A Scanner Jitter Test Method of CR System Based on Improved Hough Transform Algorithm

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Abstract: Computed radiology system (CR) test technology has been applied in the testing of industrial welding defect after the promulgation and implementation of digital radiographic imaging test standards. The performance of CR system directly affects the testing rate of welding defects. Therefore, testing and evaluating the performance of CR system becomes the premise and guarantee for the application of CR system. In this paper, based on the testing image of CR phantom and the simulation of scanner dither results, an algorithm combining fault-tolerant voting and improved point-based hough transform is proposed to test the performance index of scanner dither in CR system. Experimental results show that the proposed algorithm can test not only the row and column dithering, but also the subtle arc dithering. Compared with standard Hough transform algorithm, this algorithm has higher accuracy and can avoid the influence of other image indicators around the T-shaped image quality indicator used in CR phantom.

1. Introduction

In the radiographic testing of weld defects, radiographic computer-aided imaging (CR) technology has been widely used as a new technology. CR technology refers to the technology that records the information after X-ray transmission through the object to be tested on a storage phosphorescent imaging board coated with crystals of rare earth elements europium and barium fluoride bromine to form latent image, which is read as electrical signal by special laser scanner, and then converted into digital image by computer and signal processing technology. CR testing system mainly consists of ray source and CR imaging system. The CR imaging system consists of an imaging board, a laser scanner (including reading and erasing of latent images), and a digital image processing and storage unit[1].

The performance of the testing system directly affects the testing rate of welding defects, especially with the increase of the use time, the performance of the testing system will degrade. For CR system, mechanical properties and residual shadows of the system gradually appear, which will lead to inaccurate testing results and misjudgment of omission or defect. Based on this, it is necessary to conduct a performance test on the CR system to determine whether the system can continue to be used.

2. Acquisition of test images

At present, the standard specimen widely used for CR system performance test is "CR phantom" as shown in Figure 1. The CR phantom is placed on the imaging board for radiographic imaging, and the
imaging quality of each image quality indicator (hereinafter referred to as IQI) in the imaging board is analyzed to evaluate whether the CR system meets the relevant standards. The scanner is a CR image reading device. If there is shaking or sliding in the scanner transmission system during the scanning process of the imaging board, the final image will be distorted due to the fluctuation of intensity. Therefore, testing whether the scanner has jitter or slide is an important index to evaluate the performance of CR system.

![Figure 1. CR phantom](image)

A T-shaped IQI is set on the CR phantom to evaluate whether there is shaking in the Scanner in the CR system by observing or testing the flatness of the edge of the T-shaped IQI \(^{[2]}\). At present, the performance test of CR system is still in the stage where professionals directly observe and evaluate the unprocessed images \(^{[3]}\), which is relatively inefficient. For some parameters, visual observation is prone to errors. Therefore, this paper proposes an automatic measurement method combining fault-tolerant voting and point-voting Hough transform for scanner jitter. The test process is shown in

![Figure 2. Main flow of Scanner dither test method](image)
Figure 2: First, filter and de-noise the image obtained by translocation imaging; Then, the edge testing template is convolved with the image to extract the left and right edge information of the T-shaped IQI, so as to filter the edge interference of the test block and effectively improve the real-time performance of the algorithm. Hough transform was used to fit under the constraints of horizontal Angle, linear length, spacing width and quantity statistics, to judge whether the number of tested lines in this process conforms to the preset conditions. If it conforms, there is no scanner jitter problem; if not, there is scanner jitter problem.

3. Algorithm processing and result analysis

3.1 Filtering noise reduction

The image obtained by the test card is a noisy image, noise will blur the image and reduce the image quality. In order to facilitate the subsequent analysis and processing, the pre-processing of filtering and noise reduction is carried out first. There The most commonly used filtering methods are: median filtering, mean filtering and Gaussian filtering.

At present, Peak Signal to Noise Ratio (PSNR) is one of the most commonly used standards to evaluate image quality, which is used to measure image distortion and Noise level in the image [4]. Table 1 shows the PSNR values of images before and after filtering by comparing the three filtering methods. PSNR values are shown in Table 1, it can be seen that the denoising effect of median filtering method is more suitable for the denoising effect of CR phantom.

| filtering mode      | boundary operator | PSNR     |
|---------------------|-------------------|----------|
| Median filtering    | sobel             | 14.036690|
| Average filtering   | sobel             | 15.897570|
| Gaussian filter     | sobel             | 14.451646|

3.2 Edge processing algorithm

Common edge testing operators include Roberts edge testing operator, Sobel edge detection operator and Canny detection operator, etc. Roberts edge detection operator has the best effect on the image with steep and low noise, but the extracted edge is coarse and the positioning is inaccurate [5]. Sobel operator has smoothing effect on noise, and the edge direction information is more accurate, but the positioning accuracy is not high enough. However, although canny detection algorithm can extract more complete edge information with high positioning accuracy and fine edge details, it has a lot of noise.

Table 2 shows the comparison of the edge testing results and effects of these three edge detection operators. Combined with Table 2 and the effect of specific edge detection, sobel operator is subsequently selected for edge testing.

| edge testing operator | noise | contour testing effect | detail complete effect | computation speed |
|-----------------------|-------|------------------------|------------------------|-------------------|
| Roberts               | good  | fine                   | rough                  | fast              |
| Sobel                 | good  | fine                   | rough                  | fast              |
| Canny                 | Bad   | finer                  | rough                  | slow              |

3.3 Image segmentation

The location of the test card translocation is fixed, so the position coordinates of the T-shaped IQI can be obtained, and the Image of the T-shaped IQI can be cut out to obtain the image shown in Figure 3.
3.4 Improved Hough transform algorithm

3.4.1 Hough transform
Hough transform is widely used in geometric shape testing. Through Hough transform, straight lines (line segments) can be tested from black and white images. This method is suitable for automatic recognition of scanner jitter.

The basic idea of Hough's transformation is that in the parameter space, all lines passing the point (x, y) satisfy the equation of the line

$$y = px + q$$ (1)

Where Q is the intercept and P is the slope. Formula (1) When the line is parallel to the X-axis or Y-axis, p and Q are close to infinity, increasing the amount of calculation. Therefore, the polar coordinate equation of the line is adopted

$$\rho = x\cos\theta + y\sin\theta$$ (2)

It is necessary to detect the intersection point of sinusoidal curve in parameter space to detect a line with common points in image space. For each coordinate (x, y) in the image, value and theta is calculated according to formula (2), and the value is accumulated. Greater than the threshold (p, \(\theta\)) corresponds to the straight line tested in the image space. In the image space, the grayscale value of the binary image of N×N (\(x_i, y_i\)) pixel is I(\(x_i, y_i\)). Take M discrete values and Q discrete values in the parameter space, then the standard Hough transformation in line testing can be expressed as

$$H(\rho_i, \theta_j) = \sum_{i,j=0}^{N-1} I(x_i, y_j) \rho_i \leq x_i \cos\theta + y_j \sin\theta \leq \rho_i + \frac{1}{2}$$ (3)

The steps of Hough transformation are as follows: firstly, for each pixel point (x, y), so that \(\theta\) is from -90 to 180 degrees, and formula (2) is used to calculate 270 groups (p, \(\theta\)) representing 270 lines in Hough space. Store these 270 sets of values in H. If a set of points is collinear, then each value in that set will increase H(p, \(\theta\)) by 1. So finding the line with the highest value of H(p, \(\theta\)) is the line with the highest number of collinear points, and the line with the highest value of H (p, \(\theta\)) is the line with the highest number of collinear points. All the obvious lines can be found according to a certain threshold value[6].

3.4.2 Improved Hough transform
The standard Hough transform is based on line voting. Each time two points are randomly selected from the image space to form a line, and one vote is cast on this line. Finally, the total number of lines above the threshold is reached. The improved Hough transform is based on point voting. After randomly selecting two points to form a line, it traverses along the direction of the assumed line and votes the points on the line. If the vote reaches a certain threshold, it is judged that the current assumed line is a line. The idea of fault-tolerant voting is introduced to reduce the error.
3.4.2.1 Fault-tolerant voting
This algorithm adopts the idea of fault-tolerant voting\cite{7}. This point is borrowed from RANSAC’s voting strategy\cite{8}. However, RANSAC algorithm will directly abandon the line segment that does not reach the threshold requirement. However, this algorithm does not abandon the point but also votes it. Fault-tolerant voting can avoid identifying these points as “out of line” points in the case that the line edge is uneven but does not meet the scanner jitter determination value, which makes the result more in line with the determination specification of scanner jitter.

3.4.2.2 Improved point voting Hough transform
We introduce the idea of the point-voting Hough transform. First, the value of each pixel in the image is stored in a two-dimensional array to mark the edge points. Secondly, randomly take two points at a time to establish a hypothetical line, and get the value of \((p, \theta)\) of the hypothetical line according to formula (2).

\[
\begin{align*}
dx &= \cos \theta \\
dy &= \sin \theta
\end{align*}
\]

According to the calculation results of formula (4) and Formula (5), the assumed direction of the line is obtained. If \(dx\) is greater than or equal to \(dy\), along the X-axis, otherwise along the Y-axis. Traverse each pixel on the hypothetical line, searching a line area x pixel wide to conduct a fault-tolerant poll, casting one vote at each pixel. When the voting point reaches the preset threshold, the line conforms to the line determined by the algorithm. The specific steps of this algorithm are as follows:

1) Establish a two-dimensional array in the image space to form a discrete parameter space;
2) Randomly pick two points to establish a mathematical straight line;
3) Get the midpoint of the line segment obtained in Step 2, judge whether the midpoint is the edge point, if so, proceed to point voting along the mathematical line; Otherwise, go back to Step 2;
4) If the votes of the line exceed the threshold \(T\) at a certain point, the line is considered as a line that meets the requirements. Delete all points for voting; Otherwise, go back to Step 2;
5) Repeat steps 1-4;
6) If there is a line exceeding the threshold in the statistical space, put out it.

4. Test results and experimental verification
For scanner jitter, it is necessary to cut out the T-shaped IQI, set a threshold, and identify the line segment in the graph through the improved Hough transform. The line within the threshold will be identified, and the line beyond the threshold will not be identified, and you can determine whether there is scanner jitter. That is, when the testing results are 4 straight lines, it is determined that there is no scanner jitter in the CR system. On the contrary, if the testing results are other values, it is determined that the CR system has scanner jitter.

The standard Hough transform was compared with the improved Hough transform. The threshold value of the standard Hough transform was set as an adaptive threshold value, which was calculated by the internal formula. The threshold value of the point voting Hough transform was calculated according to CR testing standard.

| Standard Hough transform | Improved Hough transform voting |
|--------------------------|--------------------------------|
| \(\rho\)       | 1.0 | 1.0 |
| \(\theta\)       | \(\pi/180\) | \(\pi/180\) |
| threshold value    | self-adaption | 450(Pixel values) |
| run time (ms)      | 163.4 | 201.3 |
| Straight number line number | 6 | 4 |

Use the line() function in OpenCV to draw in the image to obtain the image tested by the standard Hough transform and the point voting Hough transform, as shown in Figure 4 respectively.
By comparing and analyzing the experimental results in Figure 4 and Table 3, it can be found that the standard Hough transform operation speed is faster, but because there is no fault-tolerant voting, the accuracy is higher and more lines are tested. Two lines are tested in both upper and lower edges of the T-shaped IQI which has an impact on the testing algorithm results of scanner jitter. The Hough transform of point-and-vote makes the testing closer to the result of manual evaluation because of fault-tolerant voting. Moreover, due to the preset threshold suitable for testing, when the dual-filament imager image is identified, the points on the line do not reach the preset threshold, so it is not recognized as a line, which ensures the accuracy of testing.

5. Conclusions

Aiming at the scanner dithering problem in CR system performance, this paper proposes a testing algorithm based on edge feature and improved Hough transform. By extracting the edge feature information in the vertical direction of the image and combining the idea of fault-tolerant voting, the Hough transform of point-voting is used to match the edge line of T-shaped IQI. The comparison with the standard Hough transform shows that the point-based voting proposed in this paper can effectively and more accurately judge whether the edge of the T-shaped IQI is flat, so as to draw a more accurate conclusion and determine whether there is scanner jitter in the CR system.

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