and speed of the binocular stereo vision system, determines the ultimate goal of binocular stereo vision system, the accuracy of the depth calculation. Therefore, it is of great significance to study and realize camera calibration.

Common stereo calibration methods can be divided into traditional calibration method, self-calibration method and zhang zhengyou calibration method.At present, the traditional calibration method needs high precision calibration object, but the calculation is very complicated under the camera mathematical model, and the calibration speed is slow. The self-calibration method does not need reference and has low precision and robustness. Moreover, Zhang Zhengyou's calibration method also overcomes the strict requirements of traditional calibration method on calibration objects, and optimizes the self-calibration method. It only needs to use checkerboard grid for calibration, which has the advantages of high calibration accuracy, simple operation and good robustness, and is widely used. In this paper, internal parameters and external parameters are obtained based on zhang zhengyou calibration method, which can realize the calibration of binocular camera quickly and accurately.

2. Camera Calibration Principle

2.1 Camera calibration model

In computer vision technology, the next step of computer vision system can only be carried out by determining the relationship between the space geometry object and a specific point and corresponding point in the image.[1] Therefore, the establishment of geometric mathematical model is extremely necessary, and the parameters in the geometric model are camera parameters [2].In general, the acquisition of camera parameters is obtained by experiments and relevant mathematical calculation, and camera calibration is the process of obtaining camera parameters, which is also known as camera calibration. In the geometric mathematical model, to realize the transformation of the coordinate of an object in three-dimensional space into the coordinate of a two-dimensional image, four coordinate systems are needed, namely the world coordinate system, the image physical coordinate system, the pixel coordinate system and the camera coordinate system. The coordinate system commonly used in camera calibration is shown in figure 1[3].

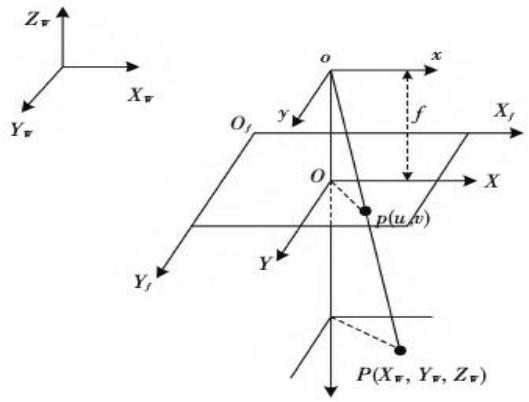

Figure 1: Coordinate System commonly used in Camera Calibration

In figure 1, the mathematical change relation between pixel coordinate system and image physical coordinate system is realized in the form of matrix, as shown in equation 1:

$$\begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} 1/d_x & 0 & 0 \\ 0 & 1/d_y & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} \quad (1)$$

In equation (1), the horizontal and vertical coordinates of pixels in the pixel coordinate system are represented by and, and the number of pixels in the unit length of the horizontal and vertical coordinates in the image physical coordinate system is represented by.[4]The mathematical change relation between the world coordinate system and the camera coordinate system is shown in equation (2) :

$$\begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix} = \begin{bmatrix} R & T \\ 0^T & 1 \end{bmatrix} \begin{bmatrix} x_w \\ y_w \\ z_w \\ 1 \end{bmatrix} = \begin{bmatrix} r_{11} & r_{12} & r_{13} & t_x \\ r_{21} & r_{22} & r_{23} & t_y \\ r_{31} & r_{32} & r_{33} & t_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_w \\ y_w \\ z_w \\ 1 \end{bmatrix} \quad (2)$$

In equation (2), is the translation vector, is the rotation matrix, and satisfies the following constraints:

$$\begin{aligned} r_{11}^2 + r_{12}^2 + r_{13}^2 &= 1 \\ r_{21}^2 + r_{22}^2 + r_{23}^2 &= 1 \\ r_{31}^2 + r_{32}^2 + r_{33}^2 &= 1 \end{aligned} \quad (3)$$

The change between image coordinate system and camera coordinate system is shown in equation (4):

$$Z_c \begin{bmatrix} X \\ Y \\ 1 \end{bmatrix} = \begin{bmatrix} f & 0 & 0 & 0 \\ 0 & f & 0 & 0 \\ 0 & 0 & f & 0 \\ 0 & 0 & 0 & f \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix} \quad (4)$$

In equation (4), is the optical axis of the camera coordinate system, perpendicular to the axis and the axis. The camera coordinate system of a certain point is represented by and in the image physical coordinate system, and the focal length of the camera is represented by f.By changing equation (4) to the pixel coordinate system, the mathematical change relation between the point and the image point in the pixel coordinate system can be obtained. Therefore, the mathematical transformation relation between the image coordinate system and the world coordinate system can be obtained [11], as shown in equation (5) :

$$Z_c \begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} f_x & 0 & u_0 & 0 \\ 0 & f_y & v_0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} R & T \\ 0^T & 1 \end{bmatrix} = M_1 M_2 X \quad (5)$$

In equation (5), is the internal parameter of the camera, including 5 parameters, respectively, Are the external parameters of the camera, respectively the rotation matrix and the translation vector, which contain a total of 6 parameters.[5-6]

2.2 Internal parameters, external parameters, distortion parameters

The camera calibration process is the process of determining the camera internal and external parameters and distortion parameters. The external parameters are determined by the relative position between the world coordinate system and the camera coordinate system. In section 1.1, we obtain the mathematical transformation relation between the image coordinate system and the world coordinate system, as shown in equation (5), in which the 3*3 orthogonal rotation matrix becomes the rotation matrix. Is the translation vector of 3*1, and the rotation matrix and translation vector are collectively referred to as the external parameters of the binocular camera system. Fx, fy, u0 and v0 are the internal parameters of the camera. The internal parameters of the camera are only related to the characteristics of the camera itself, and have nothing to do with external factors.[7]

Due to the defects in lens manufacturing process, the lens distortion exists more or less in the camera lens. There are many kinds of lens distortion, the common ones are radial distortion from lens shape and tangential distortion from camera assembly process.[8]
Generally, the radial distortion of the camera can be expressed as:

$$\begin{aligned} x_{correct} &= x(1 + k_1 r^2 + k_2 r^4 + k_3 r^6) \\ y_{correct} &= y(1 + k_1 r^2 + k_2 r^4 + k_3 r^6) \end{aligned} \quad (6)$$

Tangential distortion can be expressed as:

$$\begin{aligned} x_{correct} &= x + \left[2p_1 y + p_2\left(r^2 + 2x^2\right)\right] \\ y_{correct} &= y + \left[2p_2 x + p_1\left(r^2 + 2y^2\right)\right] \end{aligned} \quad (7)$$

3. Experiment and Result Analysis

In order to determine the internal and external parameter matrix of the camera and lay a solid foundation for depth calculation, we conducted calibration experiments on the binocular camera based on OpenCV.[9]The calibration experiment is based on the binocular camera as shown in figure 2-1. The experiment consists of two CMOS cameras that can move around. The camera can manually focus, with the highest pixel of 1.3 million and the maximum resolution of 2560*960.The operation of its calibration experiment is as follows:

Figure 2-1

1) Select calibration plate: the calibration plate used in this section is high-precision float glass, as shown in figure 2-2. Its size is 340mm 260mm, the size of each square is 25mm, and the pattern array is 129, with an accuracy of 0.02mm.

Figure 2-2

2) Image acquisition: during the system process, the camera maintains a static state to collect multiple sets of images in different directions and positions of the calibration plate, and meanwhile, the collected images are stored in calib data in the project directory in TXT format.[10]
3) Corner points extraction: corner points of each image in the calibration board in OPENCV are obtained by the function find Chessboard Corners.
4) Binocular calibration: obtain the external and internal parameters of the camera through the functions camera Matrix and dist Coeffs [16].
5) Output results: the obtained internal parameter matrix equation (8) and the translation vector and rotation matrix of the external parameters

$$\begin{bmatrix} 408.1515688 & 0 & 151.9055615 \\ 0 & 409.0666198 & 108.0811420 \\ 0 & 0 & 1 \end{bmatrix} \quad (8)$$

$$R=\begin{bmatrix} 0.6540617 & 0.7547726 & 0.0502142 \\ -0.7429259 & 0.6534511 & -0.1451294 \\ -0.1423523 & 0.0576182 & 0.9881376 \end{bmatrix}$$

$$T=\begin{bmatrix} 1.9993984 & 2.1073178 & -0.0185131 \end{bmatrix}$$

4. Conclusion

Based on OpenCV, this paper uses the principle of Zhang Zhengyou calibration method to study the calibration of camera., the camera calibration is to get the camera can be drawn from inside and outside, inside is mainly to obtain the focal length of the camera, and main is to obtain and rotation matrix and translation vector is used to describe the relative position between the two coordinate system, so the accuracy of camera calibration results affect the ranging accuracy of binocular stereo vision, for the follow-up of 3 d reconstruction work to lay a solid foundation.

References

[1] Cao Yuxiang. Three-dimensional reconstruction based on binocular vision[J].Communication World, 2018,25(12):236-238
[2] Huang Xueran. Research on 3D reconstruction technology based on binocular stereo vision [D]. Xi'an: Xi'an University of Electronic Science and Technology, 2018.
[3] Wang Han, Yin Hong. Research and implementation of binocular camera calibration based on OpenCV [J]. Fujian Computer, 2018, 34 (8): 121-122.
[4] Lu Ying, Wang Huiqin, Qi Wei, et al. Camera calibration algorithm based on Harris-Zhang Zhengyou plane calibration method[J]. Journal of Xi'an University of Architecture and Technology(Natural Science Edition), 2014, 46(06): 860-864+ 870.
[5] ZHANG Z Y.A flexible new technique for camera calibration[J]. IEEE Transactions on Pattern Analysis and Machine Intelligence, 2000, 22 (11) :1330-1334.
[6] ZHANG Z Y.Camera calibration with one-dimensional objects [C]‖Computer Vision-European Conference on Computer Vision 2002.Berlin Heidelberg: Springer, 2002:161-174.
[7] Wang Wenpeng. Research on system calibration technology based on binocular stereo vision [D]. Northwest A&F University, 2018.
[8] Huang Yutian, Sun Peng. Camera calibration and relative orientation based on parallel straight lines [J]. Tool Technology, 2018, 52(7): 126-132.
[9] Lin Yitao, Liu Yuankun, Pan Hui, et al. A new camera calibration method based on single-plane virtual target[J]. Optics and Optoelectronic Technology, 2018, 16(3): 8-14+21.
[10] Hu Song, Wang Dao tired. Comparative analysis of camera calibration methods [J]. Journal of Shanghai University of Electric Power, 2018, 34 (4): 366-370.

Author Profile

Yongchao Wang (Tianjin Key Laboratory of Information Sensing and Intelligent Control, Tianjin Polytechnic Normal University, Tianjin 300222, China)

Dong Guo (Tianjin Key Laboratory of Information Sensing and Intelligent Control, Tianjin Polytechnic Normal University, Tianjin 300222, China)