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A Geometric Correction Method of Plane Image Based on OpenCV

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Abstract: Using OpenCV, a geometric correction method of plane image from single grid image in a state of unknown camera position is presented. The method can remove the perspective and lens distortions from an image. The method is simple and easy to implement, and the efficiency is high. Experiments indicate that this method has high precision, and can be used in some domains such as plane measurement.

Keywords: Correction, Perspective distortion, Lens distortion, Accuracy evaluation.

1. Introduction

Computer Vision is widely used in some domains such as automatic industrial manufacturing line, a variety of testing and monitoring, automatic interpretation of image and so on. Its application can improve work efficiency and product quality. Since the images captured by camera have certain perspective and lens distortions, in order to obtain object's actual size, it is necessary to carry out geometric correction, and result of geometric correction affects the detection accuracy directly. How to more accurately and quickly correct image, many scholars have made a lot of research on it and gotten some results.

According to whether the calibration object is needed, the method of camera calibration is classified into traditional and self-calibration one [1]. The method proposed in the paper belongs to the former. There are several researches have been done on the traditional camera calibration method. In 1987 Tsai proposed two-stage methods with distortion model [2]. The method has high precision and less calculation. However, the method only considers the factors of radial distortion, loses sight of the effect of tangential distortion. In 1998, Zhang proposed a flexible camera calibration by viewing a plane from unknown orientations [3, 4]. The method requires the camera to shoot a chessboard in at least two different directions and the camera and chessboard to move freely. It ensures that internal and external parameters can be acquired. Zhou Fuqiang et al proposed correction method based on feature object (points, lines and other features of the object) [5-8]. The method is based on the principle that feature object still exists some properties in the ideal image. Then the distortion parameter equation is established. This method is very complicated, or needs to strictly control the relationship between image coordinate system (ICS) and world coordinate system (WCS).

The planar measurement needs an image that would have resulted if the camera had looked perfectly perpendicularly without distortions from the world plane. This geometric correction is useful for

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applications that must work on the image data itself, e.g., measurement of small-sized object on the conveyor belt, printed matter pattern detection. In these applications, the distance and angle of the camera and the world plane are almost constant, if these above methods are used again, the process of geometric correction will too complicated, and it will be very difficult for the real-time data processing to be realized. So the present study proposes a geometric correction method of plane picture based on OpenCV. The method can be used to establish relationship between no-distortion image and distorted image in plane by a checkerboard image, and easily remove the perspective and lens distortions from an image. The method is simple and easy to implement, and the efficiency is high.

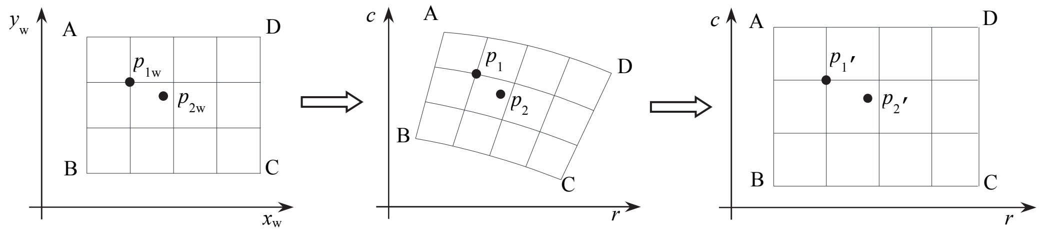
2. Design of Geometric Correction Algorithm

This algorithm is mainly used in planar measurement, shape, size, coordinate and direction of an object can be determined from an image. For the convenience of measurement, geometric deformation should be removed from an image. This creates an image that would have resulted if the camera had looked perfectly perpendicularly without distortions from the world plane.

Aiming at this special application, the following prerequisites are established: 1) Measurand is placed onto the plane and it is infinitely thin; 2) The distance and angle of the camera and the world plane is constant during measurement; 3) The camera chain, namely pinhole camera, consists of ordinary lens and area array CCD.

Research object is shown in Fig. 1. The actual shape of target in the world coordinate system is shown in Fig. 1(a). The image from a camera and geometric corrected image are shown in Fig. 1(b) and Fig. 1(c) respectively. They have their own image coordinate system. Comparing Fig. 1(b) with Fig. 1(a), there is complex geometric distortion in Fig. 1(b), e.g., perspective distortion, lens distortion, rotation, translation and scaling in image coordinate system.

Using geometric correction method, the algorithm converts Fig. 1(b) to Fig. 1(c). And the correspondence of Fig. 1(c) and Fig. 1(b) is determined.



(a) Ideal image (b) Image from the camera (c) Geometric corrected image

Fig. 1. Image distortion schematic diagram.

This algorithm is based on the idea:

1) Divide shooting plane into small square regions along X and Y axes of WCS, respectively.

2) The premise of algorithm is the 3D position of the grid corner p1w is known. Find the projection p1 of the grid corner in image, and then convert it into image coordinate P_1' corresponding to the 3D position. Through this step, pixel location of the grid corner will usually produce the best correction results.

3) For other points in square domain, their projections in image are affected by the perspective and lens distortions, but because of the smaller square, the lens distortion in square region can be ignored, we only need to remove the perspective distortion from the image. If we use homogeneous coordinates to express both the distorted coordinate P in uncorrected image and the undistorted coordinate P' in corrected image, this mapping in terms of matrix multiplication can be expressed by:

$$P' = T_P P \,, \tag{1}$$

where T_p is the 3-by-3 matrix. Matrix T_p can be calculated by four corner-points in uncorrected and corrected image. The other undistorted coordinates in corrected image can be obtained by formula (1).

It can be predicted that the smaller the divided square region, the better geometric correction will be.

4) Treat the remaining square regions in order, thus complete geometric correction.

5) For each pixel in the corrected image, its RGB value obtained by using bilinear interpolation method.

3. Geometric Correction Algorithm Implementation

The experimental device is a special measuring platform. With C++ programming language and computer vision library OpenCV, software was developed. Specific steps are as follows:

1) The camera is mounted in its proper position over the shooting plane. To ensure camera's axis is basically perpendicular to the plane. Manual focus until the image becomes the finest, and then fixes the current camera state.

2) Design and manufacture of a checkerboard pattern which is large enough to cover the shooting region, shows as Fig. 1(a). The checkerboard pattern is placed into known location in the world coordinates. The rectangular matrix layout of the rows and columns of the checkerboards enables the geometric calibration algorithm to determine the correspondence between the corners and their image points easily.

3) The image from a camera is shown in Fig. 1(b). Find corners on the image with the findChessboardCorners() function. To find the corner location with sub-pixel accuracy, the cornerSubPix() function is used.

4) Enter four corner-points in uncorrected and corrected image into getPerspectiveTransform() to compute the projective transformation matrix T_p for the square view.

5) For other points within square, the undistorted coordinates in corrected image can be obtained by formula (1) and step (4).

6) Obtain each undistorted coordinates in order, thus get a no-distortion image.

7) The undistorted coordinates in corrected image may not be integer, so the RGB value can not be obtained directly. According to bilinear interpolation method, find the four proximate points (u_1, v_1), (u_2, v_2), (u_3, v_3) and (u_4, v_4) to desired point (u, v), use the distance relation of the points, and obtain the RGB value.

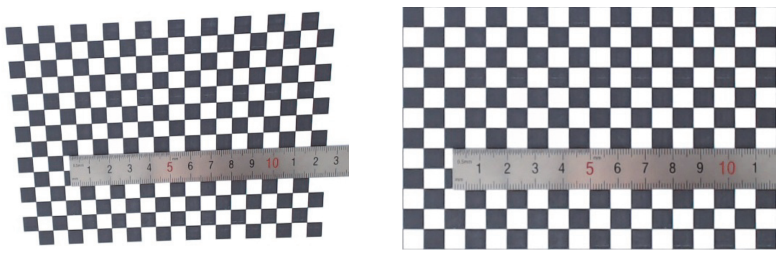
4. Experiments and Result Analysis

In order to study on the algorithm accuracy and the effects of different parameters on the algorithm accuracy, experiments are performed on different images. Analyze the experimental result, compare with other methods and study the advantages, disadvantages.

4.1. The Dimensional Accuracy of the Different Positions and Lengths

Fig. 2 shows an example of the geometric correction method. In Fig. 2(a), the image of a caliper together with the calibration target that defines the shooting plane is shown. The uncorrected and corrected images of the caliper are shown in Fig. 2(a) and Fig. 2(b), respectively. Note that the geometric correction has removed the perspective and lens distortions from the image.

To quantitatively analyze the linear dimensional precision of geometric correction, we can measure and calculate the actual size between graduation lines of the caliper according to the correspondence of the actual size and pixel of the corrected image, as shown in Table 1.



(a) The uncorrected image (b) The corrected image

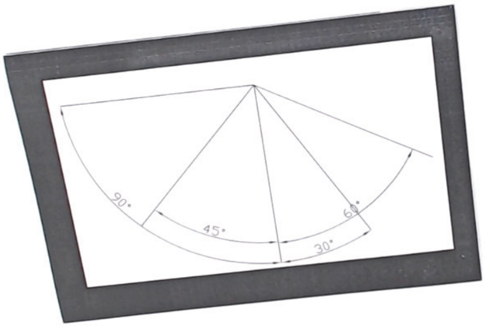
Fig. 2. Image correction result.

Table 1. The measured distance value and error.

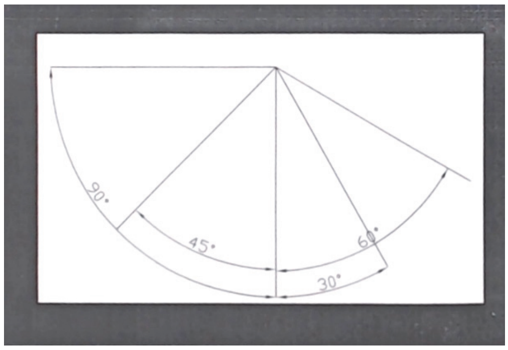
Measurement scale	Actual length / mm	Measured value / mm	Absolute error / mm	Relative error / %
1 - 2 cm	10	9.99	-0.01	0.1
2 - 3 cm	10	10.03	0.03	0.3
3 - 4 cm	10	9.95	-0.05	0.5
4 - 5 cm	10	9.95	-0.05	0.5
5 - 6 cm	10	9.99	-0.01	0.1
1 - 3 cm	20	20.06	0.06	0.3
1 - 4 cm	30	30.05	0.05	0.17
1 - 5 cm	40	40.02	0.02	0.05
1 - 6 cm	50	49.94	-0.06	0.12

The Table 1 lists nine sets of measurements. As seen from the table, the linear dimensional precision of image after geometric correction is higher (the most relative error is 0.5 %), the dimension error is distributed random, has nothing to do with the measured position and length, and does not accumulate.

The image of a rectangular board with different angles could be calibrated, the results should display as shown in Fig. 3. The uncorrected and corrected images are shown in Fig. 3(a) and Fig. 3(b), respectively. Note that the geometric correction has removed the distortions from the image.



(a) The uncorrected image



(b) The corrected image

Fig. 3. Image correction result.

To quantitatively analyze angle precision of geometric correction, we can measure the actual angles of 30°, 45°, 60°, 90° marked on Fig. 3, as shown in Table 2.

The Table 2 lists four sets of measurements. As seen from the table, the maximum absolute error is 0.2°, the most relative error is 0.33 %, and the average absolute error and relative error are 0.13° and 0.25 % respectively. Note that the angles in the corrected image have no obvious changes.

Many groups of data set out the Table 2 indicate that range error is small, and angle precision is high. We hold that this method is feasible, and it can meet the requirements of the plane measurement.

Table 2. The measured angle value and error.

Serial number	True angle	Measured angle	Absolute error	Relative error
1	30°	29.9°	-0.1°	0.33 %
2	45°	45.1°	0.1°	0.22 %
3	60°	60.2°	0.2°	0.33 %
4	90°	90.1°	0.1°	0.11 %

4.2. The Effect of Checkerboard Size on the Correction Accuracy

Based on these results, this paper further investigates the effect of checkerboard size on the correction accuracy. In this paper, the shooting plane is divided into different size of checkerboard. The distance from 6 cm to 8 cm is calculated, the calculated distance value is compared with the actual length between graduation lines of the caliper, as shown in Table 3.

The difference between the measured and actual values is graphically described in Fig. 4. As can be seen from the Table 3 and Fig. 4:

1) In cases where camera position and focal length is fixed, the smaller the checkerboard, the better geometric correction will be.

2) As we can see from Fig. 4, relative error changes smoothly in respect to checkerboard having size about 10~17.5 mm, relative error is great in respect to checkerboard having size over 17.5 mm. In a word, the selection of checkerboard size should depend on specific condition.

Table 3. The measured distance value and error.

Serial number	Checkerboard size / mm	Measured value / mm	Absolute error / mm	Relative error / %
1	7.5	19.99	-0.01	0.05
2	10	19.95	-0.05	0.25
3	12.5	20.06	0.06	0.30
4	15	20.07	0.07	0.35
5	17.5	19.92	-0.08	0.40
6	20	20.10	0.10	0.50

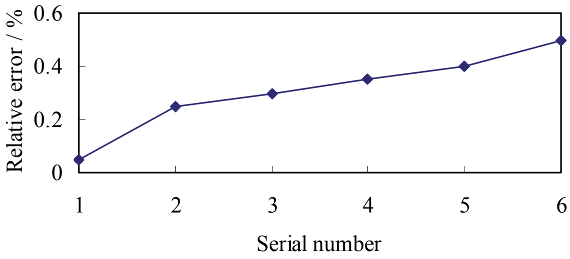


Fig. 4. The effect of checkerboard size on the correction accuracy.

4.3. A Contrast Experiment of Different Methods

The proposed method is compared with Zhengyou Zhang's calibration method and camera calibration toolbox for Matlab, experimental conditions are the same. Measurements are performed on 9 measuring locations in Fig. 2, each location is measured 10 times and its average relative error is calculated. The relative error of three methods is shown in Fig. 5. As can be seen from Fig. 5, the accuracy of the proposed method is comparable to two mature calibration methods (Zhengyou Zhang's calibration method and camera calibration toolbox for Matlab).

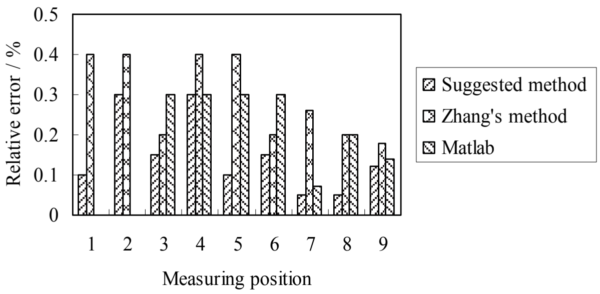


Fig. 5. The relative error of three methods.

5. Conclusions

In this paper, the geometric correction method of plane picture based on OpenCV is proposed from the point of view of a practical application. Compared with the existing methods, this method is simple and easy to come true, the computation is low. In the process of geometric correction, the relationship between no-distortion image and distorted image is stored as a template. It can be used to accelerate correction process and save calculation time but can not influence precision. Experiment indicates that this method has high precision, and can be used in some domains such as plane measurement. In order to improve the correction precision, there are some problems need to be solved, such as corner extraction precision, this is the future research direction.

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References

[1]. M. L. Qiu, S. D. Ma, Y. Li, Overview of camera calibration for computer vision, *Acta Automatica Sinica*, Vol. 26, Issue 1, 2000, pp. 43-55.

[2]. R. Y. Tsai, An efficient and accurate camera calibration technique for 3D machine vision, in *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition CVPR'86*, Miami Beach, Florida, 1986, pp. 364–374.

[3]. Z. Zhang, Flexible camera calibration by viewing a plane from unknown orientations, in *Proceedings of the International Conference on Computer Vision*, Kerkyra, Greece, 20-27 September 1999, pp. 666-673.

[4]. Z. Zhang, A flexible new technique for camera calibration, *IEEE Transactions on Pattern Analysis and Machine Intelligence*, Vol. 22, Issue 11, 2000, pp. 1330-1334.

[5]. F. Q. Zhou, K. Hu, G. J. Zhang, Correcting distortion of camera lens with collinear points, *Chinese Journal of Mechanical Engineering*, Vol. 42, Issue 9, 2006, pp. 174-177.

[6]. Z. Q. Qiu, H. W. Lu, Q. F. Yu, A correction method of fish-eye lens distortion using projective invariability, *Journal of Application Optics*, Vol. 24, Issue 5, 2003, pp. 36-38.

[7]. Y. Liu, D. F. Huang, Z. Q. et al., Distortion correction method of camera lens based on affine transformation and perspective projection, *Journal of Southwest University o f Science and Technology*, Vol. 25, Issue 3, 2010, pp. 76-81.

[8]. J. J. He, G. J. Zhang, X. M. Yang, Approach for calibration of lens distortion based on cross ratio invariability, *Chinese Journal of Scientific Instrument*, Vol. 25, Issue 5, 2004, pp. 597-599.