Recognition of Cracks on the Concrete Surface in Digital Images

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Abstract

When we estimate the quake resistance of the steel reinforced concrete structure, or the deterioration degree of materials, cracks on the concrete surface are extremely important factors. However, the conventional judgment technique using cracks needs great man power. This study we use a digital camera and some image processing methods and simplify the cracks measurement process to get more precise information of cracks.

In this research we propose a new method of processing the images of cracks, in the hope to reduce the difficulty of conventional techniques. We take a photo of a concrete surface, and preprocess it, then we analyze several characteristics of the image, especially for line parts, and cracking part will be extracted by grayscale conversion, edge enhancement and Hough conversion method.

Introduction

When we estimate the quake resistance of the steel reinforced concrete structure, or the deterioration degree of materials, cracks on the concrete surface are extremely useful factors. However, conventional way to observe cracks, to measure cracks' width and length, and related sketching methods require a lot of manpower. In quite a few cases, the analog data of sketching are not suitable for being analyzed by computers, thus those kinds of data have been estimated by experienced person, or left untouched without sufficient investigation.

In this research we propose cracks extraction and feature extraction methods which help to develop more efficient way to maintain and control concrete structure.

The cracks of the reinforced concrete

Generation mechanism of the cracks on ferroconcrete surface is complicated, usually led by two or more causes. Many of them may also interact with and influence each other. The features of the cracks of ferroconcrete are shown in Table 1. The places where cracks are seen are shown in Fig. 1.

Conventional binarization method

Conventional image-processing technique to extract cracks is performed by binary treatment of the luminance of an input picture. However, photographic unevenness due to photographing conditions such as lighting and shading, makes the image data difficult to have a uniform luminance. In order to handle such image data, we need some preprocess to reduce the photographic unevenness. Moreover, a lot has been left to subjective judgment of the analyst who did the image processing. The information provided by an image will be lessened after it is binarized, which though simplifies the later processing. In addition, the process to delete the points that do not belong to cracks is complicated as there is often very little information to help distinguishing between noise and points of cracks with the same luminance.

Table 1. Quantity of characteristics of the cracks

continuity	materials: tortoiseshell pattern
	structural: line
concentricity	surroundings of a window
	on the concrete surface above along a steel rods
	part of the junction of a beam or a pillar
direction	lengthwise direction straight line
	transverse direction straight line
	45-degree slanting straight line
pattern	single thin line
	character-like
width and the level of seriousness	less than 0.2mm ...not serious
	0.2mm : not adoptable for the part where no leakage of water is allowed
	0.3mm : need to take a certain measure
	0.5mm or more : structural trouble will occur

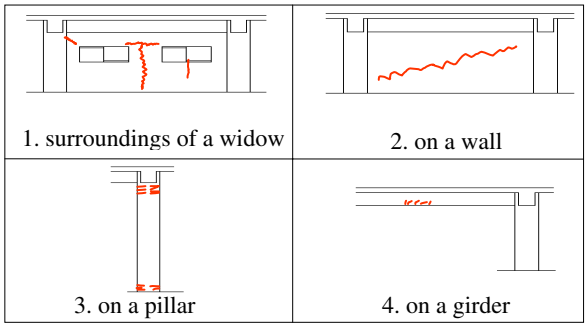
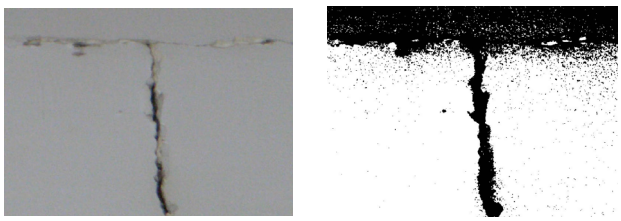


Figure 1. *The place where cracks occur*



(a) (b)

Figure 2. *Binarization without preprocessing (a) original image (b) binarized image.*

Without removing the noise of the image before binarization as shown in Fig. 2, noise will be exaggerated where cracks are extracted.

Outline of the technique of extracting cracks

In this research we propose a new method of processing the images of cracks, in the hope to solve the problems in abovementioned conventional techniques. After preprocessed as shown in Fig. 3, cracks are recognized by the Hough conversion.

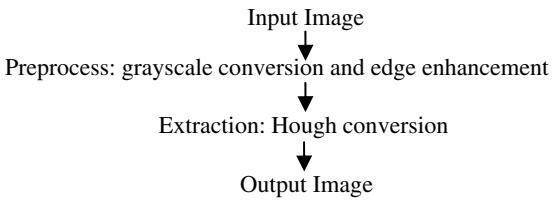


Figure 3. *Flowchart of cracks extraction with image processing technology*

1. Grayscale conversion

A grayscale conversion is a method to convert full color image with 256 gradations into 256 continuous tone grayscale image. With only black and white, each pixel is demonstrated as a different luminance.

1.1 Principle of grayscale conversion

Let the tone values of red, green and blue of a pixel be R, G and B, respectively. We can calculate a tone value in such a way as shown in Eq. (1), which demands the mean of each value of RGB. Then we can get a grayscale pixel by setting this mean value as the tone value of each new RGB color.

$$T=(R+G+B)/3 \quad (1)$$

However, human eyes are more sensitive to blue than to green, which makes us feels blue to be relatively brighter and green gloomier. Thus comes the Eq. (2) taking into account of the abovementioned situation (T: output tone value). In this research, we adopt Eq. (2).

$$T=0.298912\times R+0.586611\times G+0.114478\times B \quad (2)$$

2. Edge enhancement

Edge enhancement filters, enhances the local discontinuities at the boundaries of different objects (edges) in the image. An edge in a signal is normally defined as the transition in the intensity or amplitude of that signal.

2.1 Principle of the edge enhancement

A typical method is Roberts edge enhancement kernel. This kernel focuses on the diagonal pixel differentials, which emphasizes corners more clearly but can blur together small horizontal or vertical features.

The kernel used in this research is shown in Fig. 4.

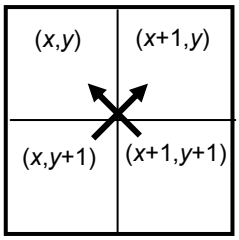


Figure 4. *Operator of Roberts*

3. Hough conversion

The Hough conversion is effective when the point is notably distributed in a line. That is, even if the straight line varies to some extent, say discontinuously or unevenly distributed, it can still be recognized.

3.1 Principle of the Hough conversion

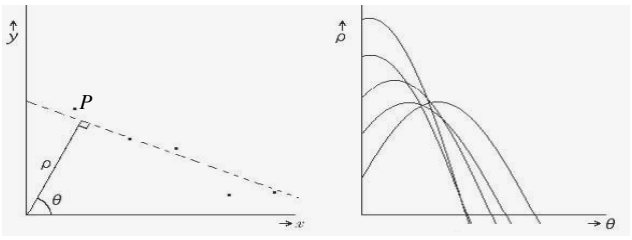
For a certain straight line, let r be the length of the perpendicular line P from the origin down to this line and θ be the angle between P and x-axis as in Fig. 5 (a). Then we can express the straight line as in Eq. (3).

$$r=x\cos\theta+y\sin\theta \quad (3)$$

Suppose a straight line passes along the point (x_0, y_0), then we can get Eq. (4).

$$r=x_0\cos\theta+y_0\sin\theta \quad (4)$$

Here Eq. (4) indicates a group of sine curves on $r-\theta$ space, (Fig. 5 (b)).and it also indicates all the points on this line which passes (x_0, y_0) in x-y space.



(a) (b)

Figure 5. *Hough conversion; (a) edge points of x-y space* (b) *locus of ρ-θ space*

Experiments and results

1. Algorithm

1.1 Grayscale conversion

The algorithm of grayscale conversion is shown in Fig. 6.

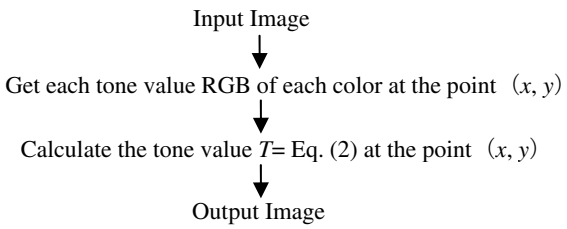


Figure 6. *Grayscale conversion algorithm*

1.2 Edge enhancement

The Roberts function returns an approximation to the Roberts edge enhancement operator for images:

$$G_{jk} = \left|F_{jk} - F_{j+1,k+1}\right| + \left|F_{j,k+1} - F_{j+1,k}\right|$$

where (j, k) are the coordinates of each pixel F_{jk} in the Image. This is equivalent to a convolution using the masks,

$$\begin{bmatrix} 0 & -1 \\ 1 & 0 \end{bmatrix} and \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}$$

where the underline indicates the current pixel F_{jk}. The last column and row are set to zero.

1.3 Hough conversion

The algorithm of the Hough conversion is shown in Fig. 7.

2. Cracks extraction experiment

An experimental result is described during which the cracks of concrete are extracted by using the abovementioned image-processing technique.

The outside of a ferroconcrete building with cracks is firstly shot by a digital camera. The part with cracks is taken out, and processed by grayscale conversion, edge enhancement and the Hough conversion. We use two kinds of input images as follows;
- cracks that occurred in a chaotic way on an outer wall (Fig. 8(a)),
- cracks in a crisscross pattern on the beam (Fig. 8(b)).

Results

The input images we use are the normally photographed pictures of cracks on real buildings. We show the result images in Fig. 9. Cracks with width less than 0.2 mm are omitted in this experiment as they are said to be free from danger. By the result of our experiments, cracks of 0.2 mm in width and those wider than 0.2 mm can all be extracted, so the extraction rate was 100%.

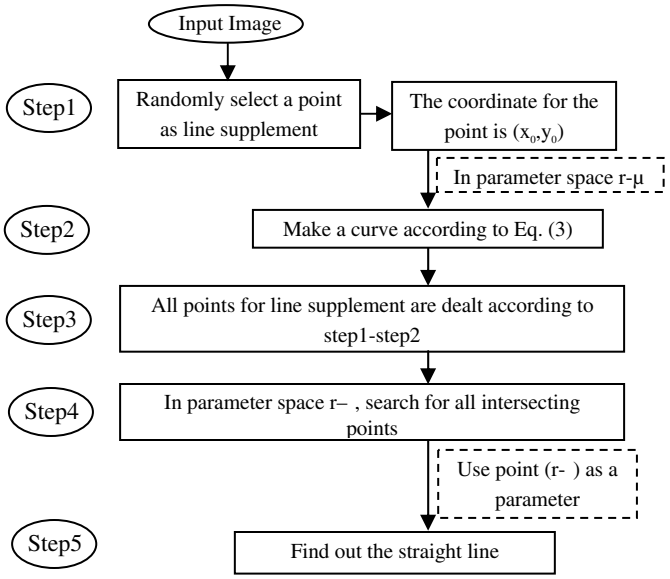
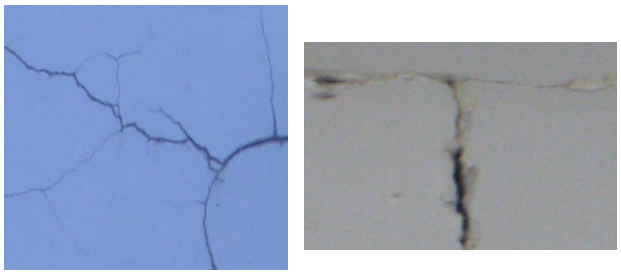
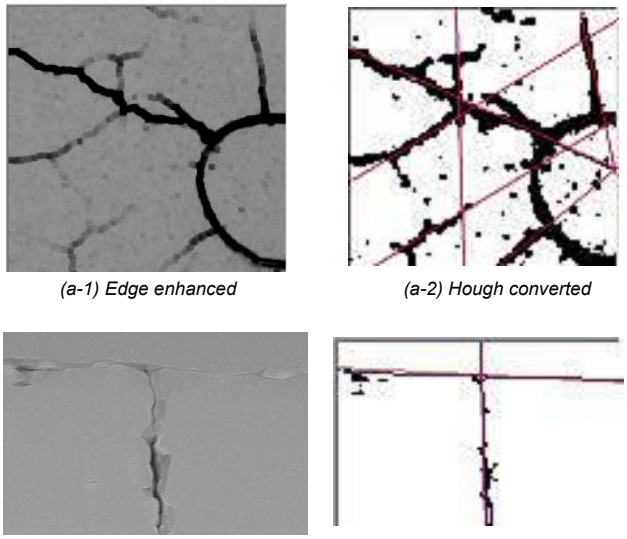


***Figure 7**. Hough conversion Algorithm*



(a) *(b)*

***Figure 8.** Input images*



(a-1) Edge enhanced *(a-2) Hough converted*

(b-1) Edge enhanced *(b-2) Hough converted*

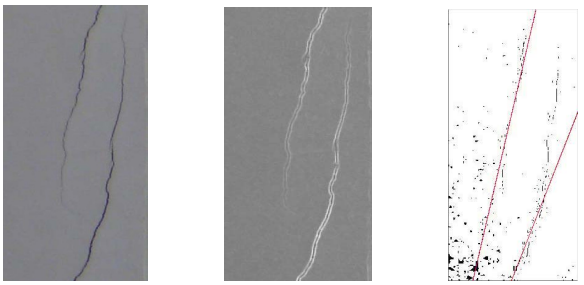
***Figure 9**. Results of edge enhancement and Hough transformation process.*

Discussion

As mentioned above, we could extract the crack patterns with a certain width in every image. For further discussion, we perform the following experiments concerning the shooting condition.

1. Illumination

We take pictures with two kinds of illumination; a fluorescent lamp and the sun light, and process them as in Fig. 10.



Input image *Edge enhancement (a)Fluorescent lamp* *Hough conversion.*

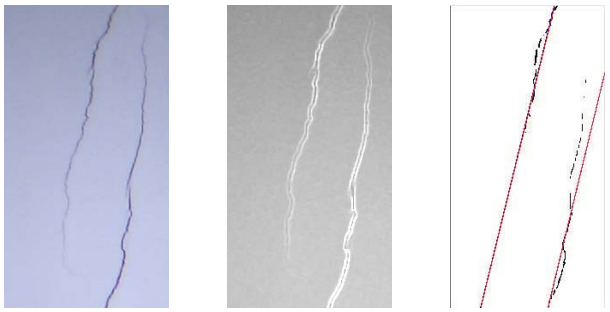


Figure 10. *Illumination*

2. Sensitivity

We try two kinds of ISO sensitivity; ISO50 and ISO400, and process them as in Fig. 11.

3. Results

It was recognized that all the cracks were extracted.

When we use two kinds of illumination, it was observed that the brightness value of the crack part was lower when we used a fluorescent lamp after the edge enhancement process.

Moreover, the photograph filmed in ISO50 has higher density value than that filmed in ISO400.

The positions of straight lines that are recognized as cracks show some difference.

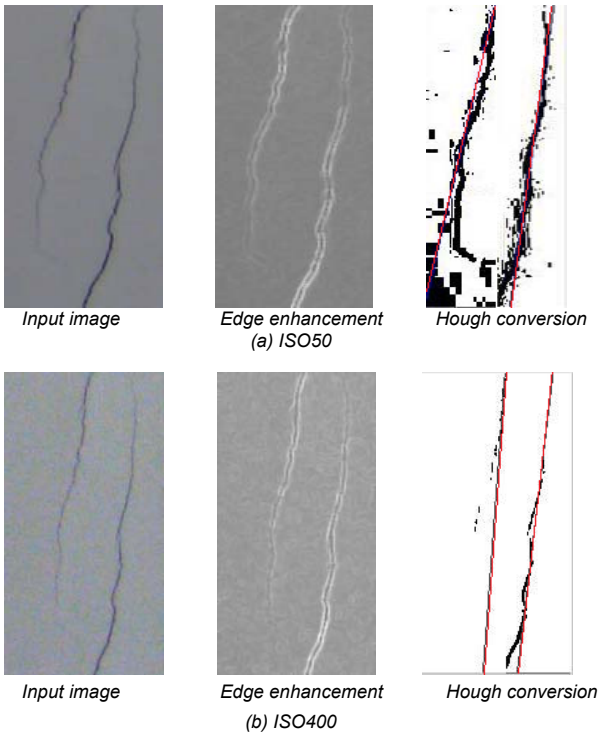


Figure 11*. Sensitivity*

Conclusion

In this study we did image processing for cracks which most commonly occur on a building surface. As for the Hough conversion, it proved to be effective in extracting the vertical, horizontal, and diagonal lines, which are the characteristics of cracks on a building with reinforced concrete makeup. We describe some observations from an experiment in the following.

(1) It became easier to extract cracks when we did edge emphasis processing as a preprocessing. Because a straight line element in an image is emphasized, a majority rule works well at the Hough conversion stage. It can be considered we can extract straight line even if the cracks are discontinued.

(2) As a photo-shooting condition, using a fluorescent lamp and ISO50 is suitable because the density value of shot image is higher than that of ISO400.

(3) We set ISO50, white balance with a fluorescent lamp, and a filmed photograph can seem to measure width of cracks automatically sequentially because we are congenial to technique suggested by this study most and examines sensitivity as a future problem.

(4) Through this study, it is noticed that by using image processing method, detailed distribution of minute cracks can be investigated, while the management of cracks is not properly applied. It will become an important task to efficiently utilize the detailed information of cracks in the future.

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Author Biography

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