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Application of Hough Transform in Thermometer Detection

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Abstracts: Hough Transform is a regularly used method in thermometer detection. It can effectively extract line segments and curves in images. This thesis mainly applies the algorithm of extracting thermometer scale lines by Hough Transform and improves the searching distance and range to improve operating efficiency.

Key words: Hough transform, scale line detection, algorithm improvement

INTRODUCTION

Line detection is a vital part in image analysis and pattern recognition. Hough Transform is a very effective and reliable method in straight line detection. When detecting the stability of thermometer readings, Hough Transform can be used to extract the location of both scale line and mercury stigma.

Hough Transform is a kind of shape-matching technique put forward by Adams (2003). It has very powerful anti-interference ability and high robustness and is widely used in straight line detection. But the enormous storage space and complicated computation amount has decreased its algorithm efficiency. Combined with practical application, this thesis applies Hough Transform to judge whether thermometers under test are qualified Chen (2007).

PRINCIPLES OF HOUGH TRANSFORM

The basic idea of Hough Transform is point-line duality. Zhao (2009) It's a certain kind of coordinate transformation of image which transforms the given curve or line in the original image into a point in the space and then makes the point to a peak value point in the transform space so that overall characteristics detection can be simplified into local characteristics detection (Zhao, 2009). Suppose the straight line equation in the original image space is:

$$y = kx+b$$

Transform it into polar coordinates as transform space:

$$\rho = x\cos\theta+y\sin\theta$$

is the distance between the original point and the straight line; is the angle between the straight line normal and axis.

The point in the space which corresponds to in the polar coordinate is a sinusoidal curve. All the points on the straight line in the original image space correspond to a family of curves in the transform space (Fig. 1 and 2) and the point is passed. It is the collinear points of the parameter which is the fitting parameter of the image space. So the straight line can be detected once the point is found out.

Basic steps and advantages and disadvantages of hough transform:

- First, carry out pretreatment of images in early days and get the edge point (binary image), that is the characteristic point®
- Set up an accumulator array, initial value of is zero. Traverse value of every pixel point and compute the correspondent value. If the value corresponds to a certain value in the accumulator array then the accumulator value plus one
- After all the points are traversed, traverse all the accumulator values and then find out the peak value of the accumulator which corresponds to the collinear point of the original image space

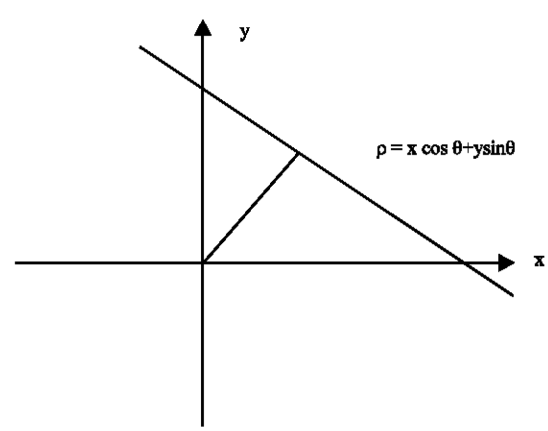

Fig. 1: Point-line duality of Hough transform

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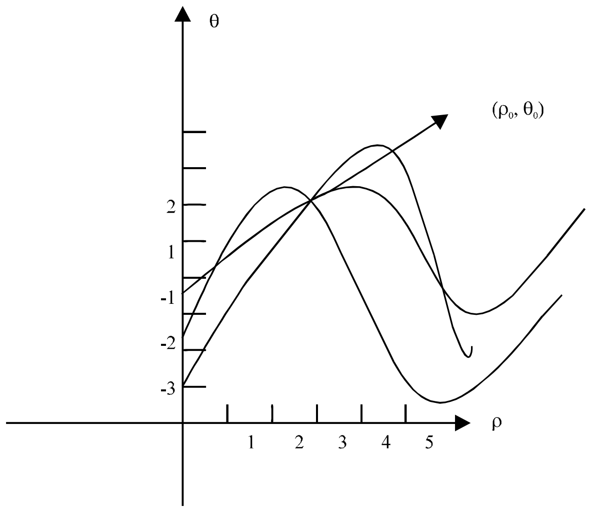

Fig. 2: Hough transform of orginial image into binary image

The following is the algorithm of Hough Transform (Jiang and Yan, 2005).

Step 1: Transform the original image into a binary image with a small amount of noise

Step 2: Get the data: Accumulator matrix in Hough Transform parameter space

- Make an accumulator array $A(\rho_i, \theta_i)$. Every element's suffix corresponds to the location of various points in the transform space. Its value shows the number of straight lines that comes across this point. Initialize $A(\rho_i, \theta_i)$ as zero
- That Gray level in binary image is zero presents that characteristic point under test corresponds to (x, y)
- As for θ, if j = 0° to 179°, increase 1°
- $\rho_i = x_i \cos(\theta)+y_i \sin(\theta_j)$
- $A(\rho_i\theta_i) = A(\rho_i\theta_i)+1$

Main advantage of Hough Transform is that it is not sensitive to image noises and can better handle local blocks and covers, etc. But there are several large drawbacks in traditional Hough Transform:

- A large amount of computation, each edge points are mapped into a curve of the parameter space which is one to many mapping
- Occupy a large memory
- Extracted parameters are constrained by quantization interval of the parameter space which is a very serious problem to high precision real-time system. If this problem can't be addressed well, it will directly affect the handling speed and accuracy of the entire system

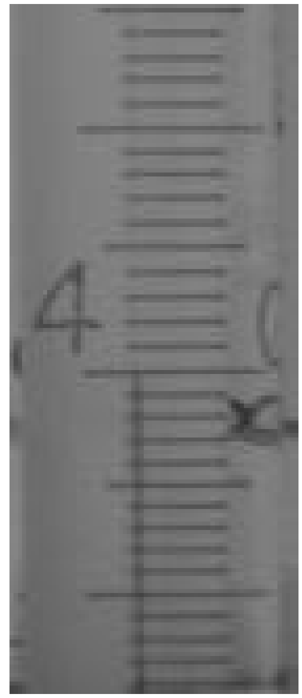

Fig. 3: Thermometa detection of Hough transform

Improvement and application of hough transform in thermometer detection: Put the thermometer under test and the standard thermometer in the same environment (temperature, humidity, etc.). Let the mercury stigma of the standard thermometer rise to zero-scale line like the following figure (Fig. 3). Here the height between the stigma of the thermometer under test and zero point should be read. According to the allowed error-limit regulations of thermometer readings in JJG130-2004 working glass liquid thermometer test procedures, you can judge whether thermometers under test are qualified. Figure 3 shows the standard thermometer; Fig. 4 shows the thermometers under test.

Next, the height between the mercury stigma and zero in Fig. 4 can be automatically detected. Early day steps are intercepting the main parts of the image and eliminating patent noises and graying and diarizing the image. The gray value varies from 0 to 255 so that it is convenient for latter operation.

- **Extract mercury stigma and scale line:** Carry out Hough Transform to the pretreated binary image to extract mercury stigma and scale line
- Apply the pixel gray scale to find out the location of the mercury liquid stigma in the vertical direction

First traverse the binary image horizontally. If four consecutive pixel gray scales are zero, then make a mark

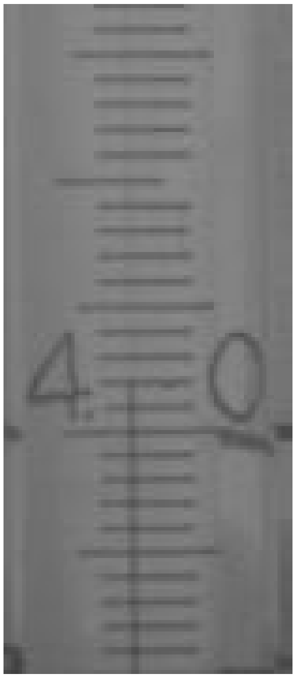

Fig. 4: Thermometa detection of Hough transform under test

as the y axis of the coordinate system where the mercury column exists. Traverse from the vertical direction of the current pixel. If four consecutive pixel gray levels are 0 in the vertical direction then set the vertical coordinate of the current location as y axis which is the location of the liquid stigma.

And then traverse horizontally along the direction of the mercury column. When the detected horizontal direction grayscale is a full 255, this means the liquid is just over the location of the plume head. The location of the liquid stigma is the present pixel vertical axis minus one.

- Using Hough Transform to find out the scale line to which the standard scale zero near the mercury stigma corresponds in the horizontal direction

Reflected in the current (Fig. 4) is the relatively longest scale line away from within 40 pixels up and down the liquid stigma. Since the scale lines are horizontal, pixel coordinates (i, j) in binary image corresponds to the transform space parameter equation:

$$\rho = |i\cdot \cos(\theta*\pi/180°)+j\cdot\sin(\theta*\pi/180°) \quad (1)$$

As for the basic Hough Transform, in the transform space, ρ is the distance between the original point and the straight line. Max ρ is the length of the diagonal. But here the scale line is horizontal, so you can just take the height of the image. In transform space, θ is the angle between the straight line normal and x axis and traverse from 0-180°. You should take into account the particularity of thermometer scale line and the thermometer is put vertically and scale line is along the horizontal direction. Thus you can traverse θ from 89-91° which can greatly reduce the scope of the search.

From two directions, find out the location of the longest tick marks down from the stigma. Traverse 40 pixels down from the vertical direction and horizontally traverse 80 pixels to the right. Then find out the location of the longest tick marks up from the stigma. Traverse 40 pixels down from the vertical direction and horizontally traverse 80 pixels to the right. Transform domain of the polar coordinate plus one when the gray value is zero. Each pixel with a gray value of 0 corresponds to a sine curve and θ which is traversed every time can be gotten through ρ (Eq. 1). This can be realized in the program by marking such a pair of (ρ, θ) and adding a cumulative one.

Pixel points in a scale line correspond to different sinusoidal curves that must intersect at the same point (ρ, θ), this point will have the most cumulative number.

So otherwise points with the most accumulated number on the sinusoidal curves correspond to the straight line where the longest scale line lies. Find out two straight lines, respectively from up and down the mercury stigma and then get the line with the closest distance and largest accumulated number where zero point lies. Thus the horizontal position of the mercury stigma and the location of the standard calibration line which the zero point corresponding to can be found out.

Specific steps: Zhao (2009):

- Initialized accumulator value $A(\rho, \theta, T)$ is zero
- Find out the location of the longest scale line down from the mercury column with 40 pixels searching height and 80 pixels width
- As for each pixel point (i, j), if the gray value is zero, then compute the gradient T_i. And traverse θ. If θ_j varies from 89-91°, then increase one.

$$\rho_j = |i\cdot\cos(\theta_j*\pi/180°)+j\cdot\sin(\theta_j*\pi/180°)|$$

$$A(\rho_j, \theta_j, T_i) = A(\rho, \theta, T_i)+1$$

- Find out (ρ, θ) that the biggest accumulator corresponds to
- Find out the location of the longest scale line down from the mercury column with 40 pixels searching height and 80 pixels width
- Repeat step

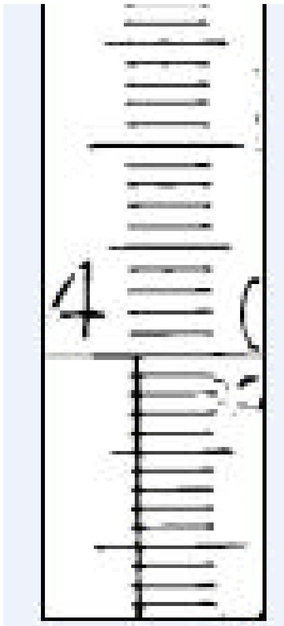

Fig. 5: The horizontal position of the standard scale line

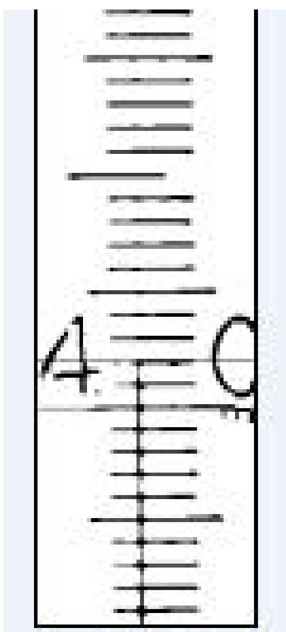

Fig. 6: Standard scale line corresponding to the zero point

- Compare the size of two accumulators, the larger one corresponds to the location of the zero scale line
- Calculate the pixels between two scale lines of one image

The maximum distance between the original point and the straight line (max ρ) depends on the height of image. It is horizontal scale line, so the searching range is limited between 89° to 91°, thus has greatly improved the searching efficiency.

In order to better calculate the pixels between two adjacent scale lines, eleven consecutive scale lines are found out. This is because the image traverses from the bottom to the top. The first scale line uses the location of x axis when finding the mercury column. When finding the following ten scale lines, you should first clear the five pixels' accumulative heights near the previous point to avoid interfering the finding of the latter scale accumulative.

When finding out the next adjacent scale line, the selected height should be between ten to twenty pixels accumulative of the present scale line. Find out ρ and θ that corresponds to the largest accumulative times, this directly corresponds to the parameter of the straight line where the scale line lies. All the straight lines where the 11 scale lines lie can be found out and then mark their height. Get the pixels of every two adjacent scale lines by the pixels of the 11 scale lines.

The ratio of the height difference between the mercury stigma and the standard scale line and that of two adjacent scales and according to the working glass liquid thermometer verification regulation, you can conclude whether the thermometers under test is qualified or not. And finally you can get the grid umber between the mercury stigma and standard scale.

The calculated formulas are as follows: Suppose 11 scale lines corresponds to the height: ρ_i(i = 0, 1, 2,...1), pixels between two adjacent scale lines are lWid1 and lWid, meanwhile, lWid is the average value of lwid1 and lWid2.

$$\text{lWid1} = \frac{\rho_5 - \rho_0}{5.0}$$

$$\text{lWid2} = \frac{\rho_{10} - \rho_5}{5.0}$$

$$\text{lWid} = \frac{\text{lWid1} + \text{lWid2}}{2.0}$$

Yvalue is the height of the mercury stigma, value is the height of the standard scale line, Dist is the grid number between the mercury stigma and standard scale line:

$$\text{Dist} = \frac{\text{Yvalue} - \text{Value}}{\text{lWid}}$$

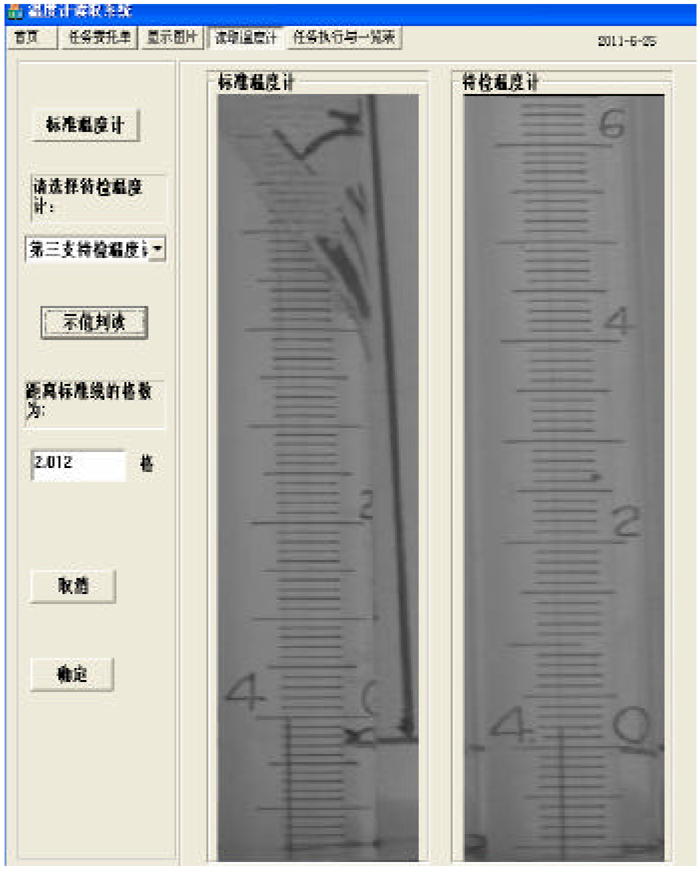

Fig. 7: The running interface

$$\text{If Dist} \geq 0, \text{ then Dist+} = 0.0005$$

$$\text{If Dist} \leq 0, \text{ then Dist-} = 0.0005$$

Make sure that the value should be thee significant figures after the decimal point.

Specific steps:

- Initialized accumulator value $A(\rho, \theta, T)$ is zero
- Parameter (ρ, θ) that the first scale line corresponds to is given. Here (ρ, θ) is the parameter that the standard scale line corresponds to
- Find out other ten adjacent scale lines. Applying loop to find out the present scale and set the accumulator that the current scale line corresponds to as zero

The next scale line should be between 10 to 20 pixels up of the present scale line and traverse in this range. According to the actual circumstances, thermometer should be put vertically and the scale line should be horizontal, thus θ can't be traversed and the value of it is 90°. Find out (ρ, θ) that the largest accumulator corresponds to and parameters that scale lines correspond to are within this scope and find out ten scale lines successively. Meanwhile, $\rho_i(i = 0, 2,\ldots 10)$ is the height of the scale line.

- Calculate the number of pixels between the two scale lines
- Calculated the deviation size from the mercury stigma to the standard scale line
- According to deviation size to judge whether thermometer under test is qqualified

This can be realized in C^{++} programming. Running interface is as follows:

CONCLUSION

Hough Transform is a far more efficient way in extracting segments. Combine theory with practice and operate it flexibly can solve problems and improve efficiency in practical application. Using Hough Transform in solving the problem of thermometer scale line extracting is of vital meaning in improving image processing real-time.

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