A Flexible Camera Calibration System for Mobile Platform

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Abstract

We propose a flexible camera calibration system for mobile platform to calibrate the camera's intrinsic parameters which based on the geometrical property of the vanishing points determined by two perpendicular groups of parallel lines. The system only requires the camera to observe a rectangle card show at a few(at least four)different orientation. The experimental results of the real images show the proposed calibration system in this paper is easy to use and robust.

1..Introduction

Camera calibration is an important problem in the research of Computer Vision and an important role in extracting 3D information from 2D images and AR (Augmented Reality). During the last years, the smart phone technology has been changing fast. The research of AR technology on mobile platform is in rapid advance. It is necessary to develop a calibration system that is suit for mobile platform. Generally speaking, the camera calibration techniques can be divided into the following three categories: traditional calibration techniques, self calibration techniques and calibration techniques based on active vision. Traditional method of camera calibration[1][2] is known as using a calibration piece, which of known structure and high precision processing. Self-calibration method can be divided into: based on Kruppa Equations self-calibration techniques [3] and using the absolute quadric techniques[4], these self-calibration methods don't depend on the calibration reference object, but all of these methods need to calculate the feature points, then calculate corresponding points, the time cost of this processing time is expensive for mobile platform. The calibration techniques based on active vision need the camera to be precisely installed in the controllable platform[5]. In our system, we use a camera calibration method which based on the geometrical property of the vanishing points determined by two perpendicular groups of parallel lines[6], and the vanishing points can be obtained from a arbitrary rectangle card. This card can be easily obtained in daily life(e.g. credit card, business card...). Compare with general method, our method is easy to use and robust.

2. Basic principles

2.1 Projective geometry of the camera model

Pinhole camera model is a useful model in computer vision. In the pinhole camera model, the camera is assumed to perform a perfect perspective transformation .the transformation relationship of each coordinate frame is illustrated in Figure 1, image coordinate frame is a coordinate frame with the origin point at the upper-left corner and unit is pixel; In perspective plane coordinate frame regard the intersection O_u between optical axis and the perspective plane as the origin point; In camera coordinate frame regard the optical center O as the origin point; The world coordinate frame is the three-dimensional space's reference frame. Let $p(u,v)^T$ be the image coordinates of the world coordinates $P_W(x_W, y_W, z_W)^T$ then, the equation of the projection

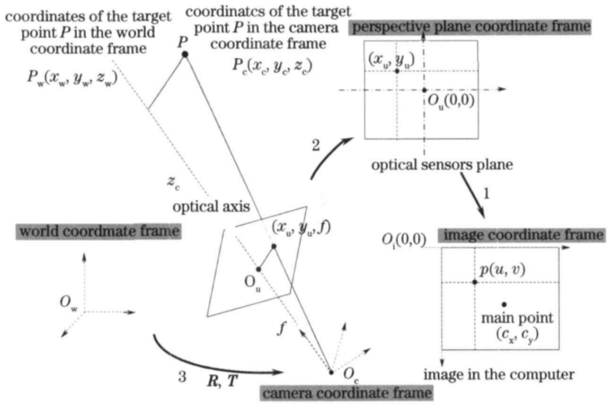

Fig 1. Projective geometry of the camera model

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is

$$\frac{1}{z_c}\begin{bmatrix}u\\v\\1\end{bmatrix}=\begin{bmatrix}f/d_x & s & c_x\\0 & f/d_y & c_y\\0 & 0 & 1\end{bmatrix}\bullet\left\{R\bullet\begin{bmatrix}x_W\\y_W\\z_W\end{bmatrix}+T\right\}=$$

$$K\bullet[R\ T]\begin{bmatrix}x_W\\y_W\\z_W\\1\end{bmatrix}, \qquad (1)$$

Where K is an upper triangle matrix accounting for the intrinsic camera parameters; and R, T is accounting for camera orientation and position, and represent 3×3 rotation matrix and 3×1 translation matrix, that is the extrinsic camera parameters. f is camera's focal length. d_x, d_y is the size of CCD/CMOS sensor pixels's length and width. (c_x, c_y) is the coordinates of the principle point, s is a factor accounting for the skew due to non-rectangular pixels. For most cameras the pixels are almost perfectly rectangular and thus s is very close to zero, in this paper, we suppose s is 0. using f_x to account for f/d_x, and f_y to account for f/d_y. Where z_c is the value that is 3D world point's z_W in camera coordinate frame.

2.2 The geometrical property of the vanishing points determined by two perpendicular groups of parallel lines

Images of a family of parallel lines pass through a common point in the image plane called their vanishing point. The line joining the camera centre and the vanishing point of the world line is parallel to that world line[7]. Using a plane that has two perpendicular groups of parallel lines. as illustrated in Figure 2. space straight lines: $L_1 // L_2$, $L_3 // L_4$, $L_1 \perp L_3$, L_1 and L_2's projection in image plane l_1, l_2 intersect at vanishing point A, L_3 and L_4's projection in image plane l_3, l_4 intersect at vanishing point B. By the vanishing point's property, we can know the lines joining the optical centre O and the vanishing point A, B are parallel to the respective lines that correspond to in the world: $OA // L_1$, $OB // L_3$, then, $OA \perp OB$, O is on a sphere which diameter is AB.

We come to the conclusion that if two perpendicular groups of parallel lines exist, the optical centre O is on the sphere which diameter is the line joining two vanishing points obtained by those parallel lines.

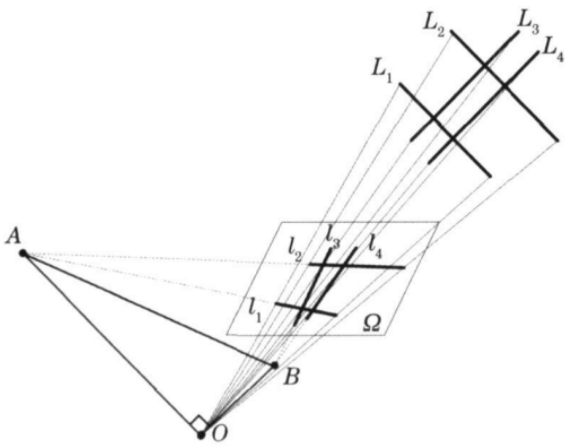


Fig 2. Geometry model of the ideal projection of two perpendicular groups of parallel lines

3. Calibration system Implementation

Our calibration system is divided in three stages(See Figure 3). First stage is pre-processing for obtaining the card image's lines. Second stage is finding vanishing points by the lines detected by first stage. And the last stage is calibration from vanishing points.

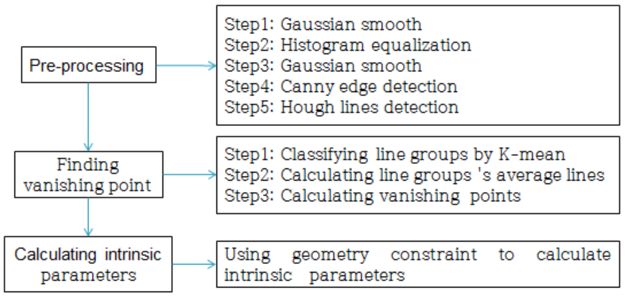


Fig. 3 Overview of the calibration system

3.1 Pre-processing

The first step in this stage is gaussian smoothing. Gaussian smoothing is the result of blurring an image by a Gaussian function. It is a widely used effect in graphics software, typically to reduce image noise and reduce detail. In this step, it is used to reduce the noising that generated by camera's sensor. Then, we enhance the edges's details of the image by increasing the global contrast through Histogram equalization. In third step, we use gaussian filtering to reduce little edge's influence. then, detect the edge by canny algorithm[8]. At last, we detect the lines by Hough lines detection[9].

3.2 Finding vanishing points

In this stage, we use the k-means algorithm[10] to classify the lines as four groups based on line's angle and intercept, respectively. Then, calculate each of the line groups's average lines. In the last step, use the classified average lines to calculate the vanishing points.

3.3 Camera calibration from vanishing points

Based on 2.2 section's principle, in image coordinate frame, the vanishing points coordinates obtained by parallel lines's projection are: $A(u_A, v_A)$, $B(u_B, v_B)$, then the vanishing points coordinates in camera coordinate frame are:

$$A((u_A - c_x)d_x, (v_A - c_y)d_y, f), B((u_B - c_x)d_x, (v_B - c_y)d_y, f),$$

The sphere equation which diameter is AB :

$$[x - \frac{u_A + u_B}{2}d_x + c_x d_x]^2 + [y - \frac{v_A + v_B}{2}d_y + c_y d_y]^2 + (z - f)^2 = (\frac{u_A - u_B}{2}d_x)^2 + (\frac{v_A - v_B}{2}d_y)^2 \qquad (2)$$

Based on 2.2 section's conclusion: optical centre $O(0,0,0)^T$ is on the sphere, then:

$$\frac{(c_x - u_A)(c_x - u_B)}{f_x^2} + \frac{(c_y - v_A)(c_y - v_B)}{f_y^2} + 1 = 0 \quad (3)$$

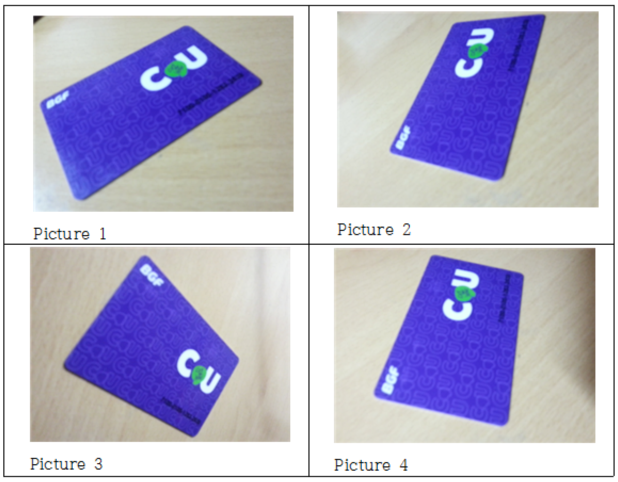
Equation(3) is a function of intrinsic camera parameters (c_x, c_y, f_x, f_y). it has four unknowns. At least four images obtained by different orientation is necessary. In Hun's method[6], they consider the lens distortion coefficient, use a non-linear optimization based on Nelder-Mead simplex algorithm to optimize the intrinsic parameters. Due to the mobile camera's lens distortion is minimal, we have solved the intrinsic parameters by the method of least squares.

Table 1 vanishing points

	Picture1	Picture2
vanishing point1	(2664.0598 , -1170.3644)	(733.19458, -834.54834)
vanishing point2	(-233.69971, -442.30933)	(-664.19867, 127.12403)
	Picture3	Picture4
vanishing point1	(946.40106, 763.35248)	(-15593.582, -3253.1704)
vanishing point2	(1932.8491, -2226.2668)	(544.02344, -708.35468)

4. Experiments

We took 4 images, shown in Figure 4 by moving around a card, so that the different vanishing points had obtained. The result of Pre-processing shown in Figure 5. The result of classifying the lines shown in Figure 6. The average lines shown on Figure 7. The result of calculating vanishing points shown on Table 1. The reuslt of calibration shown on Table 2. And we had also used Zhang's chessboard method[2] to calibrate the camera as reference, and the result shown on Table 3. Compare the result of our system with the result of Zhang's method, there are not significant difference between two method. But our system is more flexible.



Picture 1 Picture 2 Picture 3 Picture 4

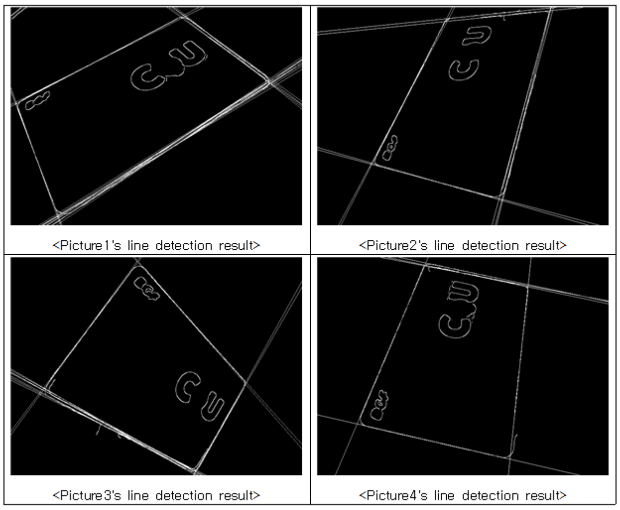
Figure 4. Test Image Sample(Using the back camera of GALAXY Note2: Resolution 480X640)

Table 2 calibration form vanishing points result

Camera parameter		Test result
focal length	f_x	528pixel
	f_y	521pixel
principle point	c_x	311pixel
	c_y	247pixel

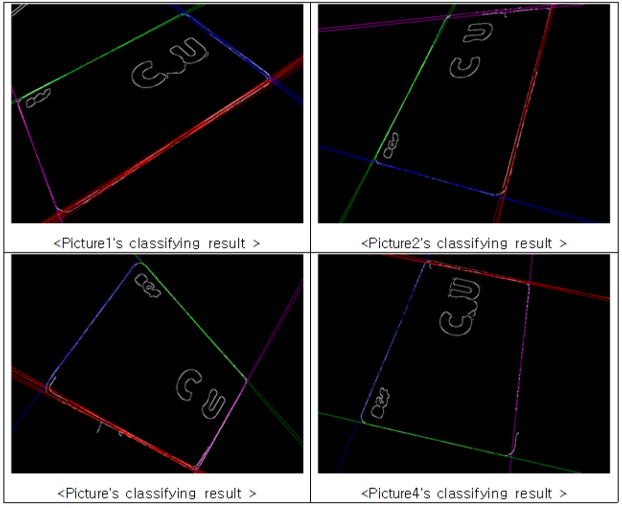
Table 3 Zhang's method calibration result

Camera parameter		Test Data1	Test Data2	Test Data3
focal length	f_x	525pixel	524pixel	526pixel
	f_y	526pixel	524pixel	526pixel
principle point	c_x	321pixel	319pixel	318pixel
	c_y	252pixel	250pixel	253pixel



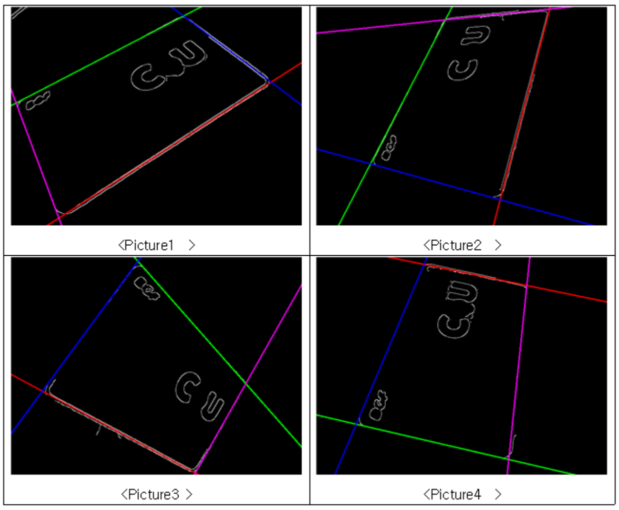
<Picture1's line detection result> <Picture2's line detection result> <Picture3's line detection result> <Picture4's line detection result>

Figure 5. The result of Pre-processing



<Picture1's classifying result > <Picture2's classifying result > <Picture's classifying result > <Picture4's classifying result >

Figure 6. The result of classifying(each of line groups are marked with Red, Green, Blue, Pink)



<Picture1 > <Picture2 > <Picture3 > <Picture4 >

Figure 7. The average lines(each of average lines are marked with Red, Green, Blue, Pink)

5. Conclusion

In this paper, we have presented a camera calibration system. this system can find the vanishing points in the image of arbitrary rectangle card and calibrate the intrinsic camera parameters by those vanishing points. Experiments have shown this system is flexible and effective.

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