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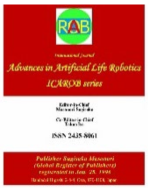

Research Article

Research on Feature Point Measurement Technology Based on Stereo Vision

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ABSTRACT

In view of the high similarity of feature points in low texture environment, this paper proposes an interactive method of manual selection of feature points based on stereo vision under the condition that automatic modeling cannot meet the requirement of 3D environment. Firstly, the model of binocular stereo vision camera with parallel optical axis is designed, then the camera calibration is carried out, and the 3D ranging system of interactive manual selection of feature point pairs is developed. In order to verify the effectiveness of the system, this paper uses corridor floor tiles with fewer texture features to carry out experimental tests. By verifying the three-dimensional coordinates of the measured feature point pairs, and comparing with the actual measured values, it is found that the measurement error is less than 1%.

1. Introduction

Distance measurement is one of the most important tasks of a computer vision system, and it is also continues to be a popular research topic in computer and robot vision nowadays [1]. Distance measurement plays an important role in robot navigation, obstacle detection, navigation of autonomous vehicles, surveillance monitoring, person localization and tracking, and many more. The distance measurement system based on binocular stereo vision is proposed in this paper. Firstly, the binocular vision model is established, a GUI interface is designed in MATLAB for calibration and the display of parameters. Then stereo rectification and stereo matching are carried out with OpenCV. Finally, the depth information is obtained by the parallax measurement of image pairs, and the distance between any two points can be calculated. The simulation experiments have been done and the results demonstrated that the measurement method is feasible. The designed binocular stereo vision system consists of five modules: image acquisition, camera calibration, image rectification, stereo matching, and distance measurement. This system can be described by the flow diagram shown in Figure 1.

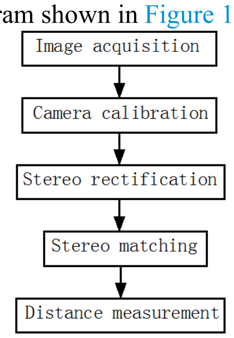

Fig. 1. System flow chart

2. Principle of binocular stereo vision ranging

Binocular stereo vision distance measurement is modeled on the distance perception methods of human eyes [2]. In this paper, the stereo vision system consists of two cameras with the same parameters that is parallel mounted and looking at the same objects, as shown in Figure 2.

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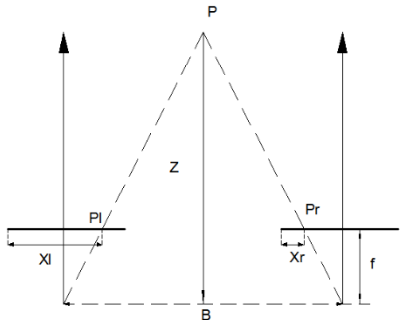

Fig. 2. Binocular vision model

Point P (X,Y,Z) is a point in the world coordinate system, and the coordinates of this feature point to the pixel coordinate system of the left and right cameras are $p_l\,(x_l,y_l)$ and $p_r\,(x_r,y_r)$ respectively. In this model, the focal length of the camera is f, the distance between point P in the measured space and the image plane of the camera is Z, namely, the depth is Z, and the baseline distance between the two cameras is B. Since the two cameras are placed in standard parallel, yl=yr, so it can be deduced from the triangle similarity principle:

$$\frac{B-(x_l-x_r)}{Z-f}=\frac{B}{Z},\frac{X}{Z}=\frac{x_l}{f},\frac{Y}{Z}=\frac{y_l}{f} \tag{1}$$

Let the parallax $d=x_l-x_r$, and the three-dimensional coordinates of P can be deduced from equation (1):

$$\begin{cases} X=\frac{B\cdot x_l}{d} \\ Y=\frac{B\cdot y_l}{d} \\ Z=\frac{B\cdot f}{d} \end{cases} \tag{2}$$

For a binocular stereo vision system, through the camera calibration, determine the focal length f baseline B between the two cameras and video cameras, and then calculated by stereo matching algorithm about the image of the coordinates of the corresponding feature points, calculate the parallax in the formula (2) above, after calculation can get feature points of three-dimensional coordinate information.

3. Camera calibration

The process of calibration is actually the process of solving the internal and external parameters of the camera [3]. Calibration is the basic and necessary process of binocular stereo vision. The result of calibration will determine the accuracy of distance measurement of the target object. In the process of camera calibration, three coordinate systems are needed: image coordinate system, camera coordinate system and world coordinate system. The camera is approximated to a pinhole model, and the parameter S (scale factor) and the homography matrix H are introduced [4]. The relationship between the points $P=[X\quad Y]^T$ in the imaging plane and $P=[X\quad Y\quad Z]^T$ in the space can be expressed as: $P=sHP$

Where H is represented by two matrices: $H=MW$

$$M=\begin{bmatrix} f_x & 0 & c_x \\ 0 & f_y & c_y \\ 0 & 0 & 1 \end{bmatrix} \tag{3}$$

M is the intrinsic parameter matrix of the camera. Where, c_x and c_y represent coordinates in pixel of the image center respectively. Since pixels on a normal camera are not guaranteed to be square, use two different focal lengths f_x and f_y.

$W=[R\ T]$,where, R , T are the extrinsic parameters of the cameras, denoting the rotation matrix and the translation vector from the left camera coordinate system to the right camera coordinate system, respectively [5].

Considering the distortion of lens, suppose $q_p(x_p,y_p)$ is the corrected point, and $q_p(x_p,y_p)$ is the distorted point, then:

$$\begin{bmatrix} x_p \\ y_p \end{bmatrix}=\left(1+k_1r^2+k_2r^4+k_3r^6\right)\begin{bmatrix} x_d \\ y_d \end{bmatrix}+\begin{bmatrix} 2p_1x_dy_d+p_2\left(r^2+2x_d^2\right) \\ p_1\left(r^2+2y_d^2\right)+2p_2x_dy_d \end{bmatrix} \tag{4}$$

Where (K_1, K_2, P_1, P_2, K_3) constitutes a 5 × 1 matrix, which is the distortion matrix of the camera [6].

The method of camera calibration used in this paper is based on the checkerboard template calibration method proposed by Zhang, which has the advantages of simple operation and high precision. In this paper, a GUI interface is designed in MATLAB for calibration and display of results. The specific steps are as follows:

(i)Self-made calibration plate; The number of c corners is 7×5 and the size of the calibration target is 20mm×20mm

(ii)Image acquisition; Images from different angles of the calibration target are collected simultaneously with a binocular camera placed in parallel, and the image resolution is 640×480. A total of 13 sets of image pairs were collected, as shown in Figure 3 and Figure 4.

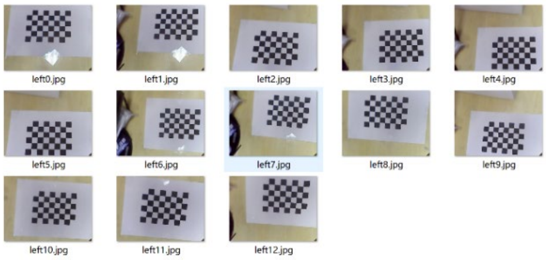

Fig. 3. Left images of calibration target images

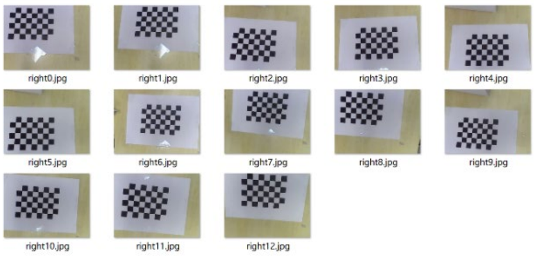

Fig. 4. Right images of calibration target images

(iii)Calibration. Click the calibration button on the GUI interface to import the binocular image pair collected. Then, corner detection and stereo calibration are carried out to obtain the internal and external parameters of the binocular camera and display them on the GUI interface, as shown in Figure 5.

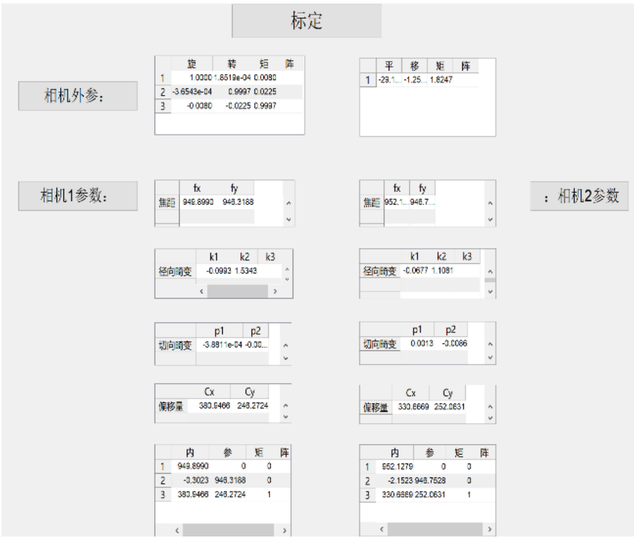

Fig. 5. GUI interface

4. Distance Measurement experiment

4.1. *Experimental scheme*

Firstly, a binocular camera model with parallel optical axis is built, and an MFC interface for manually selecting feature points is developed in VS to recover the 3D information of feature points. After the calibration of camera for internal and external parameters, and then USES binocular camera collection to get images, will be taken around the camera images to import to the human-computer interaction interface, by manually selecting the corresponding feature points about images, get three-dimensional coordinates of the point at which, in the end will be saved to the 3d coordinates . txt file.

4.2. *Experimental steps*

1) Two German Basler cameras of the same model were used to build a binocular ranging model parallel to the optical axis. The model was installed on the head of the robot at 45。 with the ground to maintain the accuracy and precision of camera installation as much as possible.

2) Complete the camera calibration according to the content in Section 3.

3) Collect corridor pictures with a binocular camera, and the left and right images obtained are shown in Figure 6.

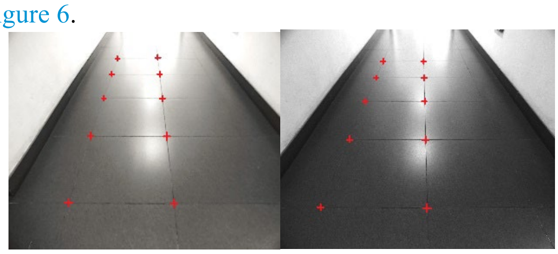

Fig. 6. image pairs

4) Import the captured image pairs in the developed human-computer interaction interface, manually select the corresponding feature points in the left and right images, and calculate the 3D coordinate information of the selected feature points in the world coordinate system according to the principle of stereoscopic vision triangulation, as shown in Figure 7.

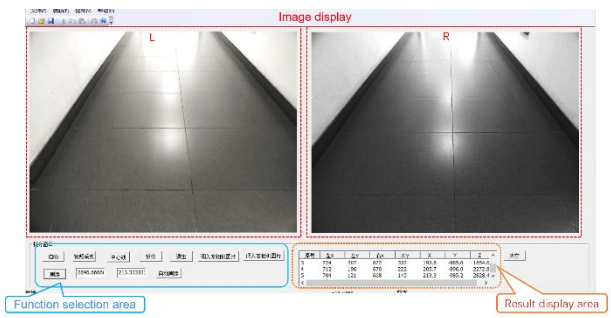

Fig. 7. Human-machine interaction interface

Developed by the man-machine interactive interface is mainly composed of three parts, the top for collected image display area, the lower left for feature selection area, can realize the function such as image acquisition, import, ranging, the choice of the lower display area for results, can be manually selected pixel coordinates and recovery feature point around the world coordinates are displayed.

5) Save the 3D coordinates of the obtained feature points in .txt file.

5. Experimental results

In order to effectively verify the accuracy of 3D reconstruction, the sample map of the corridor was selected for experimental ranging. A total of 10 feature points in the first and second column of the left number in the corridor were recovered for 3D information and calculated for distance. The results are shown in Table 1.

Table 1 3D coordinate information and error results

	x/mm	y/mm	z/mm	Measured distance L'/mm	Real distance L/mm	Absolute error Δ /mm	Relative error δ
1	172.5	-973.3	457				
2	182.5	-977.1	1051.9	595.00	600	5.00	0.83%
3	193.8	-988.9	1654.6	1197.89	1200	2.11	0.18%
4	205.7	-996	2272.8	1816.25	1800	16.25	0.90%
5	213.3	-985.2	2838.4	2381.78	2400	18.22	0.76%
1	769.6	-974.2	456.3	597.10	600	2.90	0.48%
2	778.3	-978.1	1053.1	596.88	600	3.12	0.52%
3	796.7	-989.6	1665.5	1209.60	1200	9.60	0.80%
4	809.2	-997.4	2268.9	1813.18	1800	13.18	0.73%
5	810.1	-988.9	2836.4	2380.49	2400	19.51	0.81%

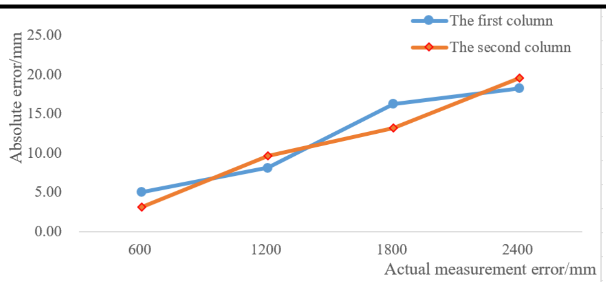

Fig. 8. Absolute error

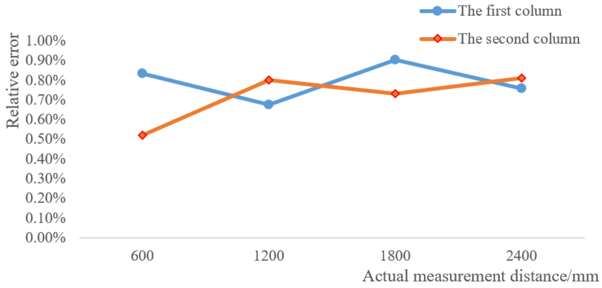

Fig. 9. Relative error

As can be seen from the data in the table and error figure, the measured distance between the floor tiles is basically the same as the real size. It can be seen from Table 1 that within the measurement range, with the increase of the measured characteristic point depth Z value, the absolute error shown in Figure 8 gradually increases, while the relative error shown in Figure 9 fluctuates within a certain range but remains below 1%.

6. Conclusion

In order to ensure the accuracy and reliability of 3D reconstruction, a 3D ranging system based on interactive manual selection of feature point pairs is developed to solve the problem that feature points in low-texture images are not easy to distinguish. In order to verify the effectiveness of the system, the corridor floor tiles with less texture features are used for experimental ranging. By verifying the three-dimensional coordinates of the measured feature point pairs and comparing with the actual measured values, the relative error is less than 1%, which proves the correctness of the developed system and the relevant algorithms.

Acknowledgements

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Authors Introduction

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