Image Correction Scheme Based on Improved Hough Transform

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Abstract

In the process of image forming, for some reasons, there often exists tilt phenomenon in terms of the collected images, thus bringing great difficulty for the image matching and fusion. This paper mainly studies problems related to the tilt correction technology of the image, such as the tilt angle detection and rotation correction, etc., and takes Hough transform algorithm as the research focus. The conventional Hough transform algorithm is one-to-many mapping matching algorithm, each feature point (edge pixel) of the image matches with parameters of all curves in the parameter space that may pass such point, and also these parameters are accumulated in unit. In order to solve image tilt problem in the application, this paper puts forwards one image tilt correction method to improve Hough transform, and obtains the image barycentric coordinate and image tilt angle based on the setting up of the image model. The image correction is realized by means of obtaining the image tilt angle and adopting the image rotation method and appropriate gray level interpolation way. Experiment proves that the Hough transform proposed in this paper can realize satisfactory results.

Key words: Hough Transform, Tilt Image Correction, Feature Point.

1. INTRODUCTION

In the image processing field, the shooting angle will result in certain linear tilt deformation in terms of the image, which will be disadvantageous to the extraction and recognition of the target feature by the computer, and thus geometric distortion of various degrees such as the geometric location, size, shape and orientation etc. will occur, which will affect the measuring accuracy of vision measurement system. Therefore, before the shape detection and size measurement, the tilt deformation correction must be carried out. In the current image tilt correction processing field, such tilt correction method based on Hough transform and so on can be adopted. However, because of the parameter space discretization, there exist the uncertainty and inaccuracy in terms of Hough transform (Hovmöller and Zou, 1999; Christou, 1991).

Image tilt deformation is a kind of linear deformation. The image correction can be realized through the rotation and distortion after the image horizontal and vertical angle are calculated. Image tilt correction can be divided into the tilt angle detection and the rotation correction. Scholars have researched the image tilt deformation correction technique for many years, and put forward many feasible methods. Hough transform was first established in 1962 by Hough, and used to detect the image’s tilt straight line. Ballard expanded the application range of Hough transform in 1981, thus making curves of various shapes can be tested by using Hough (Pan, 2015). At current, the Hough transform is widely applied in fields such as the pattern recognition and image processing. Hough transform is an effective way to detect the graphics in the binary image, such as a straight line, circle, ellipse, etc. The generalized Hough transform put forward later can detect graphics of any shape, thus solving many problems such as the pattern recognition and computer vision. Hough transform method is very effective for linear graphic correction, and the tilt angle can be found by calculating the possible path of the image space target pixel coordinate in the parameter space. Although there are advantages, the shortage of the conventional Hough transform cannot be ignored. How to improve the Hough transform to solve its defects is an important direction in later research (Schlapfer and Richter et al., 2015; Illingsworth and Kittler, 1988).

This paper introduces the current research status of tilt correction algorithm, and sums up the currently used tilt correction algorithms, and analyzes types and models of image tilt deformation and the geometric distortion, then, this paper puts forward the tilt image correction algorithm to improve Hough transform, which realizes the image correction by obtaining integer image pixel after the gray level interpolation is processed on non-integer corrected value. The final experiment verifies the effectiveness of such method in this paper.
2. IMAGE DISTORTION CORRECTION RELATED TECHNOLOGY

2.1. Graying

Every point \((x,y)\) in the image is mixed by three primary colors \(R\), \(G\), \(B\) in their own value ranges and \(R\), \(G\), \(B\) in different contents will form different colors in the color image. The image with only black and white colors, just like that in the black-and-white television, is called gray-level image. If the degree of black color, namely the depth of black color, of the image is different, the image is also called one-color image. Gray image is not consisted of pure white and black, instead, gray-level image is described by dividing the depths of black and white colors into 25 gray levels. Gray image can be transformed into binary image through the following Formula (1) and vice versa.

\[
Gray(i,j) = 0.11 \times R(i,j) + 0.59 \times G(i,j) + 0.3 \times B(i,j) \tag{1}
\]

In this formula, \(R(i,j), G(i,j), B(i,j)\) are the component values of \(R, G, B\) of the pixel \((i,j)\) in the original image respectively. \(Gray(i,j)\) is the gray-level value calculated, namely the value of pixel \((i,j)\) in the new image. As green is the color to which human eyes are most sensitive, the green color has the maximum weight (Z Xu and B Shin et al., 2015; Yifang, 2016).

The color components in the image are represented by \(R, G, B\) and the gray-level value to perform graying processing is represented by \(g\). The transformation methods include the following.

1. Maximum value method, namely to find the maximum value among the three components, as indicated by Formula (2).

\[
g = \max(R,G,B) \tag{2}
\]

2. Mean value method, namely to find the maximum mean value of three components, as shown in Formula (3).

\[
g = \max \frac{R+G+B}{3} \tag{3}
\]

3. Weighted mean value method, assign values to three components according to their own different indexes and importance in order to satisfy the fact that \(g\) is equal to the weight and mean of \(R, G, B\), as indicated in Formula (4).

\[
g = \frac{0.11R + 0.59G + 0.3B}{3} \tag{4}
\]

2.2. Binaryzation

Image binaryzation is to set the gray-level value of the pixel points in the image into 0 or 255. In other words, it presents the entire image into the visual effect with only black and white colors. The binaryzation of binary gray image is to transform all the gray-level values within the range of 0 and 255 into the image with only two gray-level values: 0 and 255 so as to segment all useful targets from the image and reduce the interference of the background image. The key to image binaryzation is the selection of the threshold \(t\). When \(t\) is selected, gray image will be transformed into binary image according to Formula (5).

\[
f(i,j) = \begin{cases} 
1, & f(i,j) \geq t \\
0, & f(i,j) < t 
\end{cases} \tag{5}
\]

In the above formula, \(t\) is the threshold. When the gray-level value of the sampling point \((i,j)\) is \(f(i,j) \geq t\), then \(f(i,j) = 1\) represents the text image and when the gray-level value of the sampling point \((i,j)\) is \(f(i,j) < t\), then it represents the background.

The most important step of image binaryzation processing is to select a reasonable threshold for the processing. The common binaryzation methods include local threshold method, global threshold method and dynamic threshold method (B Li and K Peng et al., 2012; J Dennis and HD et al., 2013).

1. Local Threshold Method
Local threshold method is to divide the original image into smaller images, divide the entire image into $n$ windows according to certain rules and then divide the pixels of every window from $n$ windows into two parts for binaryzation with the uniform threshold $t$. The segmentation of each image is random. If one of the sub-images is just located within the target region or background region, a worse result may produce if it is segmented according to the statistical result.

(2) Global Threshold Method
An image includes target objects, in order to extract the target object from a multi-value digital image directly, search the gray-level value which occurs the most frequently and segment the image with that value or the gray-level value which is certain gray-order bigger or smaller than it. The most common method is to set a global threshold $t$ and divide the image data with $t$, the pixels bigger than $t$ and the pixels smaller than $t$. Set the value of the pixels bigger than $t$ as white (or black) and that of those smaller than $t$ as black (or white). Its strength is that it is implemented based on the histogram of an image and histogram is a one-dimensional array which is easy to obtain.

(3) Dynamic Threshold Method
Firstly, divide the image into smaller blocks, calculate the histogram of each block and calculate the threshold of every block according to the peak value of each histogram. Then, the threshold of every pixel point is obtained through the interpolation of thresholds of the neighborhood blocks and the binary threshold of this pixel is confirmed according to the distribution of the pixels of the neighborhood pixels. In this way, the binary threshold of every pixel point is not fixed, instead, it is determined by the distribution if its surrounding neighborhood pixels.

2.3. **Geometric Space Transformation**
In general, the tilted image approximation is seen as a parallelogram and there are four kinds of tilt modes: horizontal tilt, vertical tilt, horizontal vertical tilt and mixed tilt, as shown in Fig.1-Fig.4.

![Figure 1. Horizontal tilt](image1)

The shape of the image with horizontal tilt is still a standard rectangle. What has changed is the clockwise or counterclockwise rotation in the horizontal direction of the image. Tilt correction shall be performed on this kind of images in the horizontal direction.

![Figure 2. Vertical tilt](image2)

No rotation has occurred in the horizontal direction of the image with vertical tilt, instead, there is a sheering with the angle of $\alpha$ in the vertical direction and $\alpha$ is called vertical tilting angle. For the image with vertical tilt, calculate its vertical tilting angle $\alpha$ and then perform pixel transform on the image in order to reconstruct the image and get the image after vertical correction.
Tilt occurs on both the horizontal and vertical directions on the image with mixed tilt. This tilt mode is most common among the four modes and it is also the tilt mode which research shall be conducted in tilt correction.

3 HOUGH TRANSFORM

The basic idea of Hough transform is to transform one point of the image space into a curve or a surface in the parameter space. The points with the same parameter characteristic will intersect in the parameter space after transformation and the detection of the feature curve will be completed by judging the accumulation of the intersection. In essence, Hough transform is to perform coordinate transformation on the image and transform the lines in the image space into the focal point in the parameter space so as to change the problem of detecting the curve of the given shape in the original image into the problem of searching the peak point in the parameter space. It can detect not only straight lines, but also the shapes such as circle, ellipse and parabola conveniently (Xu and Zhou et al., 2012).

Represent the straight line in the rectangular coordinate system with equation \( y = kx + b \) and map it into point \((\rho, \theta)\) in the corresponding polar coordinate system. Any two points \((x_1, y_1), (x_2, y_2)\) of this straight line meet the equations of \( y_1 = kx_1 + b \) and \( y_2 = kx_2 + b \). Every point of all the points in the straight line confirmed by these two points: \((x_i, y_i), (x_j, y_j)\) corresponds to a sinusoid in the parameter space. These sinusoids will intersect in point \((\rho, \theta)\). In this way, we only need to find which point has the maximum overlaps in the parameter space. If we can find this point, we can find the equation of the straight line according to the straight line in the original image space.

The core of Hough transform is the transformation of two coordinate systems, a point or a line segment has different representation forms in different coordinate systems. Hough transform firstly requires the establishment of a new coordinate system. A straight line \( L \) (as indicated in Fig.5) in the rectangular coordinate system will become a point after Hough transform. On the other hand, a certain point of all straight lines will be represented as a sinusoid in the new coordinate system after Hough transform (Razavi and Gall et al., 2012; Cho et al., 2014).
The purpose of Hough transform is to search the transformation from the regional boundary to the parameter space and use the corresponding parameters which satisfy most boundary points to describe the boundary of this region. The collinear point in the image space corresponds to the intersecting line in the parameter space. In turn, all the lines which intersect in the same point in the parameter space will correspond to the collinear point in the image space, this is point-line duality (Ballard, 1987).

Given some edge points in the image space, confirm the linear equation which connects these points through Hough transform. Transform the linear detection problem in the image space to the detection problem of the corresponding point in the parameter space and conduct simple accumulated statistics in the parameter space (Smereka and Dulęba, 2014). Then the detection task is accomplished, as shown in Fig.6 and Fig.7.

The procedures to correct tilting image with Hough transform are as follows.
Step 1: Transform every pixel point to be processed in the rectangular coordinate system into the parameter linear equation in the polar coordinate system. There is one point in the image place \( XY \) and the linear equation which includes this point meets the following Formula (6),

\[
q = px + y
\]  

In this Formula (6), \( p \) is the slope and \( q \) is the intercept.

Build a two-dimensional cumulative array \( A(\rho, \theta) \) in the parameter space \( (\rho, \theta) \) and set the initial value as 0. Here, \([\rho_{\text{min}}, \rho_{\text{max}}]\) and \([\theta_{\text{min}}, \theta_{\text{max}}]\) are the value range of the expected radius and angle.

Step 2: Set and initialize the two-dimensional matrix counter \( H(\rho, \theta) \). Conduct statistics on the number of the reference points in the polar coordinate system. Every new added pixel point to be processed corresponds to the addition of the values of its parameter line. There are several points \((x, y)\) in the image space which satisfy Formula (6). In other words, these points have passed the straight line with the slope of \( p \) and the intercept of \( q \). After transforming these points into the parameter space, they will pass point \((p, q)\). Correspond the lines in the image space to the points in the parameter plane and simplify the calculation with polar coordinate equation. The polar coordinate equation of Formula (6) is as follows.

\[
\rho = x \cos \theta + y \sin \theta
\]  

Then point \((x, y)\) in the image space \( XY \) corresponds to a sinusoid in the parameter space \( (\rho, \theta) \); calculate the corresponding \( \rho \) value according to Formula (7) and accumulate array \( A(\rho, \theta) \) according to the values of \( \rho \) and \( \theta \).

Step 3: Perform statistics on the reference points in the polar coordinate system through the two-dimensional matrix counter and then calculate the local maximum value of this counter. Since every maximum value corresponds to the straight lines of the original image in the rectangular coordinate system in proper order, then select the maximum value and transform it into the angle, namely the tilt angle of the image. After the accumulation, select the maximum-value unit and its corresponding parameters are the polar coordinate radius and angle of this straight line, this line is the one we need to detect.

Step 4: To perform tilt correction to the image is to contrarotate the image and achieve image correction according to the tilt angle detected. In the rotation process, use the proper gray-level interpolation to restore the gray-level loss of the pixel in the rotation with the following Formula.

\[
x = r \cos(\theta + \phi) = x \cos \theta - y \sin \theta, \quad y = r \sin(\theta + \phi) = x \sin \theta + y \cos \theta
\]  

Represent it in the form of matrix as follows.

\[
\begin{bmatrix}
x' \\
y'
\end{bmatrix} = \begin{bmatrix}
\cos(\theta) & -\sin(\theta) \\
\sin(\theta) & \cos(\theta)
\end{bmatrix} \begin{bmatrix}
x \\
y
\end{bmatrix}
\]  

In above Formula, \( x = r \cos \phi, \quad y = r \sin \phi, \quad x' = r \cos(\theta + \phi) = x \cos \theta - y \sin \theta \) and \( y' = r \sin(\theta + \phi) = x \sin \theta + y \cos \theta \).

If represented with homogeneous coordinate, Formula (9) can be written with the following matrix representation, as indicated in Formula (10).

\[
\begin{bmatrix}
x' \\
y' \\
1
\end{bmatrix} = \begin{bmatrix}
\cos(\theta) & -\sin(\theta) & 0 \\
\sin(\theta) & \cos(\theta) & 0 \\
0 & 0 & 1
\end{bmatrix} \begin{bmatrix}
x \\
y \\
1
\end{bmatrix}
\]  

In this way, the coordinate relation before and after the image rotation can be shown by Formula (11).
\[
\begin{align*}
    x &= x' \cos(\theta) + y' \sin(\theta) - \cos(\theta) - \sin(\theta) \\
    y &= -x' \sin(\theta) + y' \cos(\theta) + \sin(\theta) - \cos(\theta)
\end{align*}
\] (11)

4. SIMULATION EXPERIMENTS AND ANALYSIS

This paper adopts the improved Hough algorithm to calculate the tilt angle, and adopts the double linear interpolation method in the process of image rotation correction to finally complete the linear tilt image correction. Programming simulation experiments are carried out by using Matlab2012. Images before and after the correction are as follows:

![Original image](image1.png)
![Image binaryzation](image2.png)
![Hough transform](image3.png)
![Image after edge detection](image4.png)
![Tilt corrected image](image5.png)

Figure 8. Correction results for tilt image 1.
The above image correction shows that the method in this paper has good adaptability. First read the image, turn into grayscale map, remove the discrete noise points, and use the edge detection to conduct the reinforcement on the image’s horizontal line and transform collinear points in the image space into a bunch of straight line (or curves) intersecting at one point in the parameter space. If such point of intersection can be detected in the parameter space and also its parameters can be determined, then the collinear equation of the straight line in the image space can be found, so as to realize straight line detection. Detect the image border based on Hough transform, and obtain tilt angle, and after the tilt angle is detected, the correction of such image can be realized by adopting the image rotation correction method and double linear interpolation method. Realize the tilt correction algorithm by using the method in such paper, and its main advantage is that the influence by noise and curve interruption is small. This method can not only be used to detect the line segments, but also directly segment targets of some known shapes and it is likely to determine the accuracy from the border to the sub pixel.

5 CONCLUSIONS

Hough transform is a kind of algorithm to detect the straight line and tilt angle. This paper, based on the tilt phenomenon of the collected image, discusses the image tilt correction method and puts forward an improved image registration method based on image registration method based on Hough transform tilt correction, and
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