AN ACCURATE CORNER DETECTION ALGORITHM IN THE INFRARED IMAGE

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ABSTRACT

In HCI (Human-Computer Interaction), the camera is often with wide angle lens and the captured image is usually distorted. The infrared image is more blurred than general image, so the contrast and the brightness is lower. In this paper, a cross shape mask is used to get the preliminary chessboard internal corners. And the adaptive threshold is put forward to remove outliers and align the corners. With considering the local symmetry property around the internal corner and the chessboard line architecture, the final internal corner coordinates with the sub-pixel accuracy can be computed with the Orthogonal Vector. Some traditional algorithms are experimented to show its improvement.

KEY WORDS

Corner detection, Camera calibration, Grid point

1. INTRODUCTION

In human-computer interaction table-top system that based on computer vision, the infrared camera is widely used, due to its invisibility and good sensitivity for camera lens. And the infrared camera calibration is an important part in it. In camera calibration, we need to recognize the internal corners of a planar checkerboard calibration pattern image which is an essential part.

In [1], the author has proposed an interactive approach to obtain the internal corners of planar checkerboard pattern image. It adopts an automatic mechanism for counting the number of squares in the grid and predicting the grid corners. If working with a large number of images, this tool is especially convenient. In [2], some functions implement the automatic internal corner detection. But the algorithm is not stable for specific corner detection tasks.

In this paper, we propose an effective method to recognize the internal corners of the planar checkerboard. It is based on the characteristics of local intensity and the grid line architecture of the planar checkerboard pattern image, and we adopt the cross mask as [3] to realize the corner detection.

2. CROSS MASK CONSTRUCTION FOR INTERNAL CORNER DETECTION

Fig.1 shows an original planar checkerboard pattern image with serious radial distortion. The internal corners are marked with Red Cross. We can see that an internal corner of chessboard planar pattern is the intersection of two white and two black squares in the grid. The local circle area around the internal corner is obviously two-fold symmetrical.

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Fig.1 The internal corner of chessboard

Since the internal corner is the intersection of two white and two black squares in the grid, it is clear that the cross with 45° rotation is like 'X'. As shown in Fig. 2, we separate 'X' into four parts. If the cross center lies on the corner, the I and III, the II and IV are similar. So we use the symmetrical nature to obtain the position of chessboard corner.

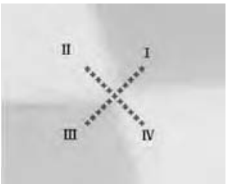

Fig.2 the cross mask for corner detection

In image *I(x,y)*, the points who santisfy the following equation will be considered as the candidate grid points for furtuer processing [4].

$$\begin{cases} d_p = \sum_{\alpha=-r}^{r} \exp\left(\left(\frac{I(i+\alpha, j+\alpha) - I(i+\alpha, j-\alpha)}{t}\right)^2\right) > g_1 \\ d'_p = \sum_{\alpha=0}^{r} \exp\left(\left(\frac{I(i+\alpha, j-\alpha) - I(i-\alpha, j+\alpha)}{t}\right)^2\right) < g_2 \\ d''_p = \sum_{\alpha=0}^{r} \exp\left(\left(\frac{I(i+\alpha, j+\alpha) - I(i-\alpha, j-\alpha)}{t}\right)^2\right) < g_3 \end{cases} \quad (1)$$

where r is the size of the cross mask, t is the normalized parameter, g_1, g_2 and g_3 are the thresholds respectively. g_1 represents the difference between I, III and II, IV; g_2 and g_3 mean the similar between I and III, II and IV seperately.

The appropriate threshold can remove most false grid points. The image gotten by infrared camera is usually with lower contrast and blurred. And this makes a great influence on the threshold selection. So in different illumination, it need different thresholds to get the best result.

In this algorithm, we adopt adaptive threshold to restrain the influence of illumination. The threshold g_1, g_2 and g_3 can be computed as Equation (2) as:

$$\begin{cases} g_1 = 2r * \exp(A * \sum_{\delta} \delta(i,j)^2 P_\delta(i,j)) \\ g_2 = g_3 = 2r * \exp(B * \sum_{\delta} \delta(i,j)^2 P_\delta(i,j)) \end{cases} \quad (2)$$

where $\delta(i,j)$ indicates difference pixel value between the center pixel and its adjacent pixels according to its four-connectivity, and $P_\delta(i,j)$ is the probability of the difference equal to $\delta(i,j)$ in whole image. A and B are constant.

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3. ROBUST CORNER DETECTION WITH SUB-PIXEL ACCURACY

3.1 Computing the Symmetry for Corner Collection

As shown in Fig. 1, the rectangular window of intensity values overlaps exactly with the 180° rotation of itself in the image domain. This symmetry is good at resisting image noise, blur especially perspective distortion.

Define *W* as the intensity of the blob window centered at candidate corner *d*, and *M* as the intensity of the same blob rotated 180°. We can get the symmetry $\rho(i,j)$ of the candidate corner as follows:

$$\rho(i,j) = \frac{1}{n}\sum_{i=1}^{n}\exp\left(-\frac{(m_i - w_i)^2}{t}\right) \qquad (3)$$

where *n* is the size of the window whose radius is equal to the size of the cross mask, m_i and w_i represent the intensity of all elements in the window and the rotated window respectively. The corner point whose correlation coefficient $\rho(i,j)$ is larger than a threshold is kept as corner candidate for further processing.

3.2 Clustering based on Local Symmetry

Now most of the candidate corners are divided into several clusters according to its eight-connectivity. Most of the clusters are concentrated at the true chessboard corners, and only few lie at the surrounding of the chessboard. The cluster centers are chosen as the corner for further processing. Every cluster center $O_i(x,y)$ can be calculated as the mean of all the point with a weight. Let P_c be the mass center of all target corners $O_i(x,y)$, showing in the Equation (4):

$$P_c = \frac{1}{n}\sum_{j=1}^{n}\sum_{i=1}^{n_i} r_i\, p(x,y) \qquad (4)$$

where n_i is the size of the j_{th} cluster, r_i represent the weight of the candidate point in the j_{th} cluster, and is proportional to the symmetry $\rho(i,j)$ of that point. *n* is the number of the clusters.

3.3 Outliers Filtering

Let D_i be the distance between point p_i and the center P_c which has been caculated as shown in Equation (4). Then sort *pi* according to *Di* in ascending order, and put them in set *P*. The filtering of outliers can be described as:

step1: Get P_1 and P_i;

step2: Make line L_j, compute the distance between other points in *P* and L_j,

if there are few points on the L_j

Get the point P_1 and P_{i+1}, goto step2.

else if j!=1

Compute the slop of L_j, and compare it with the slop of L_{j-1},when L_j and L_{j-1} are not similar parallel, get P_1 and P_{i+1}, goto step2.

step3: Remove the points who are nearest on the L_i to set Sx_i;

With above steps, by the same method to get the other parallel lines *H* and points sets *Sy* which are nearly vertical to *L*. The points in both *Sx* and *Sy* are the inner points of chessboard.

3.4 Corner Extraction with Sub-pixel Accuracy

Orthogonal Vector Theory [5] is used to detect the corners with sub-pixel accuracy. As shown in Fig.3, the orthogonal vectors of the corner should be perpendicular to gray grad of the adjacent area.

$$\varepsilon_i = G(I_{p_i})^T (q - p_i) \qquad (5)$$

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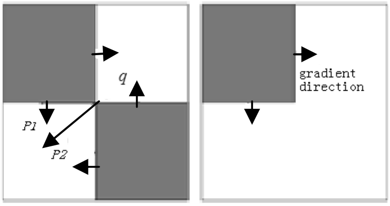


Fig.3 Principle of sub-pixel corner detection.

$G(I_{pi})$ expresses the image gradient of point q and its neighborhood p_i, both sides of the above equation are multiplied by $G(I_{pi})$. Then supposing the error is 0, the entire neighborhood equation can be established as:

$$\sum_{i\in\Omega}(G(I_{p_i})G(I_{p_i})^T)q-\sum_{i\in\Omega}(G(I_{p_i})G(I_{p_i})^T)p_i=0 \qquad (6)$$

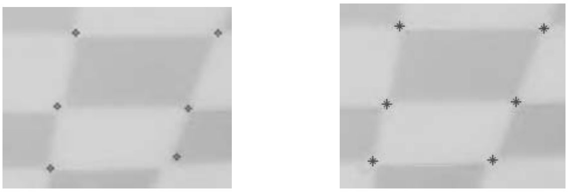
After solving q, the new q point would be taken as the center of the search window. Equation (6) can be solved via iteration method.

4. EXPERIMENTAL RESULTS

In order to confirm the validity of this algorithm, we use it to detect the a 6*8 chessboard image via an infrared camera. We also use the Harris feature and the algorithm in OpenCV to detect the corners for comparison as shown in Fig. 4. From the results, we can see that, Haaris detector cannot work with the infrared image. The algorithm especially for extracting the chessboard inner corner in OpenCV can get most corners successfully. However, with close observation as shwon in Fig. 5, the corner accuracy of the corners detected by OpenCV is still had distinct deviation in compared with our result. That shows the proposed method is more robust and accurate in the corner detection of infared images.

(a) (b) (c)

Fig.4 The corner extraction of chessboard (a) Result by Harris detector; (b) Result by OpenCV functions; (c) Result by the proposed method.



(a) (b)

Fig.5 The accuracy comparison between (a) OpenCV result and (b) The proposed method.

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5. SUMMARIES

This article presents a novel method to extract the corner of the serious distorted infrared image. Firstly, the cross shape mask is adopted to extract the corners. Secondly, the symmetry weight is added to calculate the cluster center. Thirdly, the line chessboard structure is analyzed and utilized to remove the outlies and align the corners. Finally, the sub-pixel accuracy is achieved using the orthgonal vector theory. The experiment has proved the robustness and accuracy in the infrared image.

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