

A Crack Segmentation Approach Using the Combination of Gray Thresholds and Fractal Feature

Yang Song^{1,2, a}, Shao Longtan^{1, b}, Guo Xiaoxia^{1, c}, Liu Xiao^{1, d}, Zhao Bo Ya^{1, e}

¹State Key Laboratory of Structural Analysis for Industrial Equipment, Department of Engineering Mechanics, Dalian University of Technology, Dalian 116024, China

²Educational Technology & Computing Center, Dalian Ocean University, Dalian 116023, China

^aocean_epoch@163.com, ^bShaolt@dlut.edu.cn, ^chanyuer@dlut.edu.cn,

^dddpluixiao@yahoo.com.cn, ^ezhaoboya@gmail.com

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Abstract. A segmentation method of combining gray-level threshold and fractal feature for crack images is proposed, and the fractal law for the perimeter and area of the target is introduced as the constraint condition for the image segmentation of crack. At first, Otsu algorithm is used for the initial segmentation of the crack image, and then the edge of crack is optimized in accordance with fractal law. At last, boundary of crack is determined, and the final result of the image segmentation is obtained. This method makes full use of the fractal geometry law and image information, to effectively solve the problems such as crack contour detection, regional connection and cross crack identification. Several typical examples are analyzed, and the results show that this method has a good segmentation effect on crack images, and it can also be used to identify the other images which have fractal feature.

1. Introduction

Image segmentation is the main objective on image processing and computer vision. It refers to the technique and process which pick up the interesting targets in the regions of the divided images with various features. It is the key step from image processing to image analysis. Research on image segmentation has been for decades, with the major methods: threshold methods [1-6], partial differential equation method [7, 8], mathematical morphology method [9, 10], wavelet transform method [11-13] and neural network method [14-15]. All the methods are based on images with good quality and clear objective which can be completely segmented. However, they fail to fully take into account the complex situation of the images. When faced with an image with complex background, they fail to satisfy the actual needs of engineering applications.

Crack identification for concrete members has its own characteristics and requirements: first of all, the cracks are picked up from images to obtain the clear crack texture. And more importantly, the real geometric scale such as length and width of the real crack is given with relatively accurate estimation, in order to make a reasonable assessment for the structure safety. Therefore, it is very important to determine the form of cracks. In addition, the cracks in concrete members lack regular geometric characteristics. The irregular geometry and different length make the conventional detection methods difficult to form effective implementation.

On the quality of images, there are many holes and impurities on the surface of concrete members. Besides, peeling and spalling also often appear on the edge of crack. Especially, images will be polluted by some environmental factors like flooding, light, aging and dusk of the practical

engineering structure. Since the gray scale between the disturbances and cracks is similar, segmentation method standardized by gray threshold will not achieve the desired effect. Therefore, it is difficult to detect the image identification of the object crack and edge detection for the concrete in work.

In image recognition, fractal geometry is an important aspect of a relatively independence, particularly owning its special advantages in the image identification on the irregular texture and rough surface. Today's studies have shown that: the object crack (ceramics, rocks, pavement, concrete, etc.) all follow the fractal law[16]. Therefore, some researchers have adopted the fractal theory for crack identification: Handong Huang and others[17] apply Barnsley's iterated function system (ISF) theory to rock crack analysis, using fractal features and affine transformation to deal with image processing ; Hua Wang and others [18] adopt fractal Brownian motion model to analyze the texture characteristics of road surface; Xiangjun Yu and others [19] utilize fractional Brownian random field model to segment the crack image on the road.

In this paper, a method combined with gray threshold segmentation and crack fractal analysis is adopted on image segmentation and edge detection for cracks of concrete members. Besides, some key issues such as the gap filtering and regional connectivity are also discussed.

2. Image Identification Based on Fractal Law

Currently, as for the image-identified method based on fractal theory, dimension calculation of box, area and volume becomes a mainstream except for affine transformation. The analysis and calculation are related to image pixel feature. But we know that the fractal law of images has its own features, described by its own characteristics.

Here we proceed from the other side: According to fractal geometry theory, for irregular shapes, the perimeter and area meets the following relationship:

$P^{1/D} \propto A^{1/2}$, in the formula, D is the fractal dimension; P is the perimeter of the object to be identified; A represents the area. Take the logarithm from the two side of the above formula and obtain:

$$\log P = 0.5D \log A + C \quad (1)$$

Where, C is a constant; C and D can be determined by curve fitting. Based on the above formula, we define the following functions:

$$F(P, A) = \log P - 0.5D \log A - C \quad (2)$$

If the identified object satisfies fractal law, the object image will satisfy as follows, in the certain range of error:

$$F(P, A) \approx 0 \quad (3)$$

This is the requirements of the image fractal nature itself, not related to the image pixel features. Fractal law will no longer be described by gray distribution. Therefore, compared with the popular fractal analysis methods which are related to gray scale, it does better on anti-interference. However, in practical image, the object image obtained from the image pixel gray analysis will deviate from this condition to a certain extent by the mixture of the non-target information, because there exists various interference. Therefore, in order to exclude non-target information of images and get access to the better target ones, formula (3) can be mandated to satisfy.

3. Two-Step Solution of considering the Crack Fractal Law

According to the preceding discussion, the optimization problem of formula (3), can be solved through the following ways, and the algorithm steps are as follows:

(1) Threshold image segmentation method (such as the Otsu threshold method) is adopted to do coarse-grained segmentation for original image. Then several closed images in high gray-value region are obtained (usually, omission can be avoided since the gray scale is high in crack region). The images will undergo binarization processing (not mandatory). Here, the process will not be described in detail;

(2) The obtained high gray-value region is analyzed and thief point is excluded. The regions which may contain cracks will be saved.

(3) Regions containing cracks are calculated to optimize and determine the crack boundary, to meet the requirements of formula (3). This process mainly consists of the following two steps:

(a) Search for Middle Line

To determine the boundary of crack, the proper middle line should be obtained as a reference. We adopt the following ways to obtain crack middle line:

1) Search in the crack region line by line, calculate the midpoint of each segment and, calculate the slope based on the middle point of the three lines from the obtained current line.

2) Determine the next direction according to the slope: horizontal or vertical, and then determine the midline point by the direction.

3) After the completion of midline point calculation, carry out the cycle starting from the point, and the middle line will be obtained after the cycle.

(b) Expansion and Contraction of Boundary

4. Experiment Result and Analysis

In order to verify the proposed method, we dealt with three typical examples as to some key problems in crack image identification: spalling and peeling, large-scale pollution, and bifurcation situation

$$F(P, A) = \log(P) - 0.5463 \cdot \log(A) - 1.0055 \quad (4)$$

Fractal law of cracks in concrete structures is obtained by fitting calculation of the 30 cracks with different lengths and widths in the images of 10 concrete structure beam cracks. The area and perimeter relationship is as follows:

The fitting degree is as follows: $R^2 = 0.9567$. It shows that the concrete surface crack curve follows fractal law, with a high fitting accuracy.

4.1 Experiment 1 Spalling of Crack Region

Surroundings of concrete cracks are usually accompanied by a number of spalling and peeling. Also, crack boundary may be changed when cracks pass through surface bubbles. As shown in Figure 1 (a), the gray scale of the spalling regions is relatively high, affecting crack identification. Figure 1 (b) is the segmented image by Otsu algorithm. Figure 1 (c) is the image of crack middle line. Figure 1 (d) is the effect of crack identification by the method proposed in this paper. Judging from the above, the interference region of cracks is better excluded. Therefore, the ideal image of cracks is obtained.

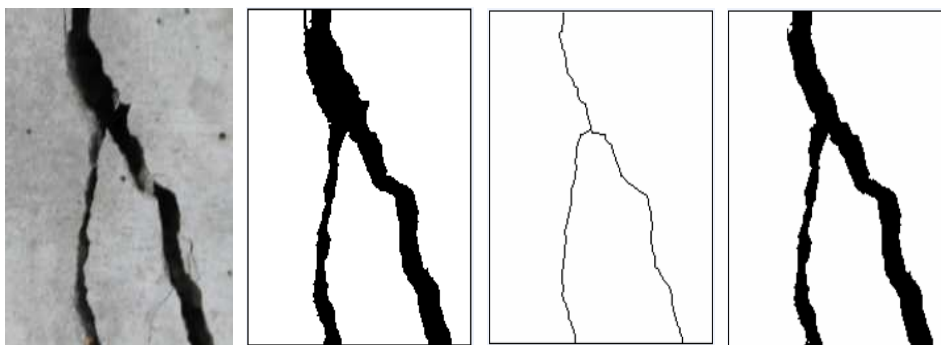


(a)original image (b)image after otsu segmentation($F(P,A)=0.0860$)
 (c)middleline image (d)image after fractal optimization($F(P,A)=0.0447$)

Fig.1 Fall off the edge of the crack image

4.2 Experiment 3 Identification of Cross Cracks

There are many arborescent cross cracks in concrete cracks. Figure 2(a) shows the cross crack image of concrete members. The crack width is large because of the influence from the above surface holes. We adopt the method in this paper to process the image. Figure 2(b) is the crack image obtained by Otsu algorithm. Figure 2(c) is the crack middle line image cracks extracted. Figure 2(d) is the final result given by the method in this paper. Comparing the above crack identification figures, we can easily perceive that the method in this paper can solve the identification problem of cross cracks. Besides, it can amend the crack edges, to obtain the more realistic crack shape.



(a)original image (b)crack image after otsu segmentation($F(P,A)=0.0199$)
 (c)middle line image (d)image based on fractal optimization($F(P,A)=0.0096$)

Fig.2 The image of cross cracks

Seen from the above examples, the method in this paper is more effective than the simple gray method. It can effectively solve the crack problems of regional connectivity, edge detection, and thief point excluded.

5. Conclusion

This paper proposes the image segmentation method combining gray scale and fractal features for the identification problem of concrete cracks. It synthetically utilizes the gray information of images and their own features, with a stronger noise-resistance and applicability. The results show that this method can provide an effective way for the regional connection, gap filtering, edge detection and image restoration of the concrete cracks. Furthermore, it can also be promoted for the application of other image identification with fractal features.

References

- [1] Sahoo P K.A survey of threshold techniques. Computer Vision Graphic,Image Process,1988,41(2): 233~260.
- [2] Otsu N.A threshold selection method from gray_level histogram.IEEE Trans. On SMC.1979,9:62~66.
- [3] Yan xueqiang,Ye Xiuqing,Liu Jilin,et,al.Maximum entropy image thresholding algorithm based on the histogram defined on quantization image. PR & AI.1998,11(3):352~358.
- [4] Xue Jinghao,Zhang Yujin,Lin Xinggang.Image segmentation algorithms based on cross entropy and fuzzy divergence.Acta Electronica Sinica.1999,27(10):131~134.
- [5] Brink A D. Tresholding of digital images using two dimensional entropies[J].Pattern Recognition, 1992,25(8):803~808.
- [6] Mohamed N Ahmed, Sameh M Yamany, Nevin Mo-hamed et al. A modified fuzzy C-means algorithm for bias field estimation and segmentation of MRI data. IEEE Trans.Med.Imag,2002,21(3):193~198.
- [7] Kooepfler G,Lopez C,Morel J M. A multiscale algorithm for image segmentation by variational method[J].SIAM-Journal on Numerical Analysis,1994,31(1):282~299.
- [8] Liu Guocai,Wang Yaonan, Duan XuanChu.Knowledge based hierarchical mumford-shah model for vector-valued image segmentation.2009,35(4):356~363.
- [9] Deng Shiwei,Yuan Baozong.Range image segmentation based on mathematical morphology[J].Acta Electronica Sinica,1995,23(4):6~9.
- [10] Liu zhimin,Yang jie,Shi pengfei.Image segmentation algorithm based on mathematical morphology[J].Computer engineering & science.1998,20(4):21~27.
- [11] Xu Chuanxiang,Shi Qingyun, Cheng Minde. Zero-Symmetrical and Zero-Antisymmetrical Dyadic Wavelet and Its Application to Edge Detection. China journal of image and graphics. 1996,1(1),4~11.
- [12] Cheng Wufan. Wavelet analysis and application in digital image processing. Beijing:Science press,2002,
- [13] Cesmeli E. Texture segmentation using gaussian m markov random fields and neural oscillator networks[J]. IEEE Transactions on neural networks,2001,12(2):2994~404.
- [14] Dekruger D, Hunt B R. Image processing and neural networks for recognition of cartographic area features[J].Pat tern Recognition,1994,27(4):461~483.
- [15] Rout S , Srivastava S P,M ajumdar J. Multimodal Image Segmentation Using a Modified Hopfield Neural Network[J]. Pattern Recognition,1998,31(6):743~750.
- [16] Xiong Zhaoxian.The fractal research on ceramics material[].Beijing:Science Press,2000,2~7.
- [17] Huang Handong,Wei Xiucheng,Ye lianchi,et,al. Application of fractal edge detection in fracture prediction[J].Oil Geophysical Processing.2002,37(1):65~69(in Chinese)
- [18] Wang Hua,Zhu Ning,Wang Qi.Fractal features analysis and classification for texture of pavement surfaces[J].Journal of Harbin Institute of Technology.2006,37(6):816~818.
- [19] Yu Xiangjun,Ma Ruoding,Liu Yan,et al.Study of fractal theory on image segmentation of pavement surface crack[J].2008,24(2-3):302~304.

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