A Novel Road Crack Detection and Identification Method Using Digital Image Processing Techniques

Weiling Huang
School of Computer and Information Technology
Beijing Jiaotong University
Beijing, China
10120467@bjtu.edu.cn

Ning Zhang
School of Computer and Information Technology
Beijing Jiaotong University
Beijing, China
nzhang1@bjtu.edu.cn

Abstract—**Road crack detection is the base of highway maintenance and digital image processing has been widely used in crack detection and identification. In this paper, a novel, effective, efficient image processing method is proposed for the extraction of road cracks from pavement images. The first stage is image preprocessing which consists of binary segmentation, morphological operations and remove algorithm which remove the isolate dots and area. Usually, after those operations above, many gaps still exists in the crack, the second stage proposed a novel algorithm to connect those break cracks. It needs to judge the type of the crack because of the difference in different types. The experimental shows that the surface crack could be detected correctly and results proved satisfying and efficient.**

Index Terms—**road crack, crack detection, mathematical morphology, gap connect.**

I. INTRODUCTION

Road crack is a kind of structural damage. Road crack detection plays an important role in highway administration and the maintenance department. Traditionally, crack detection mainly relies on manual work, which is labor-consuming, time consuming, imprecise and dangerous. Some systems use automatic algorithms for crack detection, however high success in terms of classification rate has not been achieved due to lighting conditions, various in road texture and other difficult environmental conditions. Therefore, it is necessary to propose a kind of fast and effective method to improve the efficiency of detection.

There have been many thoughtful studies on cracking auto-recognition. In image preprocessing stage, many researchers have paid great attention. For example, Histogram equalization and spatial filtering have been used to achieve the image enhancement [1].

For image segmentation, a suitable threshold is needed, in [2, 3] a solution is proposed which is to break the image into tiles. The block size is a very important parameter. It should be large enough to contain both the crack and background regions while representing only the local information. Using neural network is a solution to determine the threshold [4]. The inputs were the mean, standard deviation and co-occurrence parameter of the tile. However, after binary image processing, as noise and texture existed, there will be some isolated dots, burrs and small connected domains. Mathematical morphology is introduced into the applications of road image analysis and processing, such as described in [5-7]. But the result of them is not very well due to different lighting conditions and surface texture. Usually, even mathematical morphology method could not solve the problem that there are many breakpoints in the cracks. The algorithm of connecting crack is proposed in [7]. However, the algorithm is complex and time-consuming.

In this paper a novel method is introduced which carried out in two stages. First stage, the preprocessing stage is image segmentation and noise removing. The second stage is to connect the breakpoints of the crack.

This paper is divided into 5 sections. Following this section, Section 2 presents the method in preprocessing stage. Section 3 presents the method of the gap connection. The experimental results are presented in Section 4. Finally the section 5 concludes this paper.

II. PREPROCESSING: IMAGE BINARIZATION AND NOISE REMOVAL

The first step is binary segmentation. There are many methods, such as Otsu thresholding, Kittler thresholding, Niblack thresholding and Kapur thresholding. Otsu thresholdig is greatly influenced by lighting condition. When the crack and background is balanced relatively, the binarization effect is pretty well. However, when the crack area proportion is very high or very low, the effect is extremely bad. Niblack thresholding is also influenced by noise and the processing speed is slow. Other two methods have an ideal result. In this paper we choose Kittler thresholding.

Because there are many variations in road texture and lighting conditions is often inconformity, after binary segmentation there are many isolated noise. The crack itself isn't smooth either. There are many false branches and bending. Mathematical morphology is an important tool to solve these problems. The main operation of morphological transforms is dilation and erosion, this operation is guided by structural elements. Let the binary image is A, the structural elements is B, then:

Dilation is defined as:

$$A \oplus B = \left\{ x \left| \left[\left(\hat{B} \right)_x \cap A \right] \neq \phi \right. \right\} \tag{1}$$

Erosion operation is defined as:

$$A \Theta B = \left\{ x \middle| (B)_x \subseteq A \right\} \tag{2}$$

Opening operation and closing operation is compound formed by these two basic operations.

Opening operation is defined as:

$$A \circ B = (A \Theta B) \oplus B \tag{3}$$

Closing operation is defined as:

$$A \cdot B = (A \oplus B) \Theta B \tag{4}$$

Opening operation can remove burrs, small connected domains, isolated dots and also smooth large object's boundaries. Closing operation can be used to fill small cavities of objects, connect nearby objects, smooth borders.

Morphology operations connect the small gap in cracks. However, many isolate dots and area couldn't be removed. We define a threshold (T_1) of area and a threshold of length-width ratio (T_2). If the number of pixels of the isolate area is less than T_1 or length-width ratio is less than T_2 , it indicate that the isolate area is not one part of the crack so remove it.

According to the characteristic of crack image and method introduced above, this paper presents crack image preprocessing algorithm as follows:

- Binary the segmented image, and then negated.
- According to the image characteristics select structural element B. Its size is determined by the width of cracks. This paper, we use a 3*3 square structuring element.
- Execute Mathematical morphology operations. Closing operations fill small cavities of objects and connect nearby objects. Opening operations remove blurs, small isolate dots and smooth boundaries.
- Remove the isolate dots and area which meet one of the following conditions:
  Condition 1: The number of the pixels of the area is less than threshold T_1.
  Condition 2: The length-width ratio of the area is less than threshold T_2.

Process is shown in Figure 1.

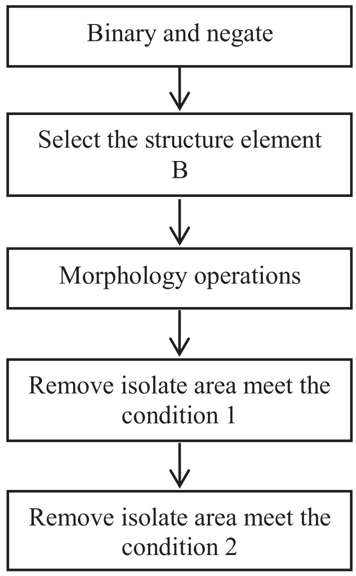


Fig. 1. Image preprocessing flowchart

III. CRACK'S GAP CONNECTION

Crack images in the binary segmentation could damage the edge of cracks and break cracks, even mathematical morphology method could not solve the problem that there are many gap in the cracks, as figure 3 shows. In fact, those four connected domain should be one connected domain. They belong to one crack. As we all know, In Mathematical morphology, after a few dilate operations, these gaps could be connected, but it is difficult for us to remain the width of the crack, usually it becomes wider. In this section we proposed a method to connect the gap while the width of crack doesn't change.

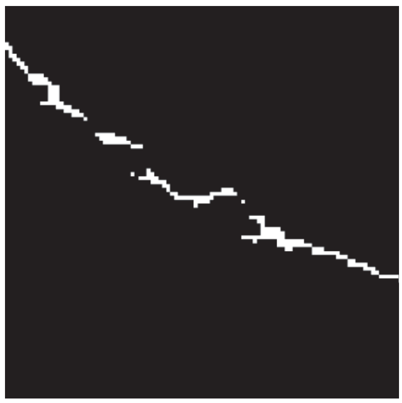


Fig. 2. The gap of the crack.

Road crack is classified as transverse, longitudinal and alligator type. Since different algorithms are used for different types of cracks, we must judge the type of one crack in crack image at first. We can obtain the crack's horizontal projection and vertical projection and named H and V respectively. If the length of H is bigger than V then this crack is transverse type, as shows in figure 4. Otherwise, this crack is longitudinal type. In the following we describe a procedure for connecting the gap of transversal cracks; the procedure for longitudinal cracks would be similar.

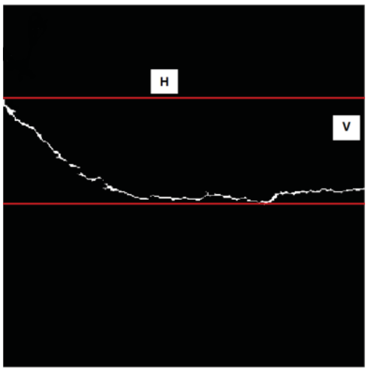


Fig. 3. Horizontal projection and vertical projection.

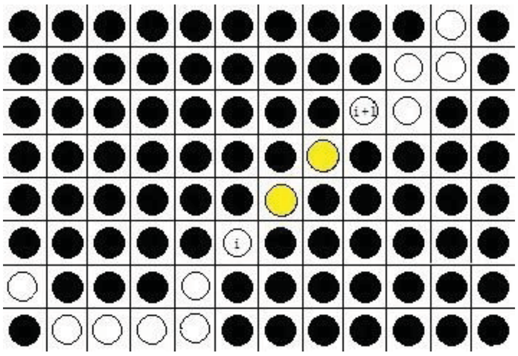
First, the algorithm detects all of the connection domains with 8-neighbors and labels them from left to right. Their tag is labeled as 1, 2, 3,⋯N. Let the amount of the connection domains is N. For every adjacent connection domain, the last point of former named P_{former} and the first point of latter named P_{latter}. The threshold of the horizontal distance is T_{hor}. The threshold of the vertical distance is T_{ver}. The procedure is summarized below:

1) Start from the first connection domain which has not been used, for example its tag is i, and its neighbor is i+1.

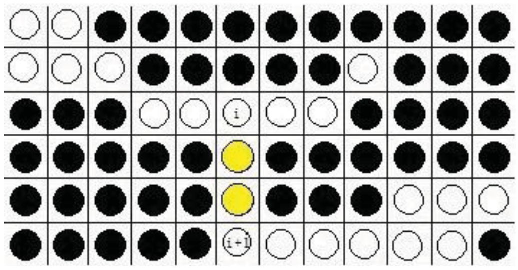
2) Case 1: $P_{former}(x) \geq P_{latter}(x)$. If the horizontal distance (D_{hor}) and vertical distance (D_{ver}) of P_{former} and P_{latter} less than T_{hor} and T_{ver} respectively, then connect these two points with shortest path. As figure 4 (a) shows.

3) Case 2: $P_{former}(x) < P_{latter}(x)$. Look for the point P which $P(x)=P_{latter}(x)$ and replace $P_{former}(x)$. If vertical distance (D_{ver}) less than T_{ver}. Connect these two points with shortest path. As figure 4 (b) shows.

4) If i+1<N, repeat above steps from 1) for next connection domain.



(a) Case 1



(b) Case 2

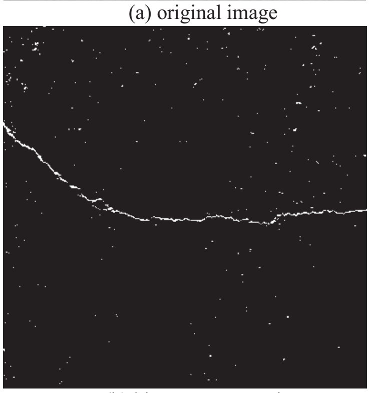
Fig. 4. The yellow points mean the gap which connected.

The process for obtaining a longitudinal crack is similar to the transverse. Now, the gap in the cracks is connected we can calculate the crack's length, width, area and so on, those are the most important index of road maintenance.

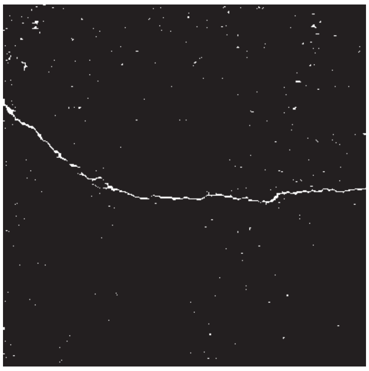
IV. Experiment Results

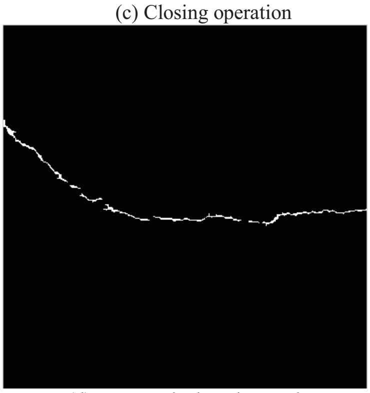
Pavement images that collected from a campus are used to do the experiment by the method described above. The proposed algorithm has been implemented use MATLAB, and its performance and results is satisfying. We have chosen different kinds of pavement images in this experiment. Fig 5(a, b, c, d, e) shows image preprocessing and crack's gap connection.

(a) original image



(b) binary segmentation


(c) Closing operation


(d) Remove isolate dots and area

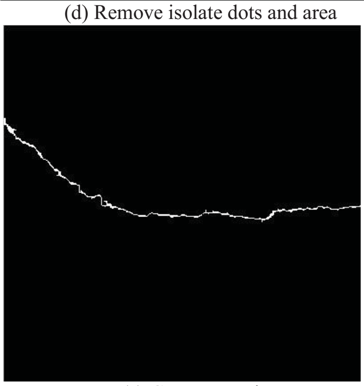

(e) Gap connection

Fig. 5. (a) Original image. (b) Binary segmentation use Kittler thresholding segmentation and negated. (c) After closing operation. (d) Remove isolate dots and areas don’t belong to cracks. (e)Connect the cracks have gap.

V. CONCLUSIONS AND COMMENTS

A novel method for extraction of road cracks from pavement images is presented. The preprocessing stage consists of binary segmentation, morphological operations and algorithm removing isolate dots and areas. The morphological operations remove most of the noise, fill holes and connect nearby objects. Then set threshold of size of connection domain and length-width ratio. If one of the volumes is less than the threshold, it indicated that it is not part of the crack. However after the operations above, the gap in the crack still exists, so this paper proposed a novel algorithm to connect these small gaps. Experimental results clearly demonstrate that the method is effective and efficient and it can provide scientific basis for the highway maintenance department.

As the algorithm of gap connection only take transverse and longitudinal types into account, further work of adding alligator type crack should be improved.

VI. ACKNOWLEDGEMENT

This research was financially supported by the China 863 High-tech Program under grant number 2012AA040912, the China 863 High-tech Program under grant number 2011AA040505 and Railway Ministry Project under grant number 2012X010-A-2.

REFERENCES

[1] L. Jing and Z. Aiqin, "Pavement Crack Distress Detection Based on Image Analysis," in Machine Vision and Human-Machine Interface (MVHI), 2010 International Conference on, 2010, pp. 576-579.

[2] X. Guoai, M. Jianli, L. Fanfan, and N. Xinxin, "Automatic Recognition of Pavement Surface Crack Based on BP Neural Network," in Computer and Electrical Engineering, 2008. ICCEE 2008. International Conference on, 2008, pp. 19-22.

[3] D. H. Kil and F. B. Shin, "Automatic road-distress classification and identification using a combination of hierarchical classifiers and expert systems-subimage and object processing," in Image Processing, 1997. Proceedings., International Conference on, 1997, pp. 414-417 vol.2.

[4] J. Bray, B. Verma, L. Xue, and H. Wade, "A Neural Network based Technique for Automatic Classification of Road Cracks," in Neural Networks, 2006. IJCNN '06. International Joint Conference on, 2006, pp. 907-912.

[5] Y. He, H. Qiu, J. Wang, W. Zhang, and J. Xie, "Studying of road crack image detection method based on the mathematical morphology," in Image and Signal Processing (CISP), 2011 4th International Congress on, 2011, pp. 967-969.

[6] Y. Chu, "Algorithm Study on Thinning and Keeping Connectivity of Bituminous Pavement Crack Images," in Information Science and Management Engineering (ISME), 2010 International Conference of, 2010, pp. 550-553.

[7] Y. Sun, E. Salari and E. Chou, "Automated pavement distress detection using advanced image processing techniques," in Electro/Information Technology, 2009. eit '09. IEEE International Conference on, 2009, pp. 373-377.