Selection of Optimum Illumination Mechanism Using DWT Synthetic Image and Discriminant Measure[Poster referred]

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Abstract

In this paper, surface defects and typical illumination mechanisms for steel plates are analyzed, and then optimum illumination mechanism is selected using discrete wavelet transform(DWT) synthetic images and discriminant measure(DM). The DWT synthetic images are generated using component images decomposed by Haar wavelet transform filter. The best synthetic image according to surface defects is determined using signal to noise ratio(SNR). The optimum illumination mechanism is selected by applying discriminant measure(DM) to the best synthetic images. The DM is applied using the tenengrad-euclidian function. The DM is evaluated the degree of contrast using the defect boundary information. The performance of the optimum illumination mechanism is verified by quantitative data and intuitive image looks. It is judged that the selected illumination mechanism could apply effectively to surface inspection system.

Discriminant measure, Optimum illumination mechanism, Steel plate, Surface inspection, Discrete wavelet transform

1. Introduction

Steel plate is most widely used in a variety of industries including automotive and shipbuilding steels. Currently, vision-based automated inspection systems used in steelmaking processes are unlikely to be accurate. There are many problems such as hazardous places, operating speed and low contrast, non-uniform, featureless steel surface image characteristic[1].

In this paper, the DWT is applied for treating with these three properties in steel plate surface images. The synthetic images are generated by applying the DWT. They are evaluated using SNR, and the best synthetic image is selected. In order to the optimum illumination mechanism is selectied using the tenengrad-euclidian based DM in the best synthetic image.

2. Steel plate surface defects and illumination mechanisms

Typical surface defects of steel plates are consist of scale, scab, crack, foreign object, etc. They are described in Figure 1. They are uneven shape surface defects. The defect regions of these surface images are darker than the defect-free regions due to incomplete diffuse reflection components.

Typical illumination mechanisms include directional illumination (DI), bi-directional illumination (BI), coaxial illumination (CI), and dome illumination (DOI). The fused illumination mechanism was constructed considering the characteristics of the typical illumination mechanisms[2]. BI & CI in Figure 2 (a) can make the reduction of shadow effect due to BI. DOI & CI in Figure 2 (b) can acquire even and bright image, regardless of irregular surface shapes.

In this paper, the parameterization of illumination mechanisms is made according to the angle and height of illumination. The effect of illumination angle for DI and BI has been investigated. The angle is changed from 30°to 70° with interval 10°. Here, 5 images can be obtained in DI and BI. DOI has 3 channels(high, middle, low) according to illumination structure height, which can be controlled respectively. Then 7 images are obtained in the DOI. In the same manner of BI, BI & CI have 5 images according to illumination angle change. Also, DOI & CI 5 images according to channel. We make use of totally 145 images, which include 25 images for DI, BI, BI&CI and 35 images for DOI, DOI & CI, respectively.

3. DWT synthetic images and discriminant measure

The DWT is applied for improving to low contrast, non-uniform and featureless properties in steel plate surface images. The
DWT filter[3] is applied using the haar wavelet transform filter. The synthetic images are synthesized using the decomposed component images by DWT. The DWT synthetic images are modelled as Eq (1).

\[ S_{d}^{1} = E_{1}^{l} + C_{d}^{1} \cdot E_{1}^{g} + C_{d}^{2} \cdot E_{1}^{b} \]  

(1)

Where \( E \) is the normalized energy image of the decomposed component image, and \( C \) is the weight between the resolution component images.

The DWT synthetic images are evaluated by SNR. The SNR is the standard deviation of the defect-free region, and is defined as Eq (2).

\[ SNR = \frac{I_{d} - I_{df}}{\sigma_{df}} \]  

(2)

Where \( I_{d} \) and \( I_{df} \) are the average of the defect and defect-free region, and \( \sigma_{df} \) is the standard deviation of the defect-free region.

Table 1 shows four normalized data of applying SNR to DWT synthetic image. As a result of comparing the normalized data, \( S_{d}^{1} \) showed the highest ones in the four defects except line crack. However, there is also relatively high value in line cracks. Therefore, the best synthetic image is determined as \( S_{d}^{1} \).

Table 3 shows four normalized data of applying SNR to DWT synthetic image. As a result of comparing the normalized data, \( S_{d}^{1} \) showed the highest ones in the four defects except line crack. However, there is also relatively high value in line cracks. Therefore, the best synthetic image is determined as \( S_{d}^{1} \).

The DM is a measure to determine which group belongs to when a certain pattern or feature is divided into several groups. The DM is based on the tenengrad-euclidian function. It is defined as Eq (3), The DM is modelled using the quantitative characteristic of compound images.

\[ DM = \left( F_{TE-d} - F_{TE-df} \right) \]  

(3)

Where \( F_{TE-d} \) and \( F_{TE-df} \) mean pixel value of image in the defect and defect-free region. \( I(x,y) \) is the weight between the resolution component images. \( T \) is an arbitrary threshold for limiting boundary information and then makes some noise be reduced a little.

The results of the DM are in Table 2 so that they can be used to determine which group belongs to when a certain pattern or feature is divided into several groups. The DM is based on the tenengrad-euclidian function. It is defined as Eq (3), The DM is modelled using the quantitative characteristic of compound images.

**Table 1 SNR comparisons for synthetic images**

<table>
<thead>
<tr>
<th>Defect</th>
<th>Scale</th>
<th>Line crack</th>
<th>Scab</th>
<th>Star crack</th>
<th>Foreign object</th>
</tr>
</thead>
<tbody>
<tr>
<td>BI &amp; CI</td>
<td>0.94</td>
<td>0.94</td>
<td>0.89</td>
<td>0.89</td>
<td>0.91</td>
</tr>
<tr>
<td>DOI &amp; CI</td>
<td>0.95</td>
<td>0.98</td>
<td>0.87</td>
<td>0.88</td>
<td>0.85</td>
</tr>
</tbody>
</table>

**Table 2 DM value comparisons for illumination mechanisms**

<table>
<thead>
<tr>
<th>Defect</th>
<th>Scale</th>
<th>Line crack</th>
<th>Scab</th>
<th>Star crack</th>
<th>Foreign object</th>
</tr>
</thead>
<tbody>
<tr>
<td>BI</td>
<td>0.90</td>
<td>0.97</td>
<td>0.80</td>
<td>0.89</td>
<td>0.91</td>
</tr>
<tr>
<td>BI &amp; CI</td>
<td>0.98</td>
<td>0.95</td>
<td>0.98</td>
<td>0.89</td>
<td>0.91</td>
</tr>
<tr>
<td>DOI</td>
<td>0.15</td>
<td>0.76</td>
<td>0.87</td>
<td>0.88</td>
<td>0.85</td>
</tr>
<tr>
<td>DOI &amp; CI</td>
<td>0.15</td>
<td>0.75</td>
<td>0.94</td>
<td>0.87</td>
<td>0.74</td>
</tr>
</tbody>
</table>

**Table 3 Parameters of optimum illumination mechanism**

<table>
<thead>
<tr>
<th>Surface defect</th>
<th>Illumination for a defect (Parameter)</th>
<th>Optimum illumination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scale</td>
<td>BI &amp; CI (70)</td>
<td>BI &amp; CI (70)</td>
</tr>
<tr>
<td>Scab</td>
<td>BI &amp; CI (70)</td>
<td>BI &amp; CI (70)</td>
</tr>
<tr>
<td>Line crack</td>
<td>BI &amp; CI (70)</td>
<td>BI &amp; CI (70)</td>
</tr>
<tr>
<td>Star crack</td>
<td>BI &amp; CI (70)</td>
<td>BI &amp; CI (70)</td>
</tr>
<tr>
<td>Foreign object</td>
<td>BI &amp; CI (70)</td>
<td>BI &amp; CI (70)</td>
</tr>
</tbody>
</table>

**Figure 3. DWT synthetic images by optimum illumination mechanism**

**Acknowledgement**

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**References**


[3] Li W C and Tsai D M 2012 “Wavelet-based defect detection in solar wafer images with inhomogeneous texture” Pattern Recognition 45 pp 742-756