Road Crack Detection Based on Video Image Processing

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Abstract—**The damage of road surface reduces its service life. In order to improve road maintenance and management efficiency, detection and recognition of pavement are studied based on video images in this paper. Firstly, we collect a large number of road surface images of 3 different conditions including transverse crack, longitudinal crack and turtle crack separately to construct road surface conditions library. Secondly, deal the road damaged image with gray, gray transform and image smoothing. Then, use mathematical morphology method to deal with crack image and projection to identify crack category. Finally, develop the pavement crack recognition software based on Matlab. Selecting the pavement samples for experiment, the results show that this identification algorithm can accurately identify the category of crack.**

Keywords-pavement crack image; image smoothing; projection; mathematical morpho1logy; fracture identification

INTRODUCTION

With the rapid development of economic construction of our country, road traffic is playing a more and more important role in the national economy, road pavement maintenance and management problems also become more prominent as well. In order to improve the service life of the road, obtaining pavement damage data and doing research on it becomes the pavement maintenance management's most important work at this stage.

Pavement crack damage is one of the most common diseases in the road destruction phenomena[1], the way to detect road conditions mainly relies on people and instruments at present. The Earth technology companies in the United States developed a pavement condition evaluation system (PCES)[2] that uses threshold segmentation to extract damaged information of the road surface. Japan's consortium developed a Komatsu system[3] which implemented the data of various pavement disease detection, such as rut, cracks and section. The HARRIS system[4] developed by Britain's Transport Research Laboratory combines data real-time processing with offline processing way to automatically detect the result which is saved as a picture, according the picture we can easily identify the location of the crack, length, type and direction of the details. Zhao Chunxia[5] developed a N-1 road intelligent checkout automobile can complete the pavement diseases data collection and testing tasks at the same time, such as crack, rut and smoothness. He Anzhi[6] developed JG - 1 type laser three-dimensional road intelligent detection system which contains a high precision laser ranging and section three-dimensional Reconstruction can realize intelligent detection to the road crack, roughness, rut and pit slot diseases data, as well as evaluate the road conditions and generate the test report. Liu Jinwei[7] developed a road detection vehicle ZOYON-RTM which collects pavement cracks image through high resolution linear CCD, completing the road crack, rutting, roughness and other pavement diseases detection.

In view of the above literature, the crack identification are all based on the road video images, but the recognition accuracy and the classification problems of the pavement crack haven't get a good solution. Therefore, this article makes projection about crack on X axis and Y axis based on projection method, and then recognizes the crack type according to the projection coordinate point of crack number in different axes.

CLASSIFICATION AND FEATURES OF ROAD CRACK DAMAGE

According to the present classification method, road pavement damage is generally divided into crack, patch, pit, surface defects, surface deformation and mixed damage. The article divides crack damage into transverse crack, longitudinal crack and turtle crack.

Transverse crack is perpendicular to the centerline of the road and accompanied by a small amount of seam. Longitudinal crack is substantially parallel to the centerline of road and accompanied by a small amount of seam. Turtle crack shows that a large mesh intertwines together. The comparison of three different kinds of crack is shown in TABLE Ⅰ.

PRETREATMENT OF THE ROAD CRACK IMAGE

Making pretreatment to the road crack image collected before can be helpful to the later recognition, it can also increase the accuracy greatly. The process of image preprocessing includes format conversion, graying, gray transform, image smoothing, image smoothing and image sharpening.

A. Graying

Transforming color image into grayscale image can reduce the amount of calculation, and the image of the converted will still be able to reflect the whole image of global and local distribution characteristics of chromaticity and brightness level[8].

B. Gray-scale Transformatio

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TABLE I. THE MAIN CHARACTERISTIC OF THREE KINDS OF CRACKS

Damage type	Damage level	Characteristics
longitudinal crack/ transverse crack	light	Fine grain, there is no loose or slight loose on the crack walls, no lines or has a small amount of seam, The width of crack is less than 5 mm.
	heavy	Broad grain, cracks throughout the pavement, crack walls are accompanied by a small amount of branch lines, the width of main crack is greater than 5 mm.
turtle crack	light	There is no loose or deformation in early crack area, the width of main crack is less than 5 mm, Crack blocks between 20 and 50.
	middle	There is slight loose or deformation in crack area, the width of crack is 2 ~ 5 mm, and an increase in the number of crack block.
	heavy	Deformation, scattered phenomenon is serious, the width of main crack is greater than 5 mm

Image gray-scale transformation is an important branch of image processing which uses a series of techniques aims at extending the dynamic range of image gray and enhancing the contrast of the image, then highlighting the gradation information of interest. Histogram equalization[9] is a kind of method which uses gray transform to adjust the image contrast quality automatically, it is a histogram correction method based on the cumulative distribution function. The relationship between transform function T (r) and the probability density function of the original image $p_r(r)$ are given in (1):

$$s = T(r) = \int_0^r p_r(r)dr \quad (0 \ll r \ll 1) \tag{1}$$

T (r) ranges from 0 to 1.

The above is based on continuous random variable, and the discrete form applied in digital image processing is shown as formula (2):

$$s_k = T(r_k) = \sum_{i=0}^{k} n_i / N = \sum_{i=0}^{k} p_r(r_j)$$
$$(0 \le r_j \le 1 \quad k=0, 1, 2, \ldots, L-1) \tag{2}$$

where, $T(r_k)$represents the conversion function of the original image at K-th gray level, $\sum_{i=0}^{k} n_i / N$ represents the number of pixels of gray levels up to total ratio of the pixels of 0 ~ j $\sum_{i=0}^{0} p_r(r_j)$ represents the sum of occurrence probability at the gray level of 0~k.

The processing steps of histogram equalization are as follows:

1) Obtaining the given image's istogram $p_r(r)$.

2) Using cumulative distribution function to do transformation with the histogram of original image.

3) Doing approximate processing, and combining the histogram whose gray level values are equal or approximate together at the same time, then getting the $p_s(s)$.

C. Image Smoothing

The high frequency domain of the image focuses on the details, false contour and noise, but the most effective image information is mainly concentrated in the low frequency domain. Image filtering is a better way to remove the image noise and high frequency interference composition. Median filtering method[10] is a nonlinear processing technology which can protect image edge and filter out noise very well. First, ranking the neighborhood pixels according to grayscale, and then selecting the middle value of the group as the output pixel. This method not only removes the isolated point noise, but also protects the boundary of the target area and keeps the image from fuzzy away.

D. Image Sharpening

In order to highlight the edge of the image texture information, we should use image sharpening to eliminate or weaken the low frequency component of the image. We need to enhance the contour information of image in the target area, so that the outside edge of the pixel gray scale values tends to zero.

Laplace operator is one of an edge enhancement operator which is commonly used to sharpen image. It adopts the second order partial derivative, and the definition is shown as (3):

$$\nabla^2 f = \partial^2 f / \partial x^2 + \partial^2 f / \partial y^2 \tag{3}$$

For digital image, differential form can be used to approximate the Laplace operator in a certain pixel point:

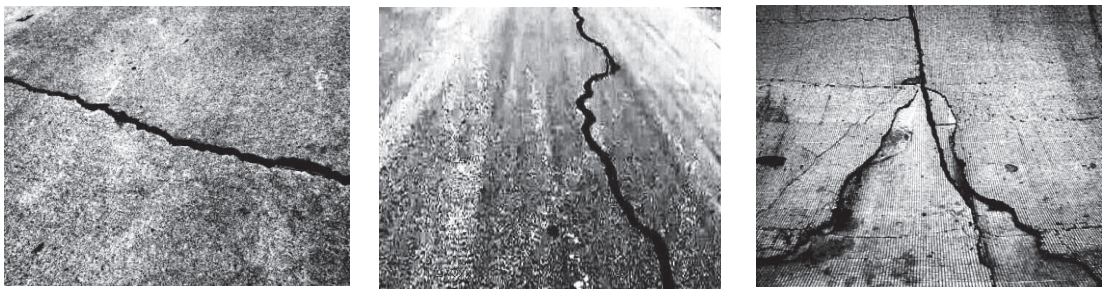
$$\nabla^2 f(x,y) = f(i,j+1)f(i,j-1)$$
$$f(i+1,j)f(i-1,j) - 4f(i,j) \tag{4}$$

Ⅳ. THRESHOLD SEGMENTATION OF ROAD CRACKS

The extraction of damaged area is the key to analyze the road crack image effectively[11]. Threshold segmentation is a kind of typical image segmentation method which divides image mainly according to the background region and target areas that occupy different grayscale range, and the key to this method is to find a suitable

Global threshold method is a method that chooses a threshold to divide the whole image into two areas, and the choice of segmentation threshold is based on the histogram of the image. These two areas are color-coded, and the typical color is black and white, color images can also be divided into red, green or any other color that has quite different hue. If the contrast of the entire image is relatively modest, the contrast of the background is close to the target, and the gray value of background image remains stable, then, using global threshold

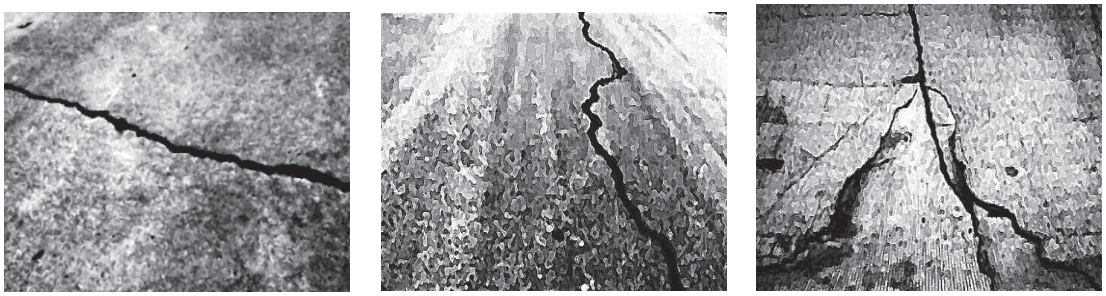
(a)



(b)

Figure 1 (a):Before grayi ng,(b):After graying

(a)



(b)

Figure 2 (a):Before sharpening,(b):After sharpening

will generally achieve a good segmentation result [12]. The formula (5) can be presented as follow:

$$g(x,y) = \begin{cases} 1, f(x,y) > T \\ 0, f(x,y) \ll T \end{cases} \quad (5)$$

where, T is a gray threshold set in advance, f represents the input image, and g is the output image.

V. The Detection and Recognition of Cracks

After the completion of the image segmentation, pavement crack image becomes clear binary image. This article chooses the skeleton extraction algorithm based on mathematical morphology[13] to detect its edge, and then identifying cracks based on image projection.

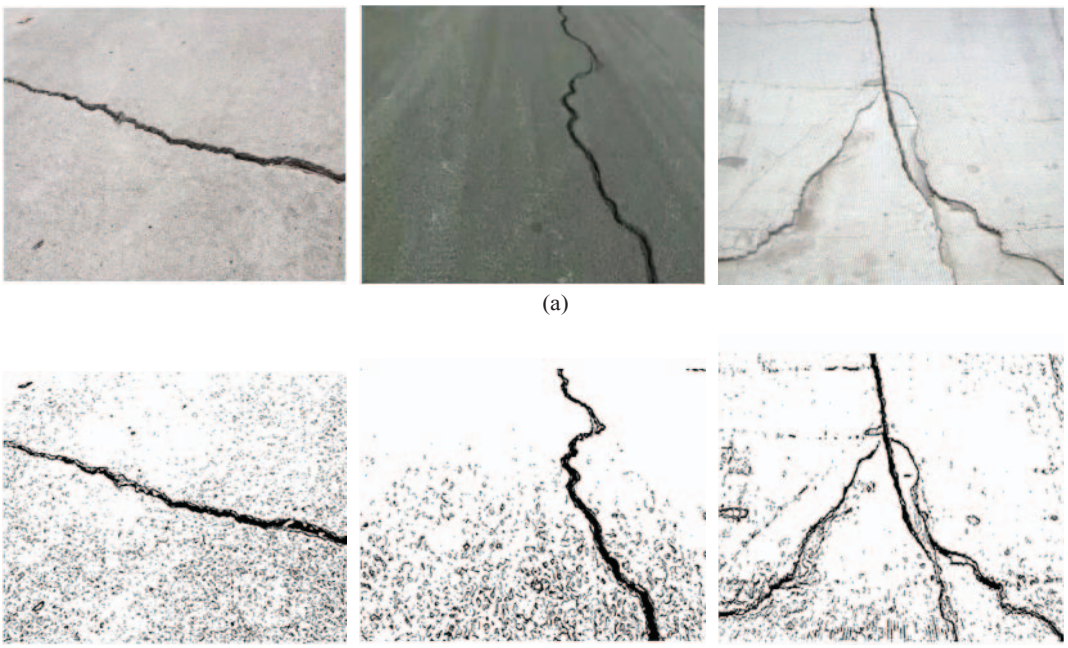


Figure 3 (a): Before the global threshold segmentation,(b): After the global threshold segmentation

A . Dilation and Erosion

Dilation is indicated by symbol $\oplus$, and A dilates B denotes $A \oplus B$. The process of dilation as follows: First, mapping the structural elements B about the origin to get $\widehat{B}$. Then, letting $\widehat{B}$ has a translation about x to get $(\widehat{B})_x$. Finally, calculating the intersection of $\widehat{B}$ and A.

Erosion is indicated by symbol Θ, and A erodes B denotes $A \oplus B$. The process of dilation as follows: After Structural elements B having a translation x, it is still in the reference point of the collection A.

B. Open Operation and Close Operation

Using structural elements D to do open operation with the target image C, noting as $C \circ D$. The process of dilation as follows: First, eroding C with D. Then, dilating the result of erosion. Open operation can make the contour of the object processed becomes more smooth and soft, and disconnect the image from the narrow gap to eliminate the subtle projection.

Using structural elements D to do close operation with the target image C, noting as $C \bullet D$. The process of erosion is contrary to the dilation. Close operation also has the function of smoothing contour, but what contrary to open operation is that it usually breaks the elongated grooves and tiny holes, and fills cracks in the contour lines as well.

C. Crack Identification

Image recognition is generally based on the certain characteristics of the image, and the selection of characteristics will affect the classification method of image recognition and the accuracy of identification results. In this paper we choose the

Suppose that you have a binary image, the values of pixel I (i, j) in the background recorded as 0, the values of pixel I (i, j) in the target area recorded as 1, we can define image projection in a certain direction: putting the projection direction as the horizontal axis, and the vertical direction of the projection as the ordinate, then counting the number of pixels to get a one-dimensional curve. Setting the road binary image I size of M * N, projection X in the horizontal direction and Y in the vertical direction is:

$$X(i) = \sum_{j-1}^{M} I(i, j) \qquad i = 1,\ 2\cdot;\cdots\ N \tag{6}$$

$$Y(i) = \sum_{i-1}^{N} I(i, j) \qquad j = 1,\ 2\cdot;\cdots\ M \tag{7}$$

According to the projection characteristics of the binary image, we put the maximum differ ence value x_{max} and y_{max} as classification characteristic[14], the calculation formula is as follows:

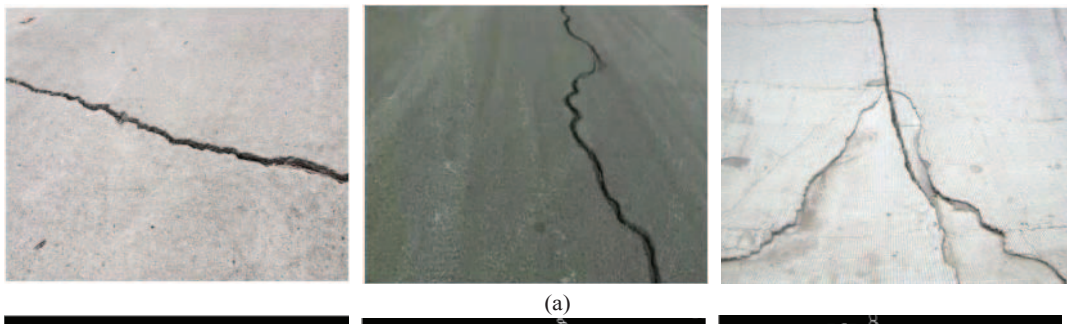
$$x_{\max} = \max(x_i) - \min(x_i) \tag{8}$$

$$y_{\max} = \max(y_j) - \min(y_j) \tag{9}$$

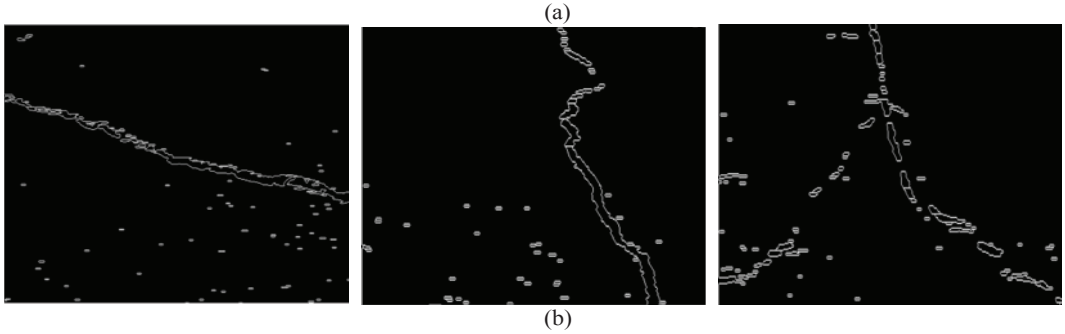
For Turtle crack, the value of x_{max} is similar with y_{max}. For longitudinal crack, the value of x_{max} is bigger while y_{max} is smaller. For transverse crack, the value of x_{max} is contrary to longitudinal crack. The following figure as an example to explain the projection of turtle crack.

VI. Software Development

The software's main function includes image reading, image preprocessing, threshold segmentation, edge detection and crack identification. The function and identify interface diagram is shown in Figure 6.

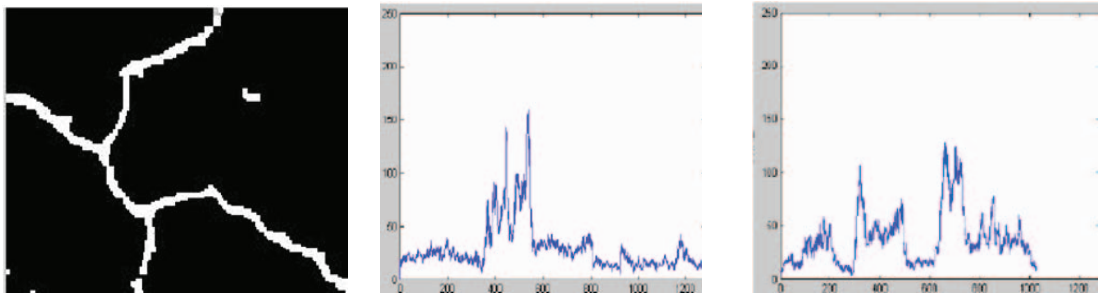


(a)



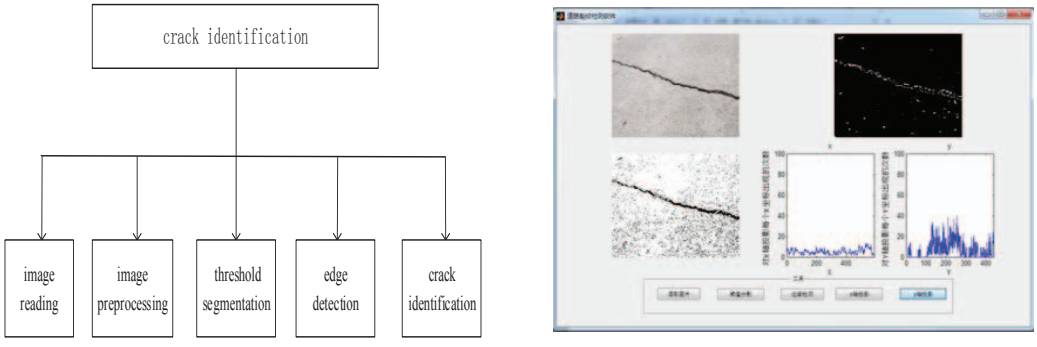
(b)

Figure 4 (a):Before edge detection,(b):After edge detection



（a） (b) (c)

Figure 5 (a):The binary image of turtle crack,(b):Projection image in X axis ,(c):Projection image in Y axis



(a) (b)

Figure 6 (a):software function diagram,(b):The recognition interface of software

Ⅶ. Conclusion

Based on the video image, we develop road crack recognition software with Matlab. This paper introduces the process of image processing and recognition in detail. We can give a clear road crack feature of image by using threshold segmentation and edge detection technology, thus laying the foundation for the later recognition. The experiment result shows: the software can identify cracks accurately, and classify cracks detailedly according to its characteristics.

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