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Segmentation of Weld Defects in X-ray Image Based on Partial Surface Reconstruction

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Abstract

Among those automatic weld defects inspection techniques based on real-time dynamic X-ray imaging, background subtraction is often adopted. The key to this method is how to estimate the weld background and it is mainly realized by low-pass filter or curve fitting methods. Generally, there are many false alarms and inaccurate defect shape due to inaccuracy of weld background obtained by these methods. This paper proposes a method of background subtraction based on partial surface reconstruction. Firstly, the possible defect positions are identified by gray-level wave analysis, and then weld background is estimated by reconstruction of these areas. This segmentation method has been employed in real-time X-ray automatic inspection system, which is being used for steel pipe manufacture in the West-East natural gas transmission project. Results show that false alarm and missed detection are decreased effectively, and the defect shape is more accurate.

Key words: weld defects, radiography testing, background subtraction

1. Background subtraction in X-ray image processing for weld defects

Real-time X-ray inspection is one of important nondestructive methods for long consecutive weld. To realize automatic inspection, many researches focus on the real-time X-ray weld image processing, and the background subtraction is one of the common methods to segment weld defects [1-3]. It contains the following steps: (1) estimate the background image(which does not contain weld defects) from the original X-ray welding image; ② obtain the residual image(which only contains defects and noises) through subtracting background image form original one; ③ transfer the subtraction image to binary image by a proper threshold and obtain the weld defects.

How to estimate the background image is the key to the background subtraction. The method at present mainly includes low-pass filter and curve fitting. By using low-pass filter, the background image estimated is inaccurate near the weld edges, which often cause many false alarms around this region. As for curve fitting method, it includes the following ways: the polynomial curve fitting, the Gauss curve fitting, the spline curve fitting and so on. These curve fitting methods usually do not so flexible to meet the diversity of X-ray weld image. It is particularly difficult to get the accurate background image for double-side weld by using those fitting methods. As a result, it will cause many false alarms, and if reduce the false alarms by desensitization, it will cause missed detection.

In this paper, a new method to estimate the background image is proposed by partial surface reconstruction. It not only decreases false alarm and miss detection effectively, but also obtains more accurate defect shape.

2. Background subtraction based on partial surface reconstruction

The partial surface reconstruction is implemented as follows: segment the possible defect region and then reconstruct partial surface in the segmented defect region to get the weld background image.

2.1 segment the possible defect region

Many methods can be used to obtain the possible defect region, and the miss detection ratio is the main concern in choosing the method. The false alarms can be eliminated by using the proposed background subtraction, and the wave analysis method [4] is used to get defect possible region in this paper. Figure 1 shows a real-time X-ray weld image of a steel pipe manufactured by double-side submerged arc welding. Let y(x) denotes the gray-level along column 180 that crosses the defect region, the y(x) is analyzed as following:

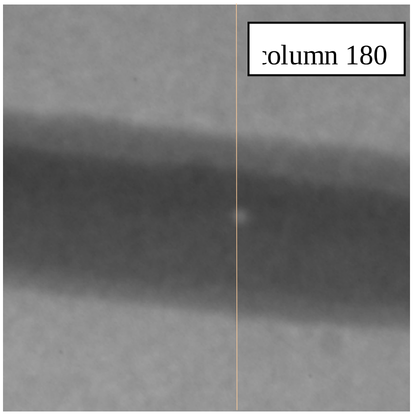

Fig. 1 Real-time X-ray image of double-side weld

(1) Get the first order difference $y'(x)$ and second order difference $y''(x)$ of $y(x)$.

(2) Search the convex interval [x_1, x_2] inside the weld region by $y'(x)$ and $y''(x)$.

(3) Analyze the image column by column, than the possible defect region is obtained and shown in figure 3 (there is a false alarm).

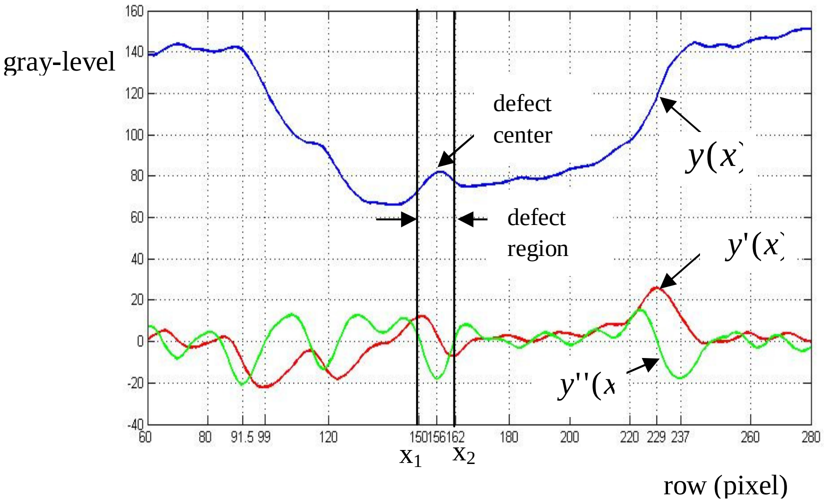

Fig. 2 gray-level wave analysis

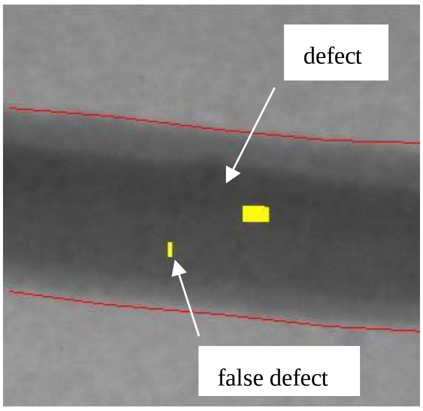

Fig. 3 Result of gray-level wave analysis

2.2 Background reconstruction in possible defect region

In the X-ray image of a weld, the gray-level changes slowly in a small region along the weld direction (row direction), while the gray-level wave profile in vertical direction of the weld (column direction) are usually similar. According to this feature, the background reconstruction of defect region can be implemented in two steps.

(1) Row reconstruction

In the row direction, use the beeline to reconstruct the background. Assume that interval $[i_1, i_2]$ is the defect region in the row m, $f(i)$ is the gray-level of pixel i in the original image, and $f_1(i)$ is the new gray-level of pixel i in the reconstructed row, let

$$k_m = \frac{f(i_2) - f(i_1)}{i_2 - i_1} \qquad (1)$$

Then

$$f_1(i) = f(i_1) + k_m(i - i_1) \qquad (i = i_1 + 1, i_1 + 2, \ldots, i_2 - 1) \qquad (2)$$

(2) Column reconstruction

In the column direction, reconstruction is performed according to the intensity of the defect district edges. Assume that interval $[j_1, j_2]$ is the defect region in the column n, and $f(j)$, $f_1(j)$ and $f_2(j)$ are the gray-level of pixel j in original image, in row reconstruction image and in column reconstruction image respectively, let

$$k_n = \frac{(f(j_2) - f_1(i_2)) - (f(j_1) - f_1(i_1))}{j_2 - j_1} \qquad (3)$$

Then

$$f_2(j) = f_1(j) + (f(j_1) - f_1(j_1)) + k_n(j - j_1)$$

$$(\ j = j_1 + 1, j_1 + 2, \ldots, j_2 - 1\ ) \qquad (4)$$

Figure 4 shows the 3-D gray-level distribution of original image. Figure 5 shows the 3-D gray-level distribution of background image after partial surface reconstruction. And Figure 6 shows the 3-D gray-level distribution of defect after background subtraction.

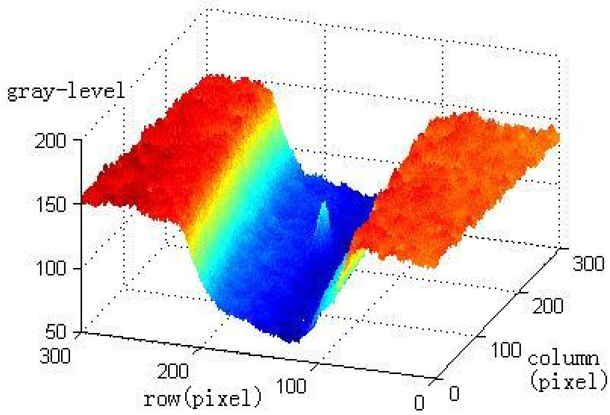

Fig. 4 3-D gray-level distribution of original X-ray weld image

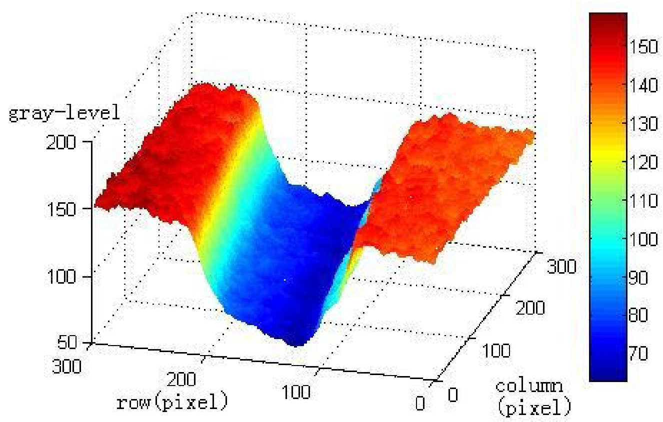

Fig. 5 3-D gray-level distribution of background image by partial surface reconstruction

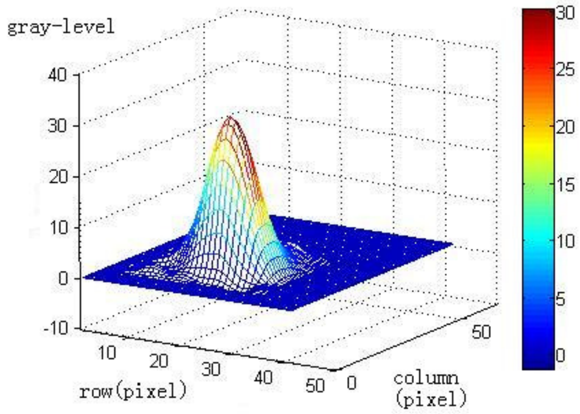

Fig. 6 3-D gray-level distribution of defect after background subtraction

2.3 Elimination of false alarms

When using single defect segmentation method, reducing the missed detections will cause many false alarms, which is the essential problem in traditional method. The method proposed above combines two segmentation methods, and the false alarm and missed detection can be dealt with separately. The background estimated by the partial surface reconstruction in the false defect region is quite close to the original image, and after background subtraction the gray-level of the residual image is very low, as shown in Figure 7. Thus, the false alarm is easy to be eliminated. After binaryzation of the residual image by a proper threshold, the weld defect segmentation result is showed in Figure 8.

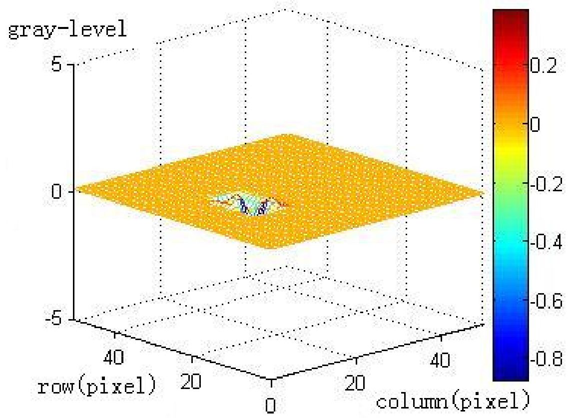

Fig. 7 3-D gray-level distribution of false defect after background subtraction

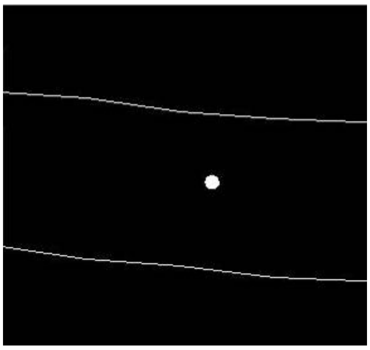

Fig. 8 Result of background subtraction based on partial surface reconstruction

3. Conclusions

In this paper, we propose a new method to estimate the background of X-ray weld image for background subtraction. Firstly, the possible defect region is obtained and a partial surface reconstruction is performed in the region, then the background subtraction method is applied to segment the weld defects.

(1) By reconstructions in row and column directions orderly, the accurate weld background image can be estimated, and the shape of defect detected is accurate.

(2) The proposed method of defect detection combines two segmentation methods, and the false alarm and missed detection can be dealt with separately, which can reduce the false alarm and missed detection effectively.

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