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Crack Detection on Concrete Surfaces Using V-shaped Features

Yoshihiro Sato
Graduate School of Engineering, Tokyo City University
Tokyo, Japan

Yue Bao
Graduate School of Engineering, Tokyo City University
Tokyo, Japan

Yutaro Koya
Graduate School of Engineering, Tokyo City University
Tokyo, Japan

Abstract—For the maintenance of concrete structures, cracks are an important indicator to determine the repair priorities. Until a few years ago, it was visually inspected by workers. Recently, the crack detection methods by using image analysis have been proposed. But, the methods are difficult to detect the cracks on the concrete surface with unevenness and stains. In this paper, we propose a crack detection method using V-shaped Features and propose a V-shaped detector for detecting V-shaped Features. The V-shaped detector is possible to detect cracks with a high degree of accuracy. It is possible to perform noise processing using the shape and size of the crack detected by V-shaped Features. Several experiments were carried out using this proposal method. As the results of the experiments, it was confirmed that cracks of 0.2 mm or less can be detected.

Keywords-component; crack detection; image processing; remote detection; breakage inspection; V-shaped features.

I. Introduction

Japan passes for 50 years from a high economic growth period, and concrete structures more than the durable period are increasing now. It is impossible to repair all of these buildings at the same time. Therefore, prioritization of repairing is performed, and the repair is carried out in order from the building which needs repair immediately. The prioritization technology is needed for the maintenance management of the concrete structure. Cracks are usually used as indexes to evaluate the health of the concrete structure. When cracks were discovered in wall of a concrete structure, it can be judged that dilapidation is happening in the building. It is described in the guideline of Japan Concrete Institute that "When cracks more than 0.2 millimeters are discovered, the building loses soundness" [1].

Up to now, various crack detection methods were studied. At first, the standard crack detection method is visual inspection by the workers. As for this method, a worker checks a concrete wall near by him. So, cracks even on an unclean concrete surface can be confirmed. Furthermore, the visual inspection can inspect width and the inside situation of the crack in detail. As shown in figure 1, a crack width is measured with a crack-scale ruler. However, the risks and personnel expenses of workers are very high. Furthermore, depending on the skills of the workers, the inspection results will differ. Therefore, it is not a highly reliable inspection.

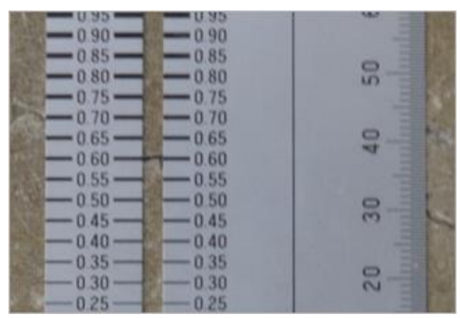

Fig1. A state measuring the crack width with a crack-scale ruler

To avoid that the detection accuracy depends on the physical conditions and abilities of workers, the methods to detect cracks using image processing had been proposed. And the time for inspecting walls with a large area can be saved. Two image analysis methods are known mainly. The first is the detection method using wavelet transform. [2-6] This method uses frequency analysis. For cracks occurring on the concrete surface, the influence of the brightness information on the photography image can be reduced by applying frequency analysis. Thus, the cracks can be detected from the concrete surface with noises of brightness by using this method. The second method is a probabilistic relaxation detection method using line emphasis. [9-11] The probabilistic relaxation method is a method extracting the shapes and the positions of cracks roughly by repeating local adjustment processing. This method performs two processes before performing the probabilistic relaxation method. "Subtraction preprocessing using a median filter" removes the light-dark change by inhomogeneity or the shadow of the light. In addition, "Multi-scale line emphasis preprocessing" reduces influence such as the wounds of the wall surface. Furthermore, the rough cracks detected by the probabilistic relaxation method extract details by performing thresholding step by step.

In the method using wavelet transform transformation, noise is removed by using line tracking processing. Therefore, noise can be eliminated by adjusting the value of the extracted area in the contour line tracking process. However, if the contour of the crack cannot be tracked, the cracks may be deleted. [7,8] Figure 2 is a result detected using wavelet transform. [7] As shown in figure 2, it is detected as disconnected cracks, and a place which is not cracked is detected. Therefore, it is not possible to remove noise using the length and shape of cracks.

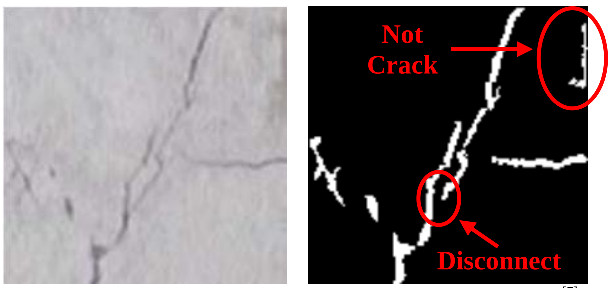

Fig2. A result of the detection method using wavelet transforms [7]

The probabilistic relaxation detection method using line emphasis emphasizes linear features. If irregularity noise on the concrete surface is linear, it is emphasized as a crack. A result detected by the probabilistic relaxation method using line emphasis is shown in figure 3. [9] As shown in figure 3, unevennesses of the concrete surface are emphasized. If a strict threshold value is set so as not to detect irregularity noise on the concrete surface, thin cracks cannot be detected. Therefore, it can be said that the accuracy of the conventional methods for the crack extraction by image analysis is not high. These are due to the following reasons. Dirt on the concrete surface reduces the accuracy of crack detection as noise.

To improve the accuracy of image analysis, we propose a V-shaped detector to detect cracks using V-shaped Features. The V-shaped detector can detect cracks with V-shaped Features in units of one pixel. And, noise processing is performed using the shape of the crack.

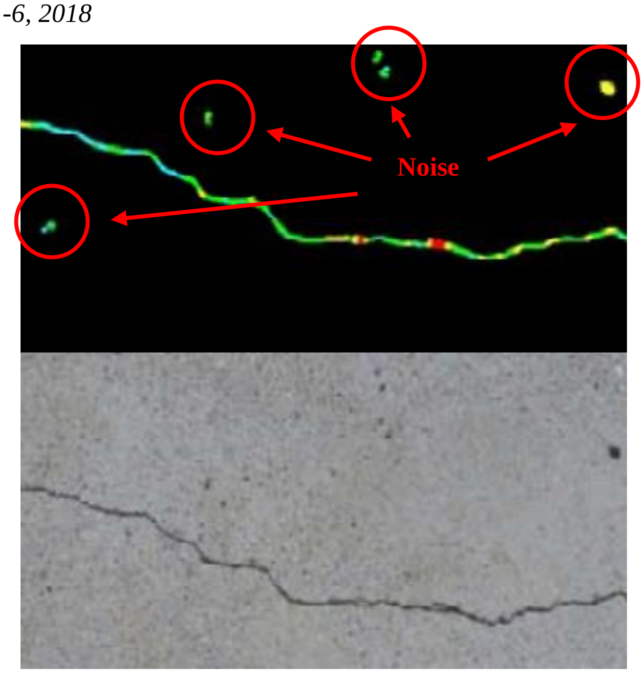

Fig3. A result of the detection method by the probabilistic relaxation method using line emphasis [9]

II. Crack Detection Method Using V-Shaped Features

A process flow of the V-shaped detector is shown in figure 4.

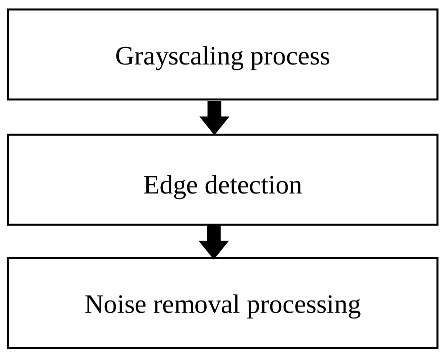

Fig4. A process flow of the V-shaped detector

A. Overview of the V-shaped detector

The V-shaped detector assumes input of grayscale images. If a color image is inputted, a gray scale conversion is needed at first. At first, edge detection is performed to the image of a concrete surface, so all the cracks and the dirt on the concrete surface are detected. Noise processing is necessary to extract cracks from the detection results including edge and noise. Noise processing is performed using "shape" of the cracks. The detection result of the crack is a result that deleted the noises from the edge detection result.

B. Edge detection

The V-shaped detector is an edge detection method specialized for the crack detection, and it does not need a filter.

In other words, it can be performed without depending on filter size. Therefore, edges of various widths can be detected by one-time processing.

The processing methods of the V-shaped detector are as follows. First, image scanning is performed in the horizontal direction of one row. And, the difference value of the neighboring pixel value is calculated in a sequence. If the difference value is larger than the preset parameter, we judge it to be a feature of the cracks. The crack is a long thin hole (groove). Changes in pixel values appear at both ends of the hole. Therefore, it is possible to find both ends of the groove by performing same processing from the opposite direction. Thus, it can be confirmed that there is a hole in between, so it is possible to detect cracks. We call this V-shaped features. The preset parameter can beforehand be set freely. In addition, this detection scans pixel by pixel, so crack detection can be done in one-pixel unit. In other words, the minimum detectable crack width depends on the image resolution of the input image. If there are three or more places where pixel values change, it cannot be judged whether they are paired. Furthermore, if pairs are not determined, cracks cannot be detected. At this time, the nearest neighbors are the pair. If the number of changes is odd, the farthest point remains. Also, points once paired will not be used again. And, if there is no pair, it will be detected as one dot edge.

The Processing result example is shown in figure 5. As shown in figure 5, the edges with various widths and the edges on one row having plural change points can be detected correctly.

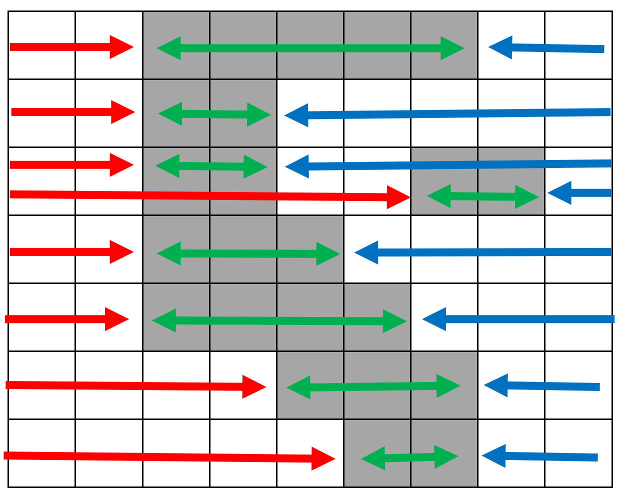

Fig5. Processing result example

C. *Noise processing*

The noise processing pays attention to whether cracks are "linearly similar". Thus, edges that are "linearly similar" from the detected edges are retrieved. In this study, a condition to be a straight line is defined as follows.

Line Definition I:

“When Cracks were enclosed with a rectangle, the density is equal to an inverse of short side.”

Line Definition II:

“The angle between the end point and midpoint of crack, it is an obtuse angle.”

In line definition I, the density calculates it from a rectangle and the ratio of the number of the constitution pixels of the edge. Figure 6 is the example which surrounded an edge with a rectangle. the density relationship between the straight line and the rectangle is shown in Equation 1. Equation 1 can be used for detecting "linearly similar" edges. In addition, even a complicated crack can be detected by lightly loosening the threshold value of density.

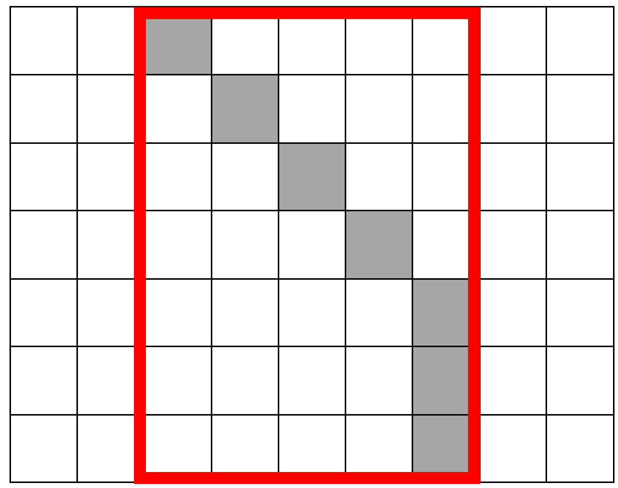

Fig6. The example which surrounded a straight line with a rectangle

Number of dots

Line – 7 pixels
Rectangle – 35 pixels
Short Line of Rectangle – 5 pixels

Line / Rectangle = 7 / 35
*= **1 / 5 <= 1 / Short Line of Rectangle*** --- *(1)*

In line definition II, as a feature of the cracks of concrete, the cracks are often straight line. Tortuous crack is few. Therefore, first, "end point of edge" and "middle point of edge" are searched from the detected edge. By determining the angle, it is possible to determine the angle between the midpoint and the end point of the detected crack. If an acute angle, tortuous cracks treated as noise. If an obtuse angle, linear cracks are extracted as cracks.

The detected edges that satisfy both line definitions are extracted as cracks.

III. EXPERIMENT

A. Overview of experiment

We photographed the cracks occurring in a concrete structure and a concrete crack specimen. The concrete structure is a bridge pier. The concrete crack specimen was made by the concrete laboratory in Tokyo City University. The V-shaped detector was created using C ++ and Open CV Library.

Fig7. Concrete crack specimen

Fig8. A bridge pier (Concrete structure)

B. Shooting device and shooting conditions

The model name of the camera used for the experiment was NIKON D7200. A resolution of captured image is 6016 * 4000 pixels. The shooting distance is 3 to 7 meters.

Fig9. NIKON D7200

C. Shooting procedure

As shown in figure 10, a tape measure is put on the ground to measure the distance between the camera and the concrete crack specimen. Figure 10 shows the scene of the experiment using the concrete crack specimen. Likewise, cracks in concrete structures are also taken with cameras.

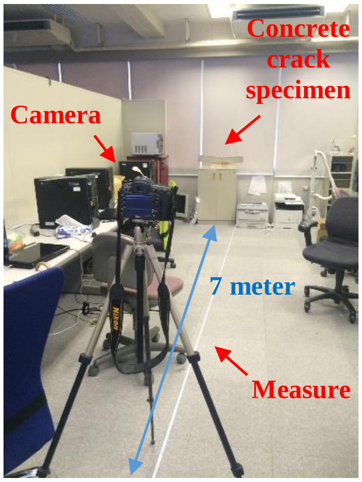

Fig10. The shooting scene of the concrete crack specimen

D. Experimental results

In the experiments, at first, it is confirmed whether simple cracks can be detected. In the experiment I to detect cracks from a distance of 3 meters, the cracks of 1 millimeter were detected out of the concrete crack specimen. Figure 11 shows the input image and figure 12 shows the photographed image from the distance of 3 meters and the detection result.

Fig11. a photographed image from the distance of 3 meters

Fig12. a detection result image from the distance of 3 meters

By the detection result, we can confirm that the algorithm of the V-shaped detector can detect cracks in the concrete.

Next, an experiment II was conducted to confirm whether the crack can be detected from a long distance. Furthermore, experiment II was conducted to confirm whether the noise processing is effective or not for a noisy image by the V-shaped detector. In the experiment II to detect cracks from a distance of 7 meters, the cracks of 0.2millimeter were detected out of the concrete crack specimen. Figure 13 and figure 14 shows the input image and the detection results.

Fig13. a photographed image from the distance of 7 meters

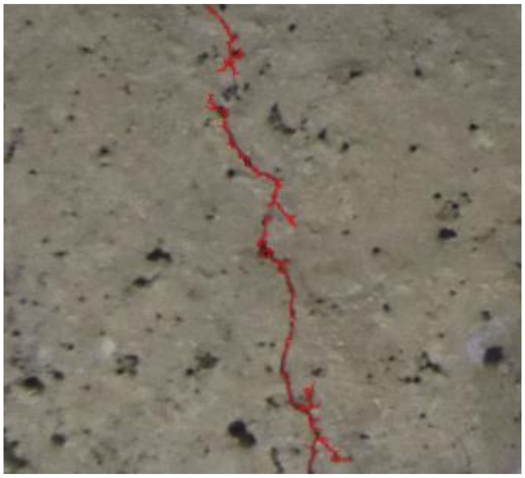

Fig14. a detection result image from the distance of 7 meters

By experimental II results, it can be confirmed that cracks of 0.2 millimeters can be correctly detected. And, it was confirmed that noise around the cracks was not detected.

Next, experiment III was conducted to confirm whether cracks can be detected from actual buildings by the V-shaped detector. The image used for the experiment is a highway bridge that is actually used from a distance of 5 meters. An experiment III to detect cracks of 0.1 to 1 millimeters from a distance of 5 meters was done. Figures 15 to 18 show the detection results.

Fig15. a photographed image I from the distance of 5 meters

Fig16. a detection result image I from the distance of 5 meters

Fig17. a photographed image II from the distance of 5 meters

Fig18. a detection result image II from the distance of 5 meters

By experimental I to III results, it was confirmed that all cracks could be accurately detected. And, it was confirmed that noise around the cracks was not detected.

IV. Consideration

The detection result of the V-shaped detector was compared to the detection result of the conventional method. Since the stochastic relaxation method using line emphasis is excellent in the conventional methods, it was chosen as the conventional method for comparison. [11] Figure 19.a is the input image, figure 19.b is a result detected by the conventional method [11], and figure 19.c is a detection result of the V-shaped detector. In figure 19.b, the detected cracks are outputted as black lines on a white background. In figure 19.c, the detected cracks are outputted as red line on an input image. As for the conventional method, unevenness on the surface of concrete was detected as crack. However, the V-shaped detector is can confirmed that the unevenness on the surface of concrete is not detected as a crack. The V-shaped detector can detect cracks accurately than the conventional method. The crack detection method using image processing is depending on the performance of the digital camera. In the experiment of this paper, we used a camera Nikon D 7200 with 2416 million pixels. The cracks of 0.2 millimeter in width were detected from a distance of 7 meters.

a.

b.

c.

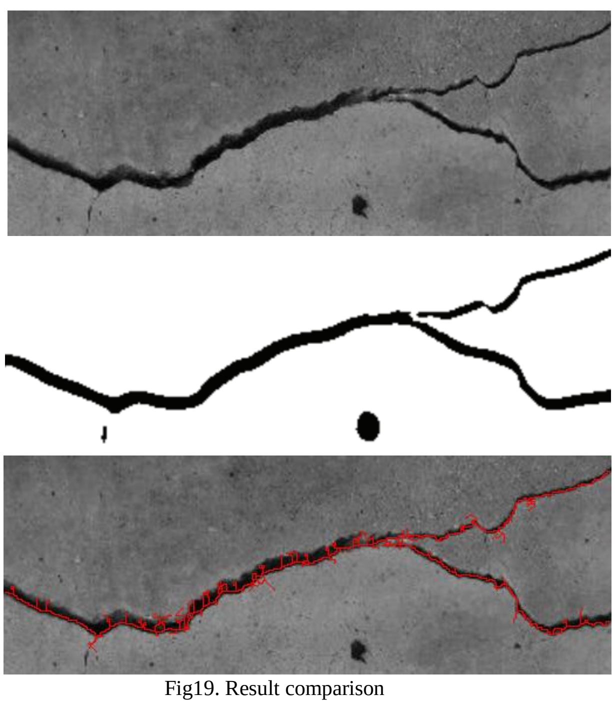

Fig19. Result comparison

V. Conclusion

Many crack detection methods were proposed. However, even with an excellent method among them, there was a problem that unevenness on the concrete surface were detected as cracks. In this paper, we propose a crack detection method using V-shaped Features. A concrete structure and a concrete crack specimen were used for the crack detection experiments. By the experiments, it was confirmed that the proposal method can detect cracks more accurately and from more long distance than the conventional method.

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AUTHORS PROFILE

Yoshihiro Sato received the B. E degree in computer science engineering from Tokyo City University, Tokyo Japan, in 2016. He is currently a graduate student at Tokyo City University. His research interest includes face recognition, defect detection and image processing.

Yue Bao received Ph.D. degrees from Kanazawa University, Japan, in 1996. He has been a professor at Tokyo City University since 2004. His research interest includes 3D display, image processing and mobile robot.

Yutaro Koya received the M. E degree in graduate school of engineering from Tokyo City University, Tokyo Japan, in 2010. He received Ph.D degree in graduate school of engineering from Tokyo City University, Tokyo Japan, in 2013. In the same year, a special researcher at Tokyo City University. His research interest includes defect detection of industrial products and 3D display.