Angle Correction Algorithm for Image Rotation Based on Key Point Detection

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Abstract

In image matching, traditional template matching method is not suitable for matching two images with large rotation angle. In order to solve this problem, this paper proposes an angle correction algorithm based on key point detection, which begins with corner detection by corner detector based on adaptively filtered curvature function. Then, a stable key point is selected and the angle of the rotation image is computed between the selected point and the geometric center of the image. Contrasting to the existing algorithms that solve rotation angle, the proposed algorithm can solve the problem of arbitrary angle rotation and has a high calibration accuracy and applicability. Experimental results demonstrate the availability and advantages of the algorithm.

Keywords: Corner Detection; Curvature Calculation; Arbitrary Angle; Image Rotation; Location Invariance

1 Introduction

In computer image processing, the technology of image matching has applied into various fields and become a key technology in machine vision inspection, and navigation and guidance fields [1]. During these applications, the two images of matching might rotate by certain angle. Therefore, it has been an urgent problem to timely correct the angle of rotary image.

Currently, traditional methods of correcting angle are based on Zernike Moment and Phase Correlation [2]. The estimation algorithms based on classic Zernike Moment are mentioned in documents [3,4]. Theses algorithms have the superiorities of insensitivity to noise and favourable robustness. However, the calculated amount of them is too large. On the basis of this, document [5] calculate rotary angle by utilizing the phase angle relation of the image to be measured and reference image. This method also has its shortages. While adopting Zernike Moment to

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reconstruct image, the selection of parameters influences the accuracy of calculation obviously. It is hard to find proper parameter to calculate the rotary angle and the system practicality is comparatively poor. The methods based on Phase Correlation method depend little on the gray level of image and have strong capacity of resisting disturbance and high matching accuracy. But while directly applying to the calculation of rotary angle, it needs large calculation to research in the total target scope and affects the timeliness. In order to solve the problem of large calculation brought by complex algorithm, on the basis of Radon transform technology, document [7] proposes the high resolution measurement method of MEMS rotary angle on account of phase related technologies. Similarly, this method is effective while the rotary angle is small. When the angle is big, the method is incapable and the matching accuracy is low. Aiming at solving above problems, this article adopts angle correction algorithm for image rotation based on key point detection. Firstly, the corner detection [8] should be conducted to the image to be measured. Secondly, a comparatively stable key point is selected from corner detected. Then, this point is connected to the geometric centre point into a line. The included angle of this line and coordinate axis is the rotary angle of the image to be measured. In this article, we set the actual image of beer bottle cap in line detection system as the object, and test and verify the effectiveness and superiority of this algorithm while solving the angle correction problems of rotary image.

2 Corner Detection Algorithm on Basis of Curvature Scale Space

2.1 Corner detection algorithm

Currently, corner detection algorithm has been researched and applied extensively. In document [9], SUSAN algorithm has been mentioned, on basis of which Rattarangsi and Chin [10] proposed corner detection algorithm based on Gauss’s Scale Space. Furthermore, scholars like Mokhtarian and Urdiales further explored and studied corner detection algorithm [11] and obtained big progress. This article adopts the corner detection algorithm of document [11], and the specific steps are as follows:

1. use Canny operator to detect the border of original image,
2. use curvature scale space to extract the contour curve of image,
3. after extracting the contour, use a comparatively low scale to calculate the curvature of each point on the contour curve and classify the maximum point local curvature into candidate corner set,
4. calculate self-adaption threshold value through curvature support area, and remove false corners (filleted corner and sharp corner) and other mistaken corners.

In step 3, the candidate corner can be determined by formula (1)–(3).

Define \( g(u, \sigma_j) \) is derived the function from Gaussian function \( g(u) \) under scale \( \sigma_j \)

\[
g(u, \sigma_j) = \frac{1}{\sigma_j \sqrt{2\pi}} \exp\left(-\frac{u^2}{2\sigma_j^2}\right), j = 1, 2, \ldots
\] (1)
Thus, the smooth of contour curve $A_j$ is

$$A_j^\text{smooth} = A_j \otimes g(u, \sigma_j) \quad (2)$$

Tests demonstrate that it is ideal when $\sigma_j = 3$. While contour curve achieve smooth, each point on the curve can be calculated by formula (3)

$$K^j_i = \frac{\Delta x_i^j \Delta^2 y_i^j - \Delta^2 x_i^j \Delta y_i^j}{[(\Delta x_i^j)^2 + (\Delta y_i^j)^2]^{1.5}} \quad (3)$$

Among which,

$$\Delta x_i^j = (x_{i+1}^j - x_{i-1}^j)/2, \quad \Delta y_i^j = (y_{i+1}^j - y_{i-1}^j)/2,$$

$$\Delta^2 x_i^j = (\Delta x_{i+1}^j - \Delta x_{i-1}^j)/2, \quad \Delta^2 y_i^j = (\Delta y_{i+1}^j - \Delta y_{i-1}^j)/2$$

$A_j = P_1^j, P_2^j, ..., P_N^j$ represents contour curve; $j$ represents current scale; $P_i^j$ represents the pixel point of contour curve; $N$ represents the number of pixel point on contour curve; $x_i^j, y_i^j$ is the coordinate of pixel $I$ under contour of scale $j$. When the distance $|P_1^j P_N^j|$, from each surrounding starting point to the ending point, is less than threshold value $T$ the curve $A_j$ is closed, or the curve is disconnected.

### 2.2 The determination of candidate corner angle

The angle of candidate corner can be determined by comparing the maximal point of local curvature and threshold value. The determination of candidate corner angle is as Fig. 1.

![Fig. 1: The Definition of Angle](image)

After determining the candidate corner, we can further screen corner according to its angle to remove false corners and corners generated from interference of marginal noise. The method is as follows:

First, select the region of support (ROS) even if the size of ROS changes with the change of curve’s local feature. Then, find the minimal points $S(t - k_1)$ and $S(t + k_2)$ in adjacent region from candidate corner $S(t)$. Thus, the ROS can be determined and the angle of candidate corner in ROS can be calculated according to cosine function. The formula (4)

$$\alpha = \arccos \frac{h_1^3 + h_2^3 - h_3^3}{2h_1 h_2} \quad (4)$$

In order to remove false corner, the self-adaption local threshold value can be applied to screen candidate corner. Through setting a dynamic curvature threshold value $T(u)$, we abandon the candidate corner under threshold value. The calculation of $T(u)$ is as formula (5)
\[ T(u) = N \times \overline{M} = N \times \frac{1}{K_1 + K_2} \sum_{i=u-K_1}^{u+K_2} M(i) \] (5)

Among them, \( N \) is a constant. Test result shows that the value range of \( N \) is from 1.4 to 1.6, \( \overline{M} \) is the average curvature of candidate corner \( S(t) \) in the region, and \( u \) the location of candidate corner on the contour curve.

### 3 Rotation Angle Correction on the Basis of Key Point

#### 3.1 The determination of key point

The article utilizes the above corner detection algorithm to detect the image and the result is as Fig. 3. The test result shows that this algorithm can accurately detect the corner without being influenced by geometrical rotation.

After corner detection, a stable key point should be determined according to the feature of image. However, during the process of rotation, the feature of image will has subtle change, which leads to the loss of some candidate corners. Therefore, the stable key point should be found in a group of detected corners. Thus, the key point would not miss due to any geometrical change.

![Original Image](a) Original Image  ![Rotated by 30°](b) by 30°  ![Rotated by 87°](c) by 87°  ![Rotated by 324°](d) by 324°

**Fig. 2: The Image rotated by different angles**

![Detection Results](a)  ![Detection Results](b)  ![Detection Results](c)  ![Detection Results](d)

**Fig. 3: Detection Results of the Corner Corresponding to Fig. 2**

In Fig 4, A is the key point selected. The reason of choosing this point is because the number of interference point is the least in adjacent region. Key point A can be detected during repeatedly rotating the image. While the image rotating, the coordinate position of candidate corner will be change and the relative position of these candidate corners will not be change. Therefore, key point A can be found through the relative unchanging position. The specific steps are as follows:

1) Detect every candidate corner \( A_i (i = 1, 2, 3...m) \). Set this point is the centre of the circle, and draw circles by the radius of the distance of \( n \) pixels. (test shows that \( n \) is nine pixels.

2) Count the number if candidate corners in every circle \( N_{A_i} \), as formula (6) (7). While the image rotates, the coordinate position of corner changes accordingly. However, the number of candidate corner is relatively stable in small range \( \delta \).
\[ N_{A_i} = \sum_{j=0}^{m} B_j, \]  

(6)

\[ B_j = \begin{cases} 
1, & \text{if } B_j \in \delta, \\
0, & \text{else}.
\end{cases} \]  

(7)

\( B_j \) represents the corner in every small range \( \delta \). When the corner is detected, we let \( B_j = 1 \) and \( N_{A_i} \) add 1.

3) Compare the \( N_{A_i} \) and find the smallest value \( N_{\text{min}} \), then corresponding corner of \( N_{\text{min}} \) is the key point. In the image of this article, \( N_{\text{min}} = 0 \), as point A of Fig. 4. Through calculating every corner to be detected by above steps, the key point can be determined.

### 3.2 Rotation angle correction

The size of all the images under detection in this article is 166166, so the geometrical central point is known. After key point A is determined, the image can be corrected according to the included angle of A and geometrical central point (the reference of all corrections is x axle and negative semiaxis is the direction). Meanwhile, the distance \( L \), between A and central point A, can shall be calculated.

During the process of detection, a circle with edge point as the centre and the length of \( n \) pixels as radium might be detected and the number of the inside corners \( N_{A_i} = N_{\text{min}} \) and the edge point can be considered as the key point A. If the distance from this point to the central point is more than \( L \) and near the radium of image under detection, this point is judged to be interference point.

Fig. 4(a) is a rotated image. A and B are random candidate corners detected. After processing the candidate corners according to the method of 2.1, statistics show \( N_A = N_{\text{min}} < N_B \). Then, point A can be judged to be the key point. By calculating the included angle of line from A to O and x axle, the angle of rotated image can be corrected and the result is as Fig. 4(b).

![Fig. 4: Angle Correction Process](image-url)
4 Experiment and Analysis

The research object of this article is round images, and the algorithm based on phase is more suitable for rectangle images, which has comparatively low accuracy while calculating rotated angle. Therefore, this article compares the algorithm proposed in this article and the algorithm[5] based on zernike moment.

The reference image in experiment is as Fig. 2(a), and 120 rotated images are to be detected. In Fig. 5(a), the image rotates by 120 times with the interval of 3 degrees. The abscissa represents the actual rotated degree, and ordinate represents the detected angle by adopting algorithm of the article and zernike moment algorithm. Under ideal situation, the curve detected should be straight line with 45° angle to the x axle. Fig. 5(b) (partial screenshot of Fig. 5 (a)) demonstrates the algorithm raised in this article has higher accuracy. Zernike moment algorithm rises and falls more obviously and test result is not very accurate. The test results are as table 1, table 2 and table 3.

![Graph](image)

**Fig. 5: Comparison of Two Methods**

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Average/Relative Error</th>
<th>Average Performance Period/s</th>
<th>Sample Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zernike Moment Algorithm</td>
<td>0.012 187</td>
<td>0.992</td>
<td>120</td>
</tr>
<tr>
<td>Algorithm of This Article</td>
<td>0.009 47</td>
<td>0.355</td>
<td>120</td>
</tr>
</tbody>
</table>

Experimental data of analysis table 1 demonstrates the average relative error of the algorithm in this article is lower than that of Zernike Moment. The certain superiority of performance period displays that rotation angle correction algorithm has more applied value on the basis of corner detection.
Table.2 The Rotation Angle Measured by Zernike Moment Method

<table>
<thead>
<tr>
<th>Actual Rotation Angle</th>
<th>4</th>
<th>40</th>
<th>77</th>
<th>90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angle Measured</td>
<td>3.870</td>
<td>40.362</td>
<td>76.002</td>
<td>93.300</td>
</tr>
<tr>
<td>Relative Error</td>
<td>0.008</td>
<td>0.009 05</td>
<td>0.012 96</td>
<td>0.036 70</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Actual Rotation Angle</th>
<th>135</th>
<th>153</th>
<th>180</th>
<th>252</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angle Measured</td>
<td>136.19</td>
<td>153.896</td>
<td>178.470</td>
<td>253.907</td>
</tr>
<tr>
<td>Relative Error</td>
<td>0.008 8</td>
<td>0.005 86</td>
<td>0.008 50</td>
<td>0.007 57</td>
</tr>
</tbody>
</table>

Data of table 1, table 2 and table 3 show the algorithm proposed in this article is obviously more accurate than that of zernike moment algorithm. Moreover, the algorithm of this article also has certain superiority on time calculation. The data of table 3 shows the inaccuracy of rotated angle and actual rotated angle of the image in image base is within 0.5 degree, even to the big rotated angle. This result cannot be realized by zernike moment algorithm. Test result proves that angle correction algorithm on the basis of key point detection has more accuracy, quicker performance period and can be adopted to ensure the angle of rotated image.

Table.3 The Rotation Angle Measured by Corner Detection Method

<table>
<thead>
<tr>
<th>Actual Rotation Angle</th>
<th>4</th>
<th>40</th>
<th>77</th>
<th>90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angle Measured</td>
<td>4.036</td>
<td>40.301</td>
<td>77.171</td>
<td>89.729</td>
</tr>
<tr>
<td>Relative Error</td>
<td>0.008 8</td>
<td>0.007 5</td>
<td>0.002 22</td>
<td>0.003 0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Actual Rotation Angle</th>
<th>135</th>
<th>153</th>
<th>180</th>
<th>252</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angle Measured</td>
<td>134.726</td>
<td>152.747</td>
<td>180.328</td>
<td>252.84</td>
</tr>
<tr>
<td>Relative Error</td>
<td>0.002 04</td>
<td>0.001 65</td>
<td>0.001 82</td>
<td>0.000 6</td>
</tr>
</tbody>
</table>

This article designs a set of on-line image correction system and work interface as Fig. 6. During work, through testing press-button, the actual rotated angle of image under detection can be tested (compared to x axle). Clicking correction press-button can complete the angle correction of rotated image and the result would display on system interface.

Fig. 6: The System of Rotation Angle Adjustment
5 Conclusion

The article raised the key point detection algorithm to correct rotation angle on the basis of corner detection. This algorithm can keep a comparatively high accuracy while detecting rotation angle. Test shows that while the image rotates by a big angle, this algorithm also leads to a high accuracy. Thus, this algorithm adapts to correct rotation by any angle and meets the high requirement of accuracy. The experimental subject of this article is bear bottle, but this algorithm is suitable for image of any shape.

The research direction of next step: because edge detection uses canny operator and the operator lacks of adaptability to the image, the interference of local noise cannot be eliminated and some corners’ detection are influenced.

References