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A Binarization Method for Crack Detection in a Road Surface Image with the Fractal Dimension

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Abstract

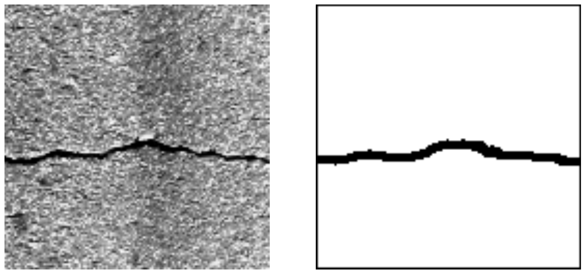
A new binarization method for crack detection in road surface image is proposed. A road surface image is consist of high frequency textures due to it's rough surface and some cracks which can have wide variation of it's form, depth, width and direction. So it is difficult to find threshold value to discriminate a background and a crack region by conventional methods based on gray level histgram. As a result of our new technique, we could get a fine quality binarized image. In the algorithm for deciding threshold value, fractal dimension is used to evaluate the fineness of binarized image locally and globally. We describe about the algorithm,test images and experimental results and compare with other binarization method.

1 Introduction

Binarization of gray level image is a significant step in region extraction and there exist a number of binarization methods. Trier[1] evaluated 15 binarization methods as promising by the procedure called goal-directed evaluation, and showed that Niblack's method[2] has the best performance as a local adaptive method and Otsu[3] method is best in global methods. In these 15 methods, threshold value is selected based on the local or global statistical information of the gray level such as gray level histgram. We propose a new binarization method for crack detection from road surface image. Binarization using only gray level information is not effective method in those images. The reason why the crack images are difficult to binarize is not only noisy background but also variation of cracks. Our approach easily improved for other kind of subjective images, so it can be a preprocessing step in general image segmentation problem. In this paper, we propose an algorithm using fractal dimension for evaluating binarized image to find a threshold value. Then, the experimental results and conclusion are shown.

2 Road Surface Image

Data set of road surface image generated by Komatsu engineering is the subjective of our proposed method. They were obtained by laser imaging system, which is measuring the scattered light from road surface. The image data has 256 gray levels and the 128 x 128 pixels. This imaging system has a merit of being free from lighting condition and darkness of region is proportional with depth of crack. At the same time, it suffer from the disadvantage of that if the depth of crack is shallow, contrast of the image become low. So the algorithm should be robust to the contrast perturbation. The results are evaluated by comparing with desired output obtained by determination of the expert. Example of test images and desired outputs are shown at Fig.1.



(a) Test image (b) Desired output

Figure 1: Example of Data set.

3 The Binarization algorithm

3.1 associated technique

Fractal dimension was proposed as a method of texture analysis named "Blanket method" by SHUMEL[4] in 1984. Codomain of the dimension is from 2 to 3 and is obtained from expression1,2,3 and 4.

$$U_\epsilon = \max\{U_{\epsilon-1}(i,j)+1, \max_{|(m,n)-(i,j)|\le 1} U_{\epsilon-1}(m,n)\} \quad (1)$$

$$b_\epsilon = \min\{b_{\epsilon-1}(i,j)-1, \min_{|(m,n)-(i,j)|\le 1} b_{\epsilon-1}(m,n)\} \quad (2)$$

$$A(\epsilon) = \frac{\sum_{i,j}(U_\epsilon(i,j) - b_\epsilon(i,j))}{2\epsilon} \quad (3)$$

$$A(\epsilon) = F\epsilon^{2-D} \quad (4)$$

ϵ is the number of blanket. Dimension is calculated for using globally and also used as a scan method with window locally. Novianto[5] proposed optimal codomain of the Fractal dimension and locally adaptive it to image.

3.2 proposed algorithm

This technique is obtained from 5 step procedure at (step 1-5)

- ***Step1***: Binarizing the input image $\boldsymbol{I(x)}$ with every threshold values from $\mathbf{0}$ to $\mathbf{255}$, we can obtained the 256 binarizedimages $\boldsymbol{I_{b_i}(x)}$ $\boldsymbol{(i = 0, 1, ..., 255)}$ respectively.

- ***Step2***: 256 $\boldsymbol{LFD_i(x)}$ images of $\boldsymbol{I_{b_i}(x)}$ by Blanket method with the 3x3 local windows are obtained.

- ***Step3***: The $\boldsymbol{FD(i)}$ values can be calculated on $\boldsymbol{LFD_i(x)}$ images by the Blanket method.

- ***Step4***: We treat the $\boldsymbol{FD(i)}$ to be a function respect to $\boldsymbol{i}$ and the fisrt local maximal value of $\boldsymbol{FD(i)}$ is chosen as the threshold value $\boldsymbol{\theta}$.

- ***Step5***: Final binarization Image $\boldsymbol{B(x)}$ can be obtained using the threshold value $\boldsymbol{\theta}$.

$\boldsymbol{FD(i)}$ can be a mesurment of the density of conected components in image. In other words, a peak of $\boldsymbol{FD(i)}$ corresponds to a local maxima of the number of connected components which are close to each other in $\boldsymbol{I_{b_i}(x)}$. Since a crack is composed of darker components in the input image, it can be appear as the first ,that is, the darkest local maxima of $\boldsymbol{FD(i)}$. An example of an input image, $\boldsymbol{LFD_i(x)}$ and binarized images are shown at Fig.2.

4 Experiment

4.1 Experimental parameter

Table 1 shows the parameters used in the experiment.

Table 1: Experimetal parametaer.

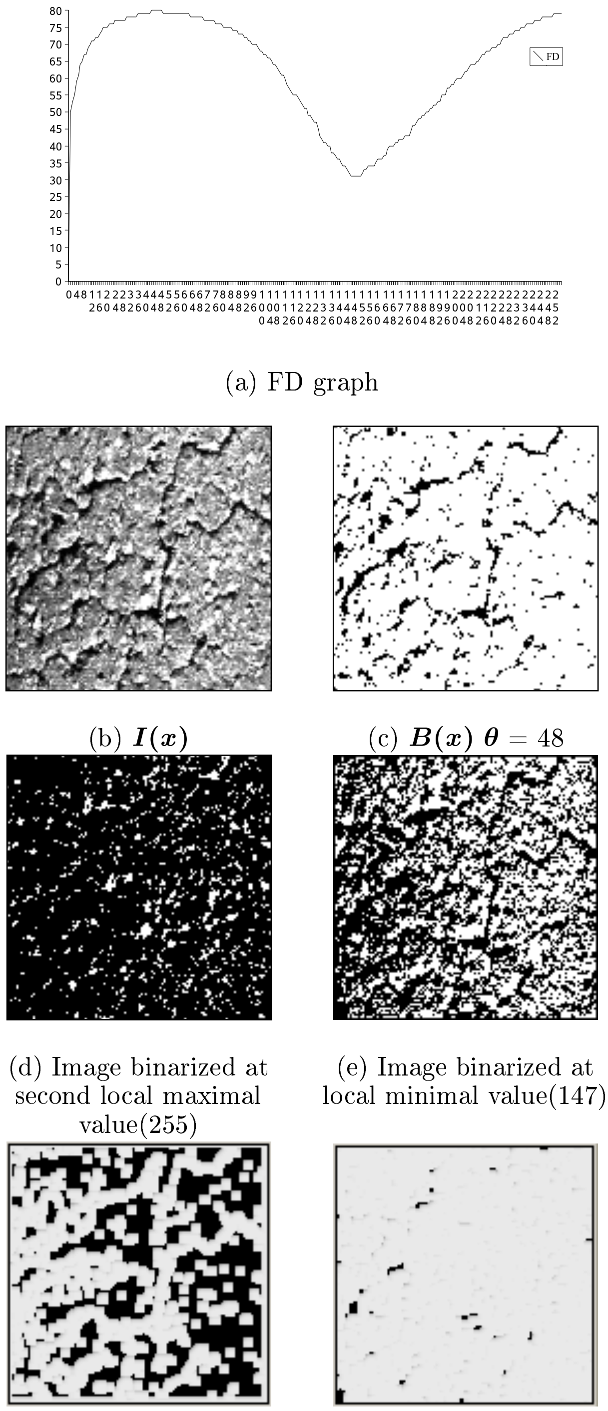
	FD	LFD
ϵ	44	44
Codomain of quantization	100	256

Novianto showed that appropriate codmain of ϵ is from 34 to 53. So we selected 44 as median value of it. ϵ in FD value relates to evaluating density of regions such as line segments, isolated points.

4.2 Experimental result

Binarized images by proposed algorithm are shown at Fig 3. And processing results by Otsu's method and Niblack's method are also shown for comparison at Fig4. We select the two methods as a promising binarization method using gray level information. One is local method, and the other is global one.

The experimental results show that the proposed technique have a sufficient performance for a one step of crack detection method. Fig.5 shows the input image, output image, gray level histgram, and FD. Selected threshold value is 48. It can be confirmed that how difficult to find it if we use the method based on gray level histgram. And actually, neither Niblack's method nor Otsu's method could work well on road surface images.



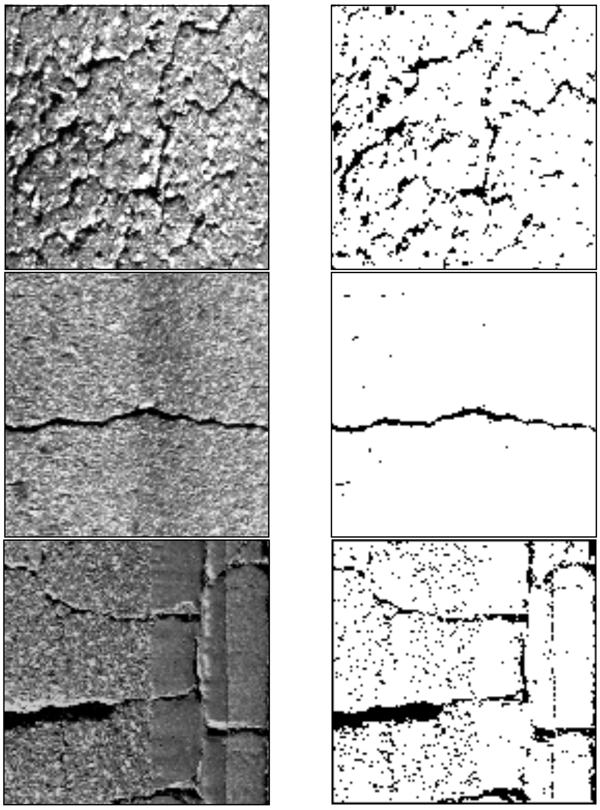
(a) FD graph

(b) $\boldsymbol{I(x)}$ (c) $\boldsymbol{B(x)}$ $\boldsymbol{\theta} = 48$

(d) Image binarized at second local maximal value(255) (e) Image binarized at local minimal value(147)

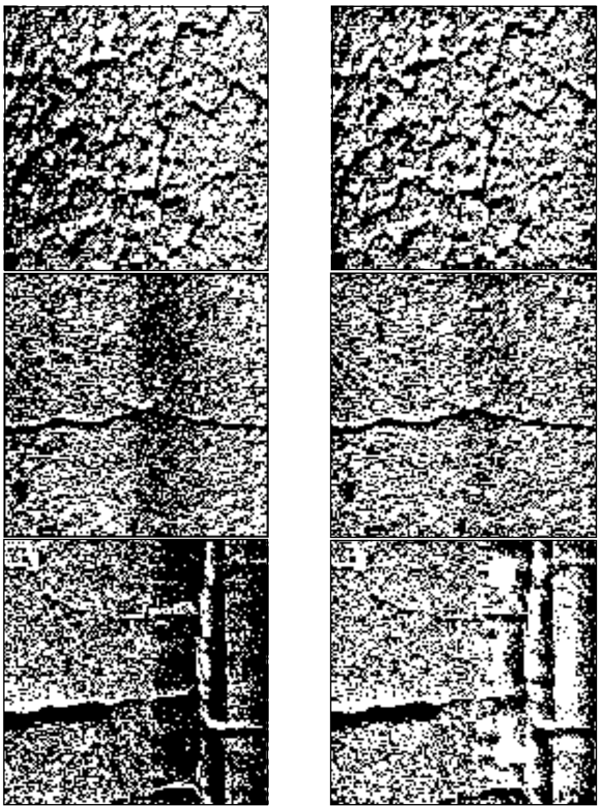
(f) $\boldsymbol{LFD_{48}(x)}$ (g) $\boldsymbol{LFD_{147}(x)}$

Figure 2: FD graph and examples of image in processing.



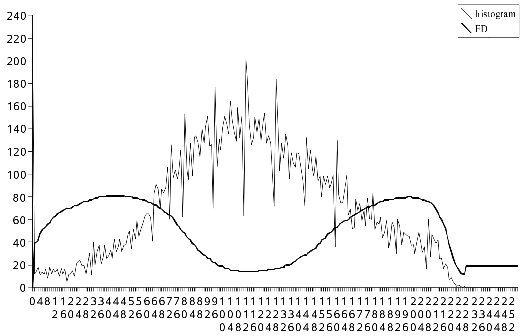
(a) Input image (b) Output image

Figure 3: Examples of binarized images by our technique.

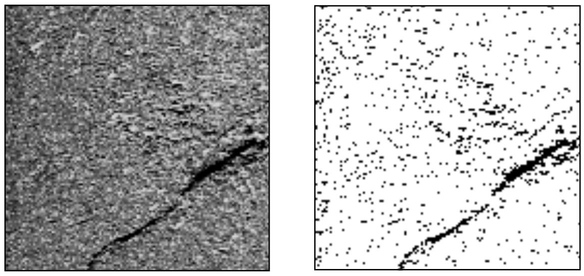


(a) Otsu's method (b) Niblack's method

Figure 4: Examples of binarized images by Otsu's method and Niblack's method.



(a) Graph of FD and gray level



(b) Input image (c) Output imagee

Figure 5: FD graph and gray level histgram.

5 Conclusion and Future Work

Results of experiment shows that the proposed algorithm can be a promising binarization of crack detection method. Some noises are also included in binarized image. This is because our proposed method is belonging to global technique, that is, only one threshold value is applied for whole image. We can easily introduce a local adaptive method utilizing LFD information.

Acknowledgements

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References

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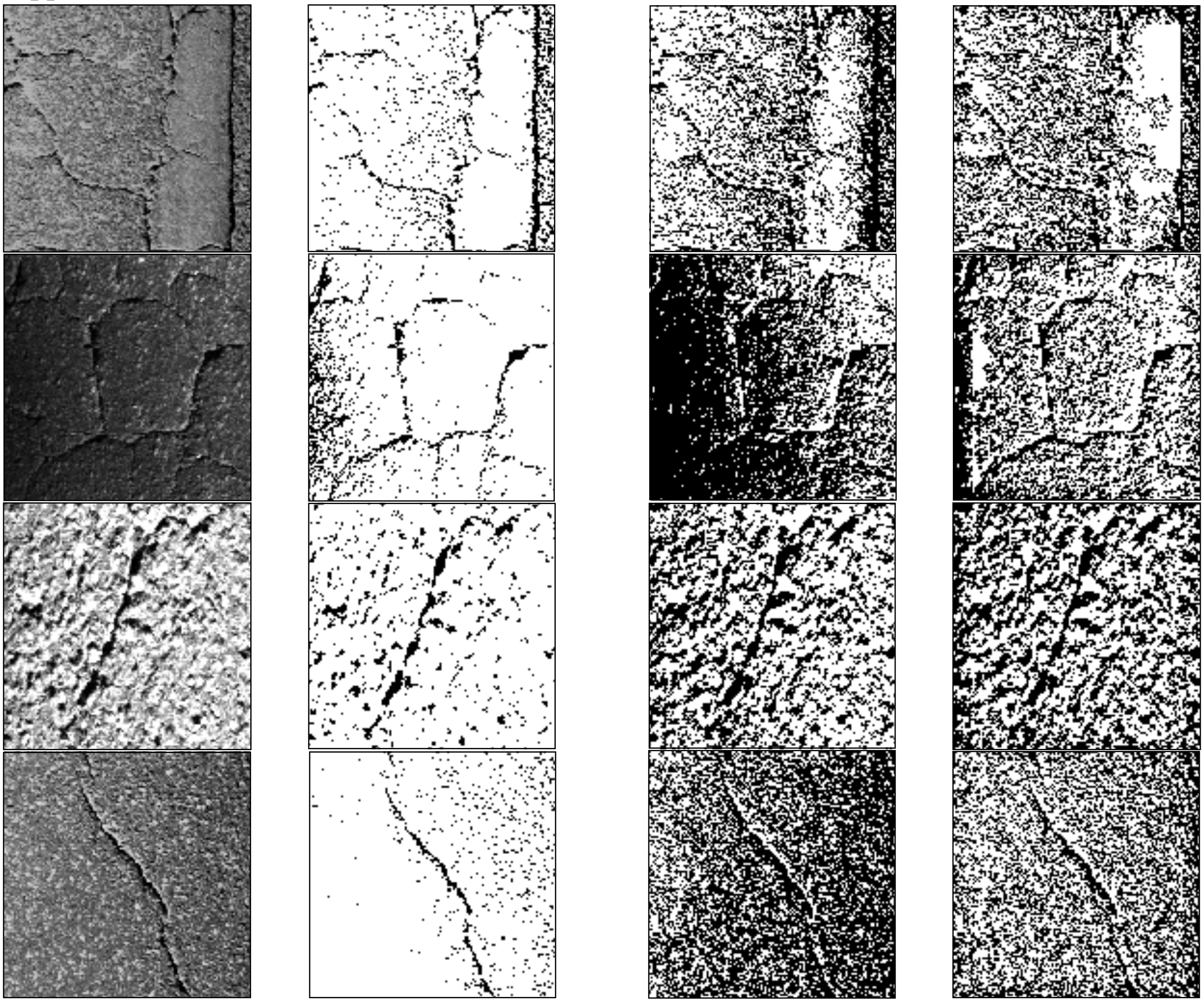
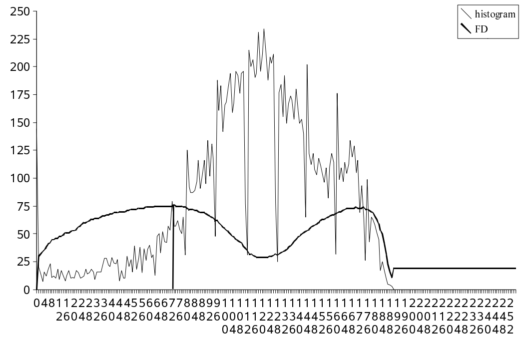
Appendices

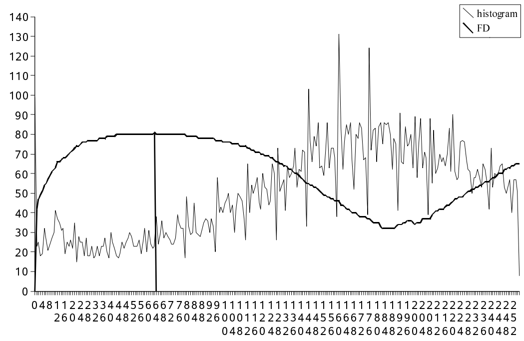
(1)
(2)
(3)
(4)



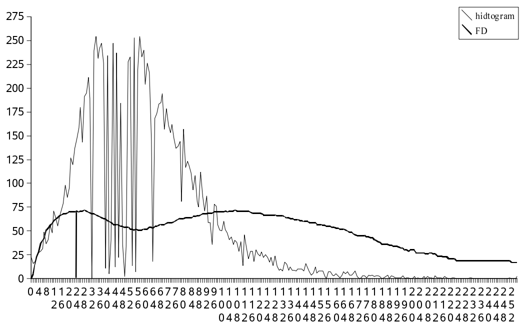
(a) Input image (b) Output image (c) Otsu's method (d) Niblack's method



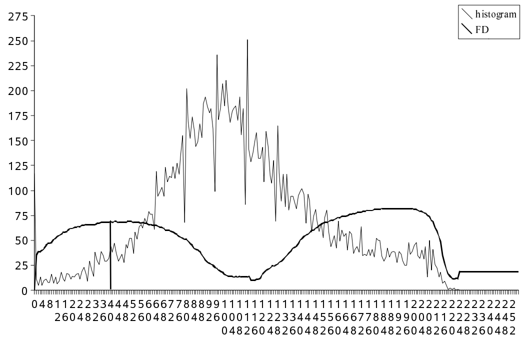
(1)



(3)



(2)



(4)