Study on the Crack Detection of Bridges Based on Digital Image Processing

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Abstract: It is necessary to carry on the inspection of the bridge after more and more bridges are built. In view of present inspection techniques, we try to explore to inspect the bridge by machine vision. Considering the practical complex working conditions, such as lighting conditions, interference of the shadows of the trees or cables, it is difficult to realize the reliable crack extraction. In this paper, we try to solve those problems with various algorithms. Some initial good results were obtained. The further research will be carried on soon.

Keywords: Crack detection, Machine vision, Image processing**.**

I. INTRODUCTION

In the bridge inspection, more and more attention is paid on the crack detection. Compared with other defects, the crack is important to determine whether the bridge will be maintained or not. Although a crack is the defect on the surface of a bridge, we will find the internal stress indirectly based on the length, width and depth of the crack on its surface.

Now people can only inspect the bridge manually in most cases. We check the cracks for each building by human being's eye or using telescope. In order to get the dimensions of each crack, they have to measure it with some tools. However, in some cases, such as the high bridge, or the bridge is not easy to reach, they have to use some telescope or special equipments. Even if we can get some results, the high accuracy is difficult to be satisfied. On the other hand, we have to consider the cost, safety and efficiency, etc.

In view of present inspection methods, it is necessary to develop some methods to detect the cracks automatically. Machine vision is a good solution. In the machine vision, it captures the images by the CCD camera; with the special image processing technique, the target object (such as the crack) is extracted; the dimensions of the target will be calculated. That is, machine vision works like human beings. It tries to help people to perform some tasks where people are not appropriate to reach.

It is different from the laboratory conditions or indoor environments, where the influence is generally controlled. But in the outside, the background is various. It makes the crack extraction more difficult. That means we have to use the compound methods to extract the cracks, moreover, we have to consider the recognition method to separate the cracks from other objects. At the same time, we will also need to consider the speed of the image processing in the real applications.

Till now, various defects' detection is developed with the machine vision. But for the crack detection, we have to consider the practical working environments, such as lighting conditions. At the same time, we also need to consider the interference by the shadow of the cables or trees etc. In this paper, based on some images of the cracks, we explored the methods to extract the cracks.

In the following sections, we will give more details explanations about each topic. Moreover, we will also provide some crack extraction results by our image processing methods.

II. IMAGE PROCESSING

After we get the image from the CCD video camera, we will detect the cracks in that image based on corresponding algorithms. Automatic crack detection is highly desirable for efficiency and objectivity of crack assessment. However, generally it is difficult to extract cracks automatically from noisy bridge surfaces. Cracks in the images obtained from the practical workspace are contaminated by noises such as oil paint, scratch, cables and so on. Besides, the light condition, focal distance seriously effected the images' quality. Thence a satisfied result cannot be obtained only with several common algorithms of the image processing.

Based on the analysis of the characteristics of images contained bridge cracks this article proposed some special image processing algorithms to obtain the cracks' area, length and width. Besides, one software using MATLAB language was developed. The processed result showed that the software was suitable for the crack detection of bridge surface.

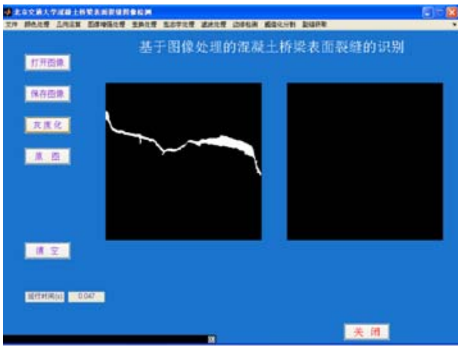

Fig.1. Interface of the software

Now we take one sample image as an example. The image processing will be explained as followings.

1. Graying

The RGB image shown in Fig.2 was obtained by the CCD camera. Normally, in order to accelerate the images' processing speed, the RGB image can be transformed to gray one shown in Fig.3 which contains the necessary information to meet the following process.

Fig.2. Original Image

Fig.3. Gray image

2. Image enhancement

The principal objective of enhancement is to process an image so that the result is more suitable than the original image for a special application. Image enhancement approaches fall into two broad categories: spatial domain methods and frequency domain methods. In this paper, the gray level transformation, fourier transformation, wavelet transformation were applied to enhance the gray images.

Fig.4. Result after enhancing image.

3. Threshold

The simplest segmentation algorithm is to threshold the image. The threshold operation is defined by:

$$S = \{(r,c) \in R \mid g_{\min} \leq f_{r,c} \leq g_{\max}\}$$

This paper applies the Basic Global Thresholding, Otsu and customized thresholding algorithm in order to divide an image into several parts according to the pixels' different gray value.

Global Threshold

Global Threshold is based on visual inspection of the histogram. The following algorithm can be used to obtain T automatically:

1) Select an initial estimate for T.
2) Segment the image using T. This will produce two groups of pixels: G_1 consisting of all pixels with gray level values>T and G_2 consisting of pixels with values <=T.
3) Compute the average gtray level values μ_1 and μ_2 for the pixels in regions G_1 and G_2.
4) Compute a new threshold value:

$$T = \frac{1}{2}(\mu_1 + \mu_2)$$

5) Repeat steps 2 through 4 until the difference in T in successive iterations is smaller than a predefined parameter T_0.

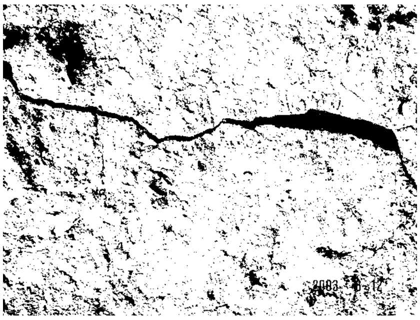

Fig.5. Result of global thresholding from Fig.4.

Otsu thresholding

It is considered to be an adaptive thresholding method. An image is divided into parts of background and object. The more inter-class variance provided, the more difference between the background and object. If a part of object area was mistaken to background, the difference will be reduced, and vice versa.

An image: I(X,Y),size:M×N.

$$W_0 = N_0 / M * N$$
$$W_1 = N_1 / M * N$$
$$N_0 + N_1 = M * N$$
$$W_0 + W_1 = 1$$
$$\mu = W_0 \times \mu_0 + W_1 \times \mu_1$$
$$g = W_0 \times (\mu_0 - \mu)^\wedge 2 + W_1 \times (\mu_1 - \mu)^\wedge 2$$

In the formulations above, N_0 represents the number of object pixels. N_1 represents the number of background pixels. μ_0 represents the average value of the object area. μ_1 represents the average value of the background area. μ represents the average gray value of the global image. g represents the inter-class variance. We can utilize the traversal method to find the largest threshold value T. The result is shown in Fig.6.

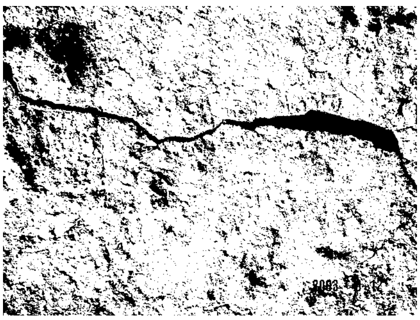

Fig.6. Result of OTSU

Customized threshold

By virtue of Matlab language, we can compare the images under the different threshold value between 0 and 255. Fig.5 shows the threshold image under the value 110.

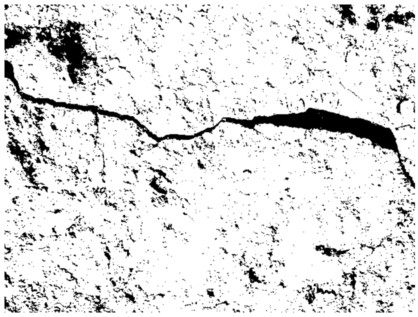

Fig.7. Result of customized threshold image

Fig.8. Result of filtering image

4. Filtering

In this paper, we utilize the median filtering method to filter the segmentation image shown in Fig.8.

5. Feature extracting

In the images with rather single background, in general the connected area of crack is larger than other feature's and the length is longer than other feature's, too.

1) Invert the background' color to black and the object' color to white. Result is shown in Fig.9.
2) Mark the region in the image obtained after filtering.
3) Compute all regions' area, length, round-degree, compare them separately. And then, get the label number N with the minimum round-degree, but its area and length are both the maximum value among those regions.
4) Keep the pixels' value 1 in the region N, and set the value of remaining region's pixels 0. The final result is shown in Fig.10.

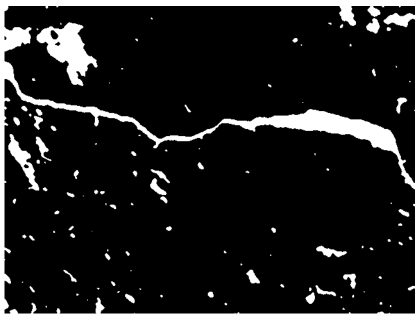

Fig.9. Result of inverting image

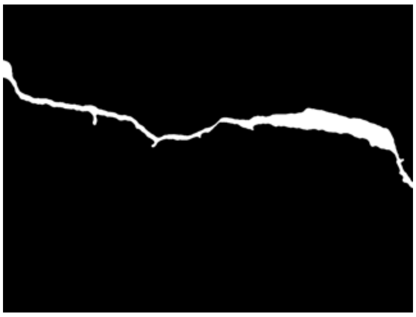

Fig.10. Final result

In the end, after the five steps above, we receive the processed image only with the crack feature. At the same time, the crack's area, length and width have been computed.

III. CONCLUSION

In this paper, we carry on the initial study on the crack detection based on the image processing technique. Some results are obtained. Next step, we will test with more samples, and consider the influence of the lighting conditions etc.

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