Recognition of Cracks on the Concrete Surface in Digital Images

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Abstract

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

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 and Hough conversion method.

It is expected this recognition system will enable a highly precise objective judgment.

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, recorded by these measurements, are not suitable for being analyzed by computers and are estimated by experienced person, and are often left untouched without sufficient investigation.

In this research we propose cracks extraction and feature extraction method using digital image and image processing, aiming to develop more efficient way to maintain and control concrete structure.

We use digital image of the cracks of the ferroconcrete structure. Convert them to grayscale, remove noises, dirt, air bubbles, etc., and them apply the Hough conversion may extract cracks.

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, further accelerate the process mutually, and generate cracks in many cases.

The amount of the features of the cracks of ferroconcrete is shown in Table 1. The places where they 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 point that does 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

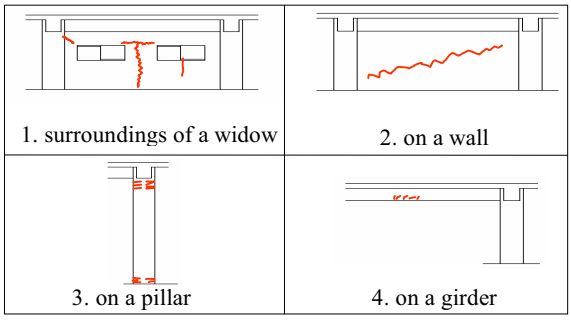
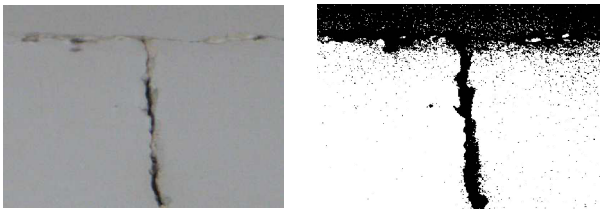


Figure 1. *The place where cracks occur*

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



(a) (b)

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

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 problem in abovementioned conventional techniques. After preprocessed as shown in Fig. 3, cracks are recognized by the Hough conversion.

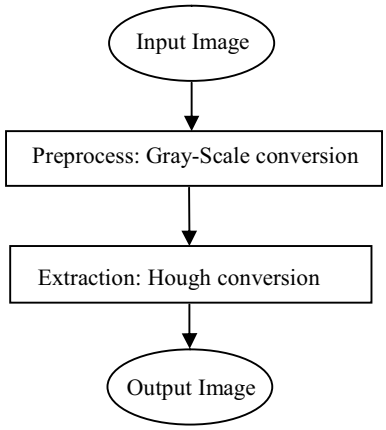


Figure 3. *Flowchart of cracks extraction with image processing technology*

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 a grayscale conversion

Let the tone values of red, green and blue of an 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. 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.

2.1 Principle of the Hough conversion

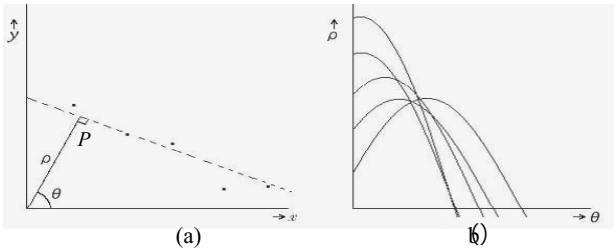
For a certain straight line, let ρ be the length of the perpendicular line P from the origin down to this line and θ be the angle between P and x-axis as in Figure 4(a). Then we can express the straight line as in Eq. (3).

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

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

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

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



(a) (b)

Figure 4. *Hough conversion; (a) edge points of x-y space (b) locus of ρ-θ pace*

Experiments and results

1. Algorithm

1.1 Grayscale conversion

The algorithm of grayscale conversion is shown in Fig. 5.

1.2 Hough conversion

The algorithm of the Hough conversion is shown in Fig. 6.

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 and the Hough conversion. We use three kinds of image on as follows;

- cracks with 45 degrees of slope the wall (Fig. 7),
- cracks that occurred in a chaotic way on an outer wall (Fig. 8),

- cracks in a crisscross pattern on the beam (Fig. 9).

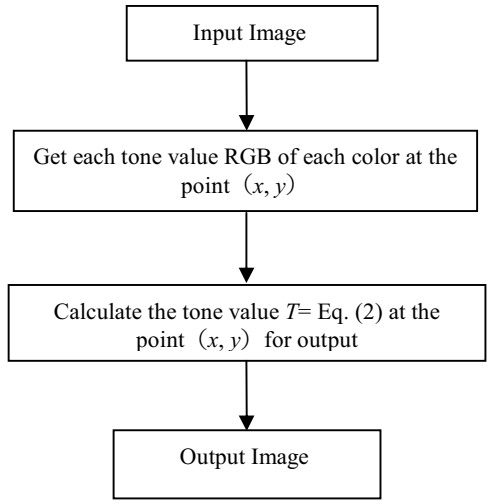


Figure 5. *Grayscale conversion algorithm*

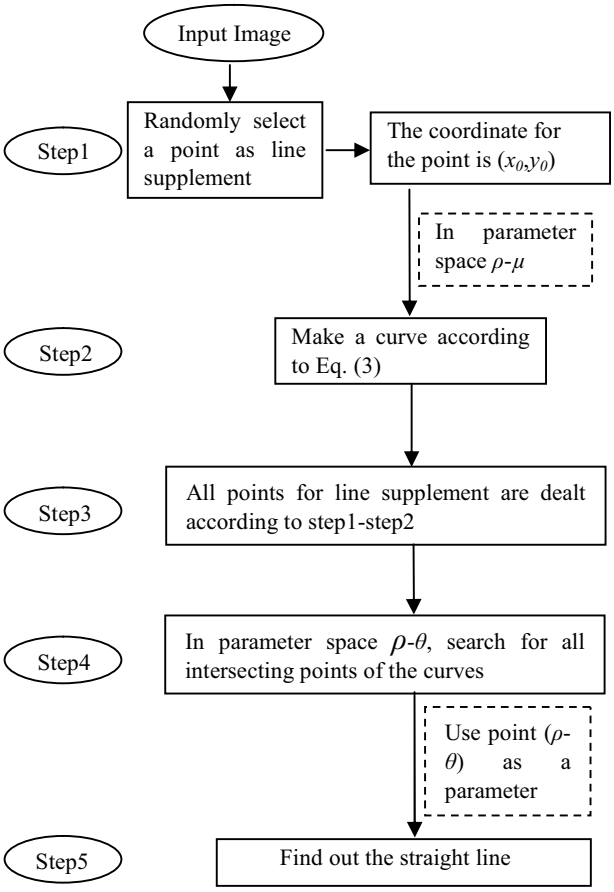


Figure 6. *Hough conversion Algorithm*

Results

The input images we use are the common pictures of cracks on real buildings and the result is shown in table 2. Cracks with width less than 0.2mm are omitted in this experiment as they are said to be free from danger. One of 3 cracks (34%) of 0.2mm in width was extracted and the other 2 were omitted. 4 of 5 cracks (80%) of 0.3mm was extracted. Cracks of 0.4mm, 0.5mm in width and those wider than 0.5mm can all be extracted with the extraction rate was 100%.

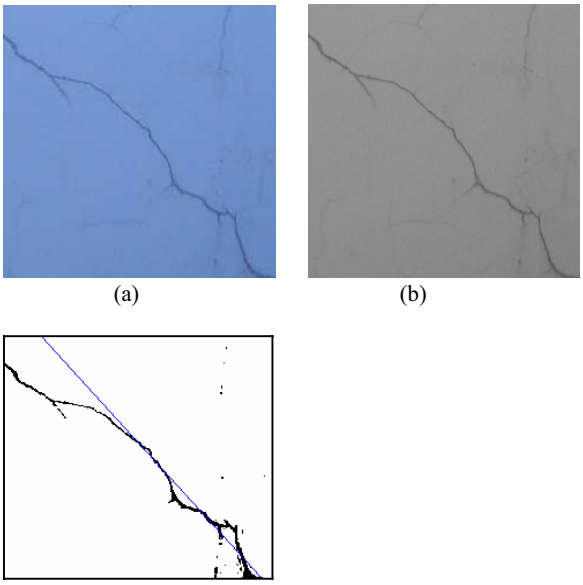


Figure 7. *Cracks with 45 degrees of slope on the wall; (a)original image (b) grayscale (c) Hough*

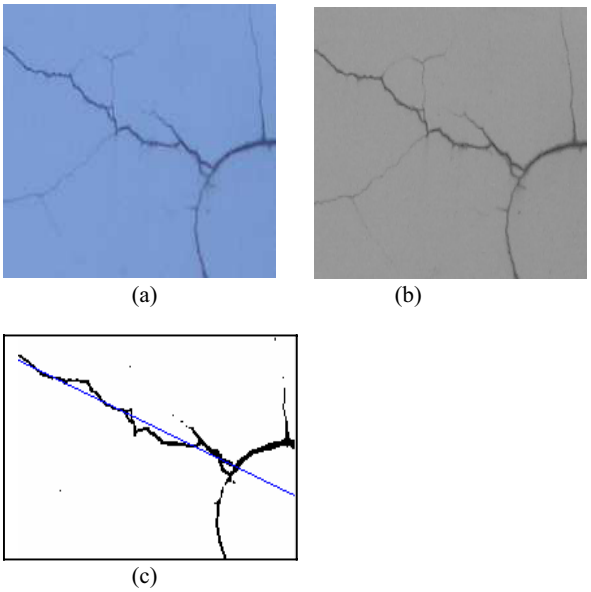
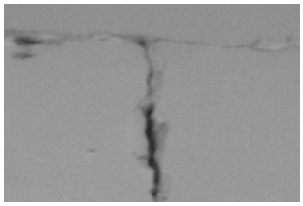
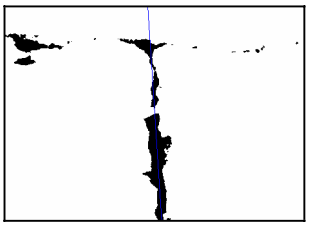


Figure 8 . *Cracks that occurred on a chaotic way in an outer wall; (a)original image (b) grayscale (c) Hough*

(a)



(b)



(c)

Figure 9 . *Cracks in a crisscross pattern in the beams; (a) original image (b) grayscale (c) Hough*

Table 2. Experimental result

	All the numbers	Extraction number	Non-extracted number	Extraction rate
0.2mm	3	1	2	34%
0.3mm	5	4	1	80%
0.4mm	2	2	0	100%
0.5mm or more	2	2	0	100%

Conclusion

In this study we reported on the method of extracting cracks Results as follows:

1. Grayscale conversion can successfully convert a full-color image into a grayscale image, which provides an excellent basis for Hough conversion.
2. Hough conversion can extract cracks despite of the shade or dirt on the surface of concrete building. Moreover, it can accurately extract all the linear features of the cracks no matter it is horizontal, vertical or slant.
3. The cracks more than 0.3mm in width can be successfully extracted. However extraction rate is still low for the thin cracks under 0.3mm in width.
4. For ferroconcrete building, it is more speedy and accurate to extract cracks by applying grayscale conversion and Hugh conversion to its digital photo than to use conventional binarization method.
5. We could only extracts the linear cracks in structures, while leaving ramous cracks on materials for future study.
6. We use a digital camera with resolution 1600*1200 pixels is used in this study. In future study, images with higher resolution will be used.
7. In this study we did not tried the automatic measurement methods of extracted cracks width. In future study, further research and development will be carried out on the auto measurement methods of extracted cracks width.
8. 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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