Camera calibration method based on binocular vision research

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Abstract

Camera calibration is mainly based on the camera imaging model, the use of image pixel coordinates and spatial coordinates of the constraint relationship between the camera parameters of the process. Camera calibration is the basis of machine vision research, the results obtained by the camera calibration directly affect the authenticity and accuracy of the entire visual system. Therefore, it is of great significance to study the camera calibration technology and to find out the key to improve the accuracy of the test results of the visual system. The constraint relationship between the calibration method for binocular camera for in-depth study, which describes the world coordinate and pixel coordinate system, and the camera coordinate system, to solve the linear model, iterative refinement are intrinsic and extrinsic parameters of the camera, with a focus on the Zhang ZhenYou checkerboard calibration principle. Hardware to build a binocular vision platform, developed a 8*7 black and white chess board, for the follow-up of the two goals set a foundation. Software on the use of MATLAB calibration toolbox to achieve the camera calibration process. Finally, the calibration parameters of the camera are compared with the parameters provided by the actual manufacturer, which verifies the correctness of the method.

Keywords

Computer vision; Coordinate transformation; Binocular calibration; Camera parameters.

1. Introduction

With the continuous development of computer application, people not only want to computer to obtain image information, and hope to be able to efficiently analyze the image information the like humans. Thus was born the computer vision is a new comprehensive subject. Bi objective is an important position in the whole computer vision, and its calibration accuracy directly affects the accuracy and effect of 3D reconstruction. The variety of computer vision applications requires the camera calibration accuracy, robustness and other aspects of the study is particularly important.

Camera calibration is to establish the relationship between spatial surface of 3D geometric position and image corresponding points between. Its purpose is to determine the camera position, attribute parameters and establish a imaging geometric model, in order to determine the spatial coordinates of objects and it's like correspondence between points on the image plane. Camera calibration needs to determine the geometric and optical properties of the camera, that is, the internal parameters. And the three-dimensional position and orientation of the camera coordinate system relative to a world coordinate system, that is, the external parameters.

2. Camera Calibration Model

2.1 Reference coordinate system

In order to describe the process of optical imaging, the computer vision system involves the following coordinate system[1], including the world coordinate system, camera coordinate system and image pixel coordinate system, as shown in Fig.1.

The world coordinate system is also called the absolute coordinate system, which is used to represent the absolute coordinates of the scene and the 3D coordinates of the scene(X_w, Y_w, Z_w).

The camera coordinate system is the optical center of the camera as the origin of coordinates, x, Y axis parallel to the image coordinates of X, Y axis, the optical axis of the camera as the Z axis, the intersection of the optical axis and the image plane is the main image, scene point 3D coordinates in the camera coordinate y can be used (X_c, Y_c, Z_c) .

The image pixel coordinate system represents the projection of the 3D point on the image plane. The coordinate origin is in the upper left corner of the image plane, and the U axis is parallel to the image plane horizontal to the right, and the V axis is perpendicular to the U axis.

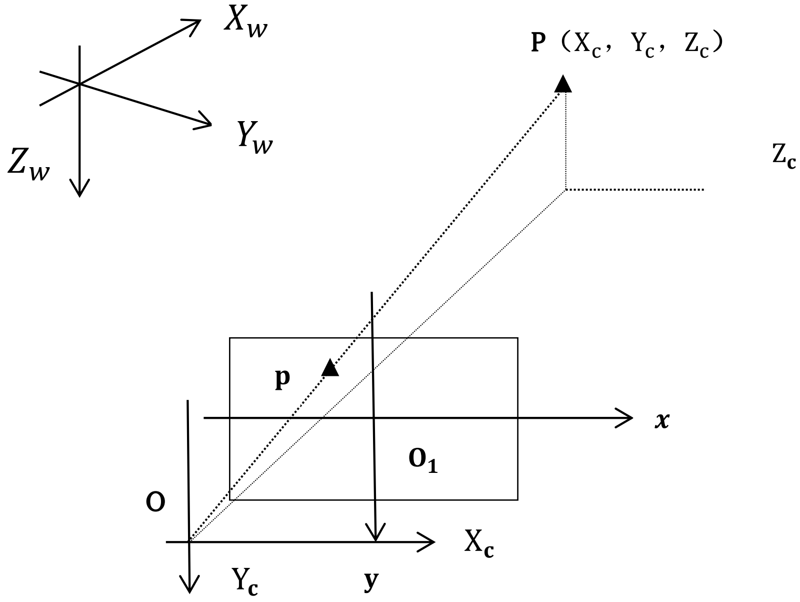

Fig.1 Reference coordinate system

2.2 Camera imaging model

The camera imaging model is the basis of camera calibration, the imaging model [2], to determine the camera's internal and external parameters of the solution. At present, two kinds of imaging models are mainly studied: two kinds of linear and nonlinear. Pinhole model is the propagation of light along a straight line transmission as assumptions, the pinhole model mainly photocentric, like plane and the camera's optical axis form, and in the practical application of camera system usually consists of one or more lens composed, and the pinhole imaging model relationship is basically the same, so available pinhole model as the camera imaging model.

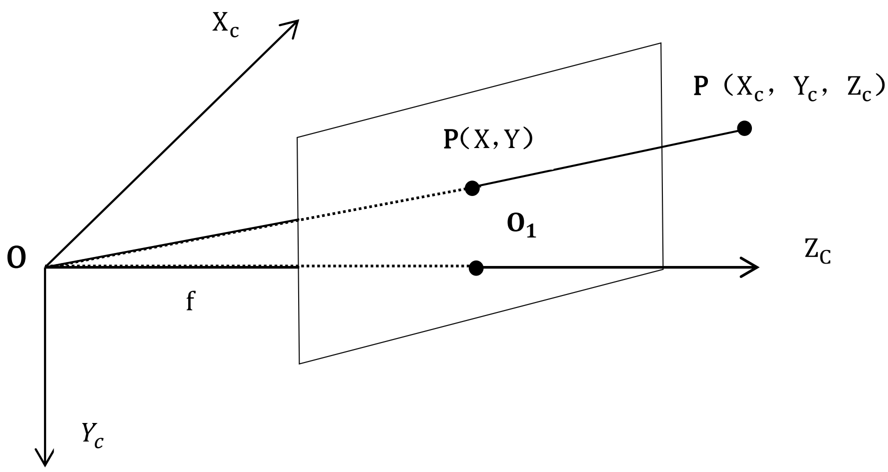

Fig.2 Pinhole imaging geometric model

Assuming the coordinates of points in the three-dimensional space at any point P (X_c, Y_c, Z_c) is o the camera coordinate system $(x, y)$is like the image coordinates of the point O, f is the focal length of the size of the camera and their mutual relations.

$$x = \frac{fX_C}{Z} \qquad y = \frac{fY_C}{Z}$$

Using homogeneous coordinates and matrix description of the projection relationship:

$$Z_c \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} = \begin{bmatrix} f & 0 & 0 & 0 \\ 0 & f & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} X_c \\ Y_c \\ Z_c \\ 1 \end{bmatrix}$$

Finally can launch coordinates and projection point P world coordinates point P(u,v)contact:

$$Z_c \begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} \frac{1}{dx} & 0 & u_0 \\ 0 & \frac{1}{dy} & v_0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} f & 0 & 0 & 0 \\ 0 & f & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} R & t \\ 0^T & 1 \end{bmatrix} \begin{bmatrix} X_w \\ Y_w \\ Z_w \\ 1 \end{bmatrix} = \begin{bmatrix} \alpha_x & 0 & u_0 & 0 \\ 0 & \beta_y v_0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} R & t \\ 0^T & 1 \end{bmatrix} \begin{bmatrix} X_w \\ Y_w \\ Z_w \\ 1 \end{bmatrix} = M_1 M_2 X_w$$

Among, $\alpha_x = \frac{f}{dx}, \beta_y = \frac{f}{dy}, M_1, M_2$ for 3 * 4 of the non-reversible projection matrix; M_1 and the formula of the $\alpha_x, \beta_y, u_0, v_0$ related, and the $\alpha_x, \beta_y, u_0, v_0$ are related to the parameters of the internal structure of the camera, so call this class of parameters for the camera's internal parameters。M_2 contains the translation vector t and rotation matrix R, these two parameters from the camera coordinate system with respect to the position of the world coordinate system, known as the external parameters of the camera. So the process of determining the internal and external parameters of the camera is called camera calibration.

3. Analysis of camera calibration experiment

3.1 Calibration experiment platform

mage acquisition platform is built based on binocular vision model. Will buy binocular stereo camera model combination fixed in a rigid frame, use the USB data line laptop connected, through the MATLAB programming to achieve binocular camera checkerboard images[3] were collected at the same time, the interface as shown in Fig.3.

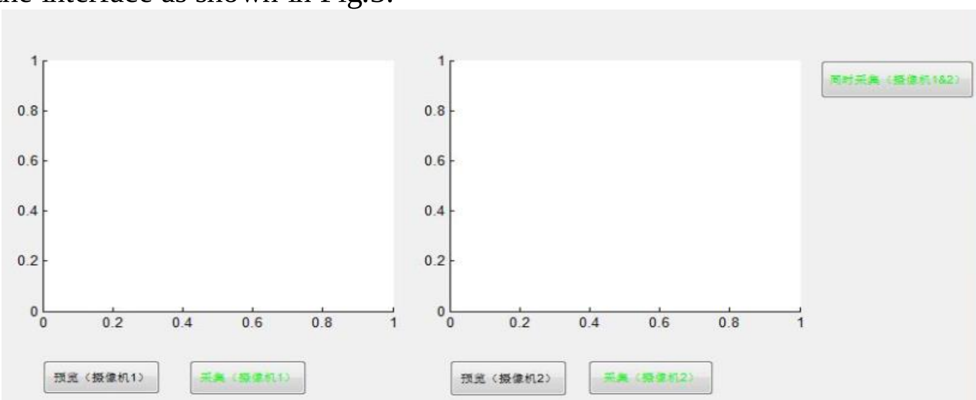

Fig.3 Binocular synchronous acquisition interface

3.2 Experimental procedure

The Zhang ZhengYou calibration method for binocular calibration, in matlab by programming realize binocular camera simultaneously collecting. At the same time using the Matlab toolbox and binocular stereo camera model combination is used to calibrate the camera parameters. The camera calibration process is shown in Fig.4.

Fig.4 Camera calibration flow chart

The realization of the whole calibration method is based on the MATLAB user interface, which is called the Calib_toolbox calibration toolbox. Mainly includes the following steps:

1） Load the image to be calibrated, call program ima_read_calib.m will be stored in the TOOLBOX photos into the operating interface, as shown in Fig.5；

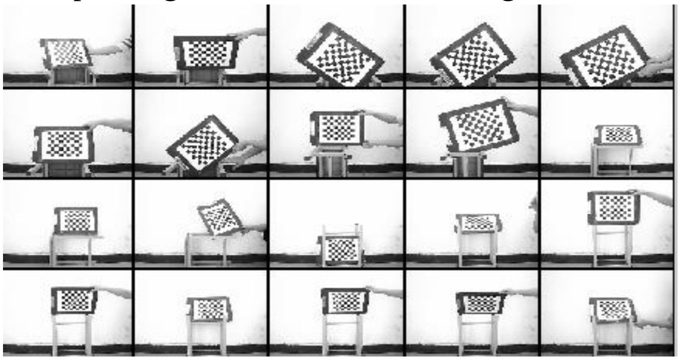

Fig.5 To calibrate the image of the board

2）Extracting the image of the chess board. Manually extract all the cross coordinates of the black and white chess board, and get the sub-pixel level corner point coordinate[4], as shown in Fig.6;

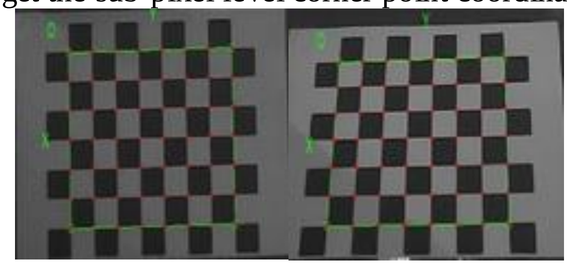

Fig.6 Corner extraction

3）Camera calibration. By extracting the corner coordinates into the equation, iterative operation, the camera parameters;

4）Binocular calibration. The calibration results of the left and right cameras are calibrated, and the calibration results are obtained by iterative optimization.

3.3 Calibration result analysis

The binocular camera calibration process is completed in the MTALAB human computer interaction interface, and the calibration results of the stereo camera are calculated by the calibration results of the camera calibration toolbox in MATLAB:

$$M_r = \begin{bmatrix} 721.51 & 0 & 319.20 \\ 0 & 726.87 & 224.51 \\ 0 & 0 & 1 \end{bmatrix}$$

$$M_l = \begin{bmatrix} 719.71 & 0 & 352.95 \\ 0 & 718.42 & 231.90 \\ 0 & 0 & 1 \end{bmatrix}$$

$$D_l = [-0.0742 \quad -0.2201 \quad -0.0045 \quad -0.0034 \quad 0]$$

$$D_r = [-0.0560 \quad -1.0085 \quad -0.0104 \quad 0.0035 \quad 0]$$

$$\mathrm{R} = \begin{bmatrix} 0.9962 & -0.0055 & 0.0054 \\ -0.0056 & 0.9997 & -0.0062 \\ 0.0054 & -0.0062 & 0.9962 \end{bmatrix}$$

$$\mathrm{T} = \begin{bmatrix} -86.7322 \\ 1.4310 \\ 6.9506 \end{bmatrix}$$

Above, M_l and M_r respectively represent the camera matrix of the left and right cameras; D_l and D_r are the distortion vectors of the left and right cameras; R is the matrix form which is obtained by the Om transform for the Rodrigues rotation vector; T is the translation vector.

Fig.7 for the left camera to describe the range of the point cloud of the back projection error size, different colors of different images, if there is a larger error, you can re calculate, optimize the results. If the map, the need to ensure that the error in the X axis and Y axis direction in a certain range, the calibration accuracy to meet the requirements, Fig.8 for the binocular camera and calibration board image location map.

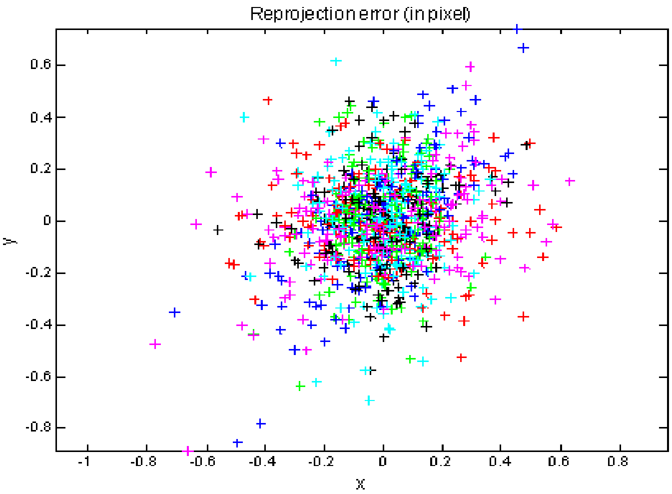

Fig.7 Back projection error of left camera

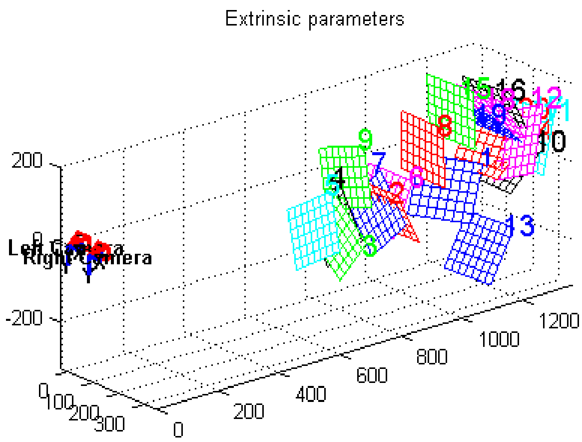

Fig.8 Position relation of binocular camera and calibration board

4. Conclusion

amera calibration is an important part of the recovery of 3D information. The accuracy of the research method directly affects the effect of the latter three dimensional reconstruction, and the key technology of the camera calibration is studied and realized. In this paper, we mainly study the method of planar template under the MATLAB programming interface. The transformation relation between imaging coordinate system and imaging model are studied, and the internal and external parameters of the binocular camera are obtained by using the left and right images of the binocular camera. This paper focuses on the Zhang Zhengyou's method of the calibration of the chess board. According to the laboratory's offer, the camera calibration process is realized based on the plane board method, and the internal and external parameters of the camera are obtained. In the MATLAB user interface, by calling the camera calibration toolbox to solve, and finally get the camera inside and outside parameters.

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