An Improved Crack Detection Technique for Pressed Panel Products

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ABSTRACT

Crack detection is an important step for quality assessment of pressed panel products. We have developed a fast and non-invasive crack detection technique, which extracts the outline of the captured image and applies a unique edge line evaluation. This technique, however, shows somewhat unstable performance once the structure under investigation is subjected to the environmental lighting condition changes. In this study, an improved crack detection technique for more stable performance is proposed. First, an LED light is used to exclude the environment lights, and the outline of an object is then extracted based on the lighting control and edge enhancement after capturing an image. Second, a rough detection at the low resolution is applied to find out every possible crack using edge line searching and curvature evaluation. Finally, at the high resolution, the local image of every possible crack is separately detected using a more specific angle evaluation process. To demonstrate the performance of the proposed technique, pressed panels with a real crack are used for experiments. It is shown that the proposed technique could extract much clearer edges compared to traditional approaches, resulting in the improved damage detection capability.

1. Introduction

Sheet metal processing plays an important role in most manufacturing industries, such as automobiles, electronics, home appliances, cans and other commercial products. These sheet metal parts possess a high strength and a small thickness, enabling the products having a high strength to weight ratio. In this paper, defect detection of pressed metal panel products is discussed, which is produced by blanking, piercing, bending, stretching, hole extrusion, stamping and a large number of other processing methods [1]. Though sheet metal forming processed is efficient, it is easily affected by several factors, which leads to various types of defects, such as cracks, necking, and wrinkles [2]. Defect detection during the manufacturing process is an important step for ensuring the panel product quality. Traditional defect detection methods are performed by experienced human inspectors. The efficiency and accuracy, however, is easily influenced by subjective factors of workers. Therefore, the development and implementation of an automated and accurate defect detection technique for quality assessment of panels is important for the press forming process.

Several techniques for crack detection have been developed in the structure health monitoring field. Signal processing and analyzing techniques using measured signal are employed to identify cracks [3-5]. Compared to sensor-based methods, image processing based crack detection techniques show some advantages. Niemueller introduced several methods to detect cracks and corrosion on the pipe surfaces [6]. Jian and Bunke developed an edge detection algorithm based on the scan line approximation technique [7]. Abjel-Qader compared and evaluated the performances of the four crack detection methods including Fast Haar Transformation (FHT), Fast Fourier Transformation (FFT), Sobel and Canny filter [8].

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We have developed a fast and non-invasive crack detection technique, which extracts the outline of the captured image and applies a unique edge line evaluation. However, this technique shows somewhat unstable performance if the structure being investigated is under the environmental lighting condition changes. Therefore, an improved light-control technique for more stable performance and better detecting accuracy is needed and discussed in this paper.

2. Improved Crack Detection Technique

The proposed crack detection technique consists of four steps, as shown in Fig. 1. First, lighting control is implemented in order to introduce the best lighting condition. Real-time images are captured on a belt conveyor system using a mounted camera. Second, to obtain the best grayscale histogram from the image taken by the camera, optimal RGB channels are selected based on the lighting control. The original image is then converted into a binary image after applying the Otsu Algorithm and image superposition. In the third step, the percolation method is applied to extract the edge line information of the object. As the final step, the angle of pressed panel edge line is obtained by evaluating the identified edge line. If the angle value is larger than the pre-defined degree, it could be considered as a crack.

![Figure 1. Four Steps for Crack Detection](image)

### 2.1 Lighting Control

On the real manufacturing line, crack detection accuracy is easily affected by random lighting conditions caused by the shadow of moving objects and lighting condition changes. To remove these effects, a dark room is installed in the manufacturing line. The LED lamp is mounted on the frame to supply the light inside the room. The room is covered by a dark curtain to reduce other lightening effects. Based on those settings, we can control the light and analyze the effect produced by the light of various colors.

#### 2.1.1 RGB Color Model

RGB color model has three channels, RED, GREEN, and BLUE. The widely used RGB to Grayscale formula is developed based on light sensitivity of human eye, which is not suitable for computer simulation. The weighted factor for grayscale to RGB conversion is given as:

$$Gray = 0.3 \times \text{Red} + 0.59 \times \text{Green} + 0.11 \times \text{Blue}$$

(1)
The grayscale image of each channel represents each light intensity as shown in Figure 3[10]. When white light is used, the gray pressed panel will reflect almost all the light and the green background will also reflect blue and green light. Then the RGB image is converted to grayscale image using the weighted method. However, the result shows that the difference between the object and the background is not ideal for Otsu Algorithm. To acquire a better image, RGB channel factors are reweighted based on lighting color and background color. Detailed steps will be discussed in the later sections.

2.1.2 Lighting Color Effects on Image Segmentation

The color of light is another important factor regarding the RGB model. In this study, multicolor LED lamp is used for experiment to produce lights with the different value in red, green and blue channels.
The red object and the black background are used to demonstrate how the color of light affects image segmentation results as below:

- Under the red light, the red object reflects almost all the red light and the background absorbs almost all, which shows the sharp change at edge of object on the RED channel.
- Under blue light, both the object and the background reflect only a small part of the light, which is hard to be separated.

2.1.3 Steps for Selecting Ideal Lighting Condition

The RGB channel and lighting color effect have been demonstrated in previous sections. Based on this, an ideal grayscale image with the maximum difference between the object and the background could be generated. The detail steps are described below:

- Using the white light to find out which color of light will be reflected more from the object.
- Doing the same procedure on the background and find out which color of light is reflected less relatively.
- Analyzing the result and select the best light that induces the maximum difference between the background and the object.

The color of this pressed panel is grey, which reflects almost all the light. In figure 3, both the blue channel and the red channel are clear enough, but the red channel is finally selected because the belt conveyor shows low reflectivity on the red light, as shown in Figure 5, which leads to the dark background and the clear object.

![Figure 5. RGB Analysis of Background and Object under Red Light](image)

The result with the light control is shown in the figure 6. Our proposed method, which maximize the difference between the object and the background produce much clearer and sharper image, as compared to Figure 13. This also has the effect of sharpening the presence of crack, leading to a better defect detection.

![Figure 6. Grayscale Image using Lighting Control](image)
2.2 Crack Detection

2.2.1 Pre-Image Processing

From lighting control, an image with the dark beltline and the red object has been captured by a camera. It has the maximum difference between the background and the pressed panel because of lighting control and channel selecting. Pre-Image processing is then applied to extract the outline of the object followed by edge line detection.

Image superposition is first employed to expand the variance by multiplying by the scale factors. Contrary to the bright pressed panel, background has a low value in the selected red channel due to the low reflectivity to the red light. Once they are multiplied by a scale factor that larger than 1, the difference will increase because of their original value.

![Figure 7. Image Superposition with Different Scale Factors](image)

Based on the processed image, a binary image is generated by applying the Otsu Algorithm that automatically calculates the threshold value $T$. The equation is given as:

$$
\sigma_0^2(T) = \omega_0(T)\sigma_0^2(T) + \omega_1(T)\sigma_1^2(T)
$$

(2)

Downscaling is then applied to reduce the computation complexity by the percolation model based shape recognition and edge line extraction. First, the shape of the object is extracted. Based on the extracted shape information, the edge line is generated by searching pixels whose neighboring pixel contains background pixels. With this procedure, the generated edge line contains a single pixel of width.

![Figure 8. Outline Extracting](image)

2.2.2 Edge Line Searching

After extracting the edge line, cracks are detected using edge line tracking and angle evaluation. Cracks are defined as a sharp change on the edge, which results in a sharp angle change. In order to calculate the angle, an edge line searching process based on the 8-pixel connectivity is employed to track all the pixels on the edge line. While searching the edge line, each pixel has eight neighbors and it has ten types of arrangements, as shown in Figure 9.
Depending on these patterns, the edge line will go through all the pixels and record their position for angle calculation.

### 2.2.3 Angel Calculation

For each pixel, the process will calculate the angle using three successive points with a pre-defined interval as shown in following figure. All the angle formed along the edge line are used for crack detection per the given threshold. For example, two types of the edge line with a sharp crack and blunt edge are compared in Figure.10 and Figure.11.

<table>
<thead>
<tr>
<th>Angle</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crack</td>
<td>63.4°</td>
<td>45.0°</td>
<td>33.1°</td>
<td>45.0°</td>
<td>74.7°</td>
</tr>
<tr>
<td>Normal Edge</td>
<td>154.4°</td>
<td>154.4°</td>
<td>175.2°</td>
<td>180°</td>
<td>191.3°</td>
</tr>
</tbody>
</table>

Through the application of trigonometry, the angle is calculated after acquiring the pixel positions. The angle change of two edge types is given in Table 1.
2.2.4 Double Detection

Image downscaling is necessary for fast crack detection, however, it leads to the fact that the crack information on edge line is also downscaled. In some cases, if the crack is incipient, it is not detected at this downscaled resolution. In order to address this issue, crack detection is performed in two separate steps. First, a rough detection at the low resolution is applied to find out every possible crack using edge line searching and curve evaluation. Second, at the high resolution, the local image of every possible crack is separately detected using a more specific angle evaluation.

3. Experiment Results

Real pressed panel products with two cracks is detected on belt conveyor in experiment. The red LED light with RGB value (255,0,0) is used and an image is taken by a camera with the 1600*896 resolution. Rough detection and local detection are both able to detect damage with high accuracy.

An experimental result with the traditional approach are shown in figure 13, for comparison. Because of the random light condition and only a slight difference between the background and the object, the binary is not produced efficiently along the edge, results in the incorrect crack localization. As illustrated, the proposed technique is able to detect the cracks in the panel with the much improved accuracy, compared to the previous approach.
Another experiment results with the proposed technique on a different panel are shown in Figure 13. Once again, the cracks are correctly identified, which confirms the efficiency of lighting-control in crack detection.

4. Conclusions

An improved crack detection technique based on lighting control is proposed in this paper. Taking full advantages of lighting control is an important for the pre-image processing and crack detection, which is composed of two steps:

- Analysis of the background and the object under different lighting condition.
- Acquisition of the best light that brings the maximum difference between the background and the object.

Pre-image processing is then applied to extract a clear and accurate outline of the object. After searching all of the outline pixels, cracks are identified by two separate steps, rough detection and local detection. Experiments with real pressed panel products are carried out on the belt conveyor system. Through the
experiment, it is shown that the proposed image processing technique is able to detect surface cracks with reasonable accuracy and stable performance.

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References and Footnotes