ISSN 2616-5775 Vol. 6, Issue 1: 83-98, DOI: 10.25236/AJCIS.2023.060113

Research on Pavement Crack Detection and Recognition Algorithm

Wang Zheng[1], Guo Jianxin[1,*], Hu Chengyu[1], Qiao Fengkang[1]

[1]School of Electronic Information Engineering, Xijing University, Xi'an, Shaanxi, 710123, China
[*]Corresponding author: guojx_516@126.com

Abstract: *In order to solve the shortcomings such as low efficiency and great risk of detection and recognition algorithm of road surface, this paper studies the algorithm program of detection and recognition of road surface from the Angle of digital image processing based on computer road and track automation technology, and makes many parameter calculations for horizontal, longitudinal, massive and mesh cracks of road surface. The results show that compared with the traditional detection and recognition methods, the algorithm program studied in this paper effectively improves the measurement accuracy of pavement cracks and the accuracy of crack identification, and the program has high feasibility in road detection and recognition.*

Keywords: *Crack in Road Surface; Digital Image Processing; Identification of Cracks*

1. Introduction

The construction of road engineering is closely related to the development of national economy, among which, the application of road maintenance and corresponding construction technology determines whether the road can achieve effective management to a certain extent [1, 2]. At present, as road detection level lags far behind foreign countries, there are some problems such as low efficiency and high risk in road management, especially in road crack detection investigation [3]. The use of computer road automation detection technology instead of workers to measure and evaluate road cracks and damage can effectively improve the accuracy and effectiveness of measurement, so as to reduce the impact of road cracks on passing vehicles, to achieve efficient maintenance and effective management of the road.

At present, domestic and foreign scholars and relevant practitioners have studied the pavement crack detection and recognition algorithm and achieved results. In terms of foreign countries, Japan's PASCO company started the research on the detection and identification of road cracks as early as the 1960s. France followed Japan in developing the road camera vehicle (GERPHO) system, which uses 35 mm film film to capture road cracks. Compared with the previous original manual photography measurement has a milestone progress. By the late 1980s, Japan, Canada, the United States and other countries have developed the second-generation detection and recognition system that can rapidly capture images and systematically evaluate the types and grade of cracks [4]. Nowadays, researchers devote a lot of energy to the development and improvement of pavement crack image extraction algorithm. In 2018, the California Institute of Technology proposed a weighted coefficient based algorithm that captures cracks to create a flow of information that allows researchers to model faults. In 2019, Berkeley developed a computer algorithm system for high-speed processing of digital images that can be used in field tests of pavement crack detection and is widely used to evaluate the effectiveness of test detection methods. As far as domestic is concerned, Nanjing University of Science and Technology, and some enterprises in related fields developed the first crack detection and recognition vehicle (N-1 road condition detection car) in our country in 2022, which marked that our country broke the monopoly position of foreign companies in the intelligent recognition and detection of road crack. In the next year, JN-1 intelligent detection vehicle was successfully launched, which was equipped with high-precision digital image processing and acquisition equipment inside the vehicle, which could effectively shoot road surface images in the process of high-speed driving, quickly carry out digital image processing, and then analyze the types of road cracks and the degree of road surface diseases. In 2017, Zhejiang University proposed a real-time online detection system for any region in fracture sample images. Relying on the improved BP neural network, it has excellent performance and has an unshakable position in related fields in China [5].

ISSN 2616-5775 Vol. 6, Issue 1: 83-98, DOI: 10.25236/AJCIS.2023.060113

However, most road crack detection work in our country still uses semi-artificial and semi-machine detection and recognition mode, the detection and recognition system has great limitations. Therefore, it is urgent for us to invest more manpower and material resources in further research.

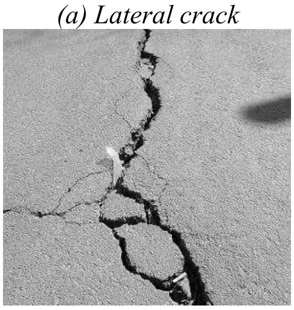
In view of this, this paper studies the principle of pavement crack image detection algorithm. The paper introduces some mainstream algorithms, develops the degree of pavement crack detection and recognition based on Matlab platform, carries out simulation research on pavement crack detection, and analyzes and summarizes the image processing experiment. It is proved that the developed program has high feasibility in road detection and recognition.

2. Theory of Pavement Crack Identification

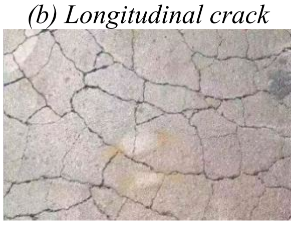
At present, our highway infrastructure has taken a qualitative leap, but there are still convex, crack, loose and other road diseases [6]. Cracks, in particular, will not only affect driving stability, shorten the use of the road, but also affect the local perception of the road. The causes of pavement cracks can be roughly divided into construction factors, climate factors and driving factors [7]. From the perspective of crack morphology, pavement cracks can be divided into transverse cracks, longitudinal cracks, gridlike cracks and massive cracks, as shown in Figure 1.

Modern pavement crack detection and recognition includes two main contents: basic image capture of pavement crack by camera and image acquisition device, and analysis and processing of possible pavement crack images collected by various image processing software in computer. As the key of computer analysis and processing, detection algorithm is of great significance to the whole pavement crack detection work. The schematic diagram of pavement crack detection algorithm is shown in Figure 2.

(a) Lateral crack



(b) Longitudinal crack



(c) Grid crack

(d) Massive crack

Figure 1: Fracture classification.

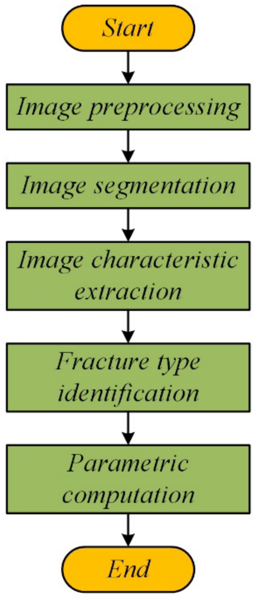


Figure 2: Block diagram of pavement crack detection and recognition algorithm.

3. Principle of Pavement Crack Image Detection Algorithm

3.1 Common Processing Mode

(1) Grayscale processing of images

Image gray processing is the first step of image preprocessing algorithm. Grayscale is a kind of image with only black and white brightness information, and its display performance is better. At present, most of the collected pavement crack images need to be processed with gray level. In Matlab, gray image is often regarded as a digitized matrix, and the value in this data matrix is the gray value of image color, while the elements in each numerical matrix represent the pixels of gray image [8].

In the RGB model, to achieve the graying of pavement crack images, it is only necessary to use the same values of R, G and B, and the RGB values used are called gray values [9].

At the same time, the weighted average method can also be used for gray processing of colored pavement crack images. According to the importance of RGB and other indicators, the three components are usually taken with unequal weights for weighted average operation, so as to complete the gray processing of pavement crack images. The mathematical formula of weighted average algorithm is as follows:

$$Gray = R \times 0.299 + G \times 0.587 + B \times 0.114 \quad (1)$$

According to Formula (3.1), gray processing of color pavement crack image can be completed, so as to obtain gray image of pavement crack containing only bright information.

If you want to display a gray image in Matlab, you can directly call up the imagesc function (that is, image scaling function), and use the gray image scaling function to display a pavement crack image well, as shown in Figure 3

(2) Median filtering of image

After gray processing, the characteristics of pavement cracks can be seen more clearly. However, because the collected image information also contains a lot of noise interference information, so in order to better process the image for the next step of image segmentation, it is necessary to add the median filtering algorithm of pavement crack image in the image preprocessing algorithm. Filtering algorithms can be divided into traditional median filtering algorithm and multi-structure median filtering algorithm according to different forms of templates [10].

ISSN 2616-5775 Vol. 6, Issue 1: 83-98, DOI: 10.25236/AJCIS.2023.060113

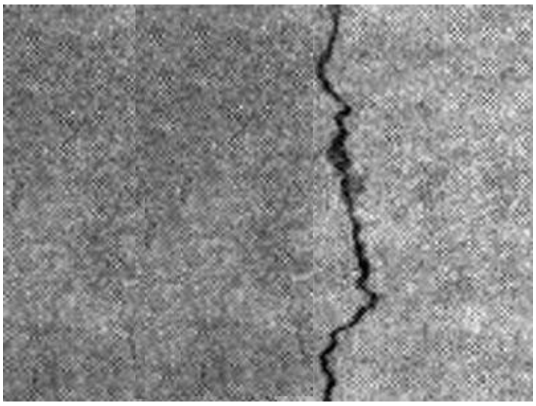


Figure 3: Gray-scale image display of pavement cracks.

The traditional median filtering algorithm uses a single image processing template which mainly arranges the signal data sequence inside the window according to certain rules. If the length of the initial data sequence is *M*, it can be expressed as:

$\left\{x(0), x(1), x(2)..., x(m-1)\right\}$, the length of the window is denoted as *2n+1*, as $\left\{w(0), w(1), w(2)..., w(2n)\right\}$, Then it takes *m-2n* permutations of length *2n+1*. The traditional median filtering algorithm flow can be shown in Figure 4

When the amount of calculation is large, in order to filter the noise of pavement crack image better, the multi-structure median filtering algorithm can be used. Multi-structure median filtering adopts several 3×3 structural elements of different shapes to filter the gray image successively, and processes the gray image of pavement cracks from several different angles, thus completing the noise filtering of the gray image of cracks more effectively [11]. The basic principle of multi-structure pavement crack image filtering is shown in Figure 5 The multi-structure median filtering algorithm can be used to denoise the crack gray image better and enhance the crack display effect.

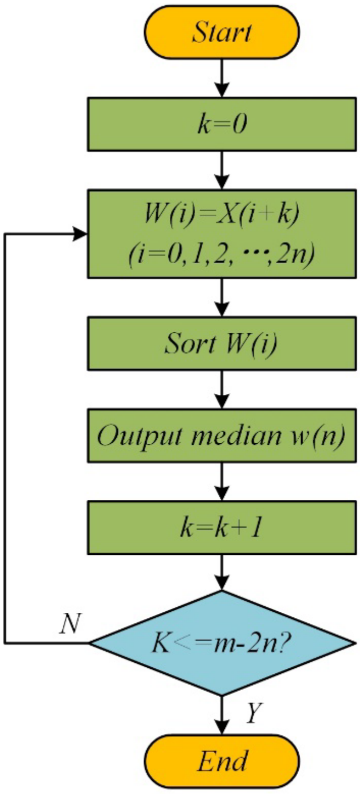


Figure 4: Flow chart of traditional median filtering algorithm.

ISSN 2616-5775 Vol. 6, Issue 1: 83-98, DOI: 10.25236/AJCIS.2023.060113

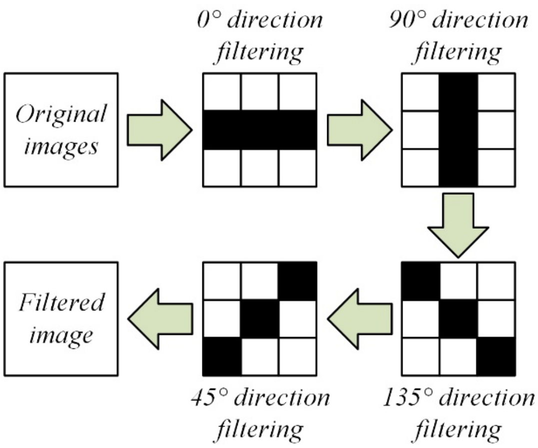


Figure 5: Multi - structure median filter flow chart.

(3) Image enhancement processing algorithm

Considering that the crack image quality is affected to varying degrees due to the uneven illumination in the actual environment, the image enhancement algorithm can effectively correct the adverse effects of illumination and other shooting factors on the crack image, so as to improve the clarity of the image [12]. Image enhancement algorithms mainly include histogram equalization and GAMMA transform.

The purpose of histogram equalization is to make the gray level of the image easier to distinguish. Assume that the collected crack image is transformed by the following formula:

$$s = T(r), 0 \le r \le L-1 \tag{2}$$

Where, L is the gray level of the crack image. Our aim is to equalize the grayscale probability distributions:

$$P(s) = 1/(L-1) \tag{3}$$

The distribution relationship of gray level before and after transformation is as follows:

$$P(s) = p(r)(dr/ds) \tag{4}$$

Hence:

$$T(r) = (L-1)p(r) \tag{5}$$

Discretization can be expressed as:

$$s = (L-1)/MN*(0+1+2+...+L-1) \tag{6}$$

After histogram equalization processing of pavement crack images, image enhancement processing results as shown in Figure 6 can be achieved.

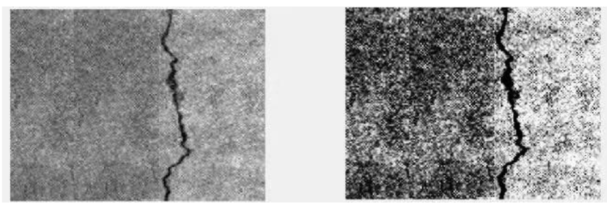


Figure 6: Histogram original gray image and equalization results.

The image enhancement algorithm of GAMMA transform is mainly used to correct crack images, which can enhance the contrast of pavement cracks. Its transformation formula is as follows:

$$s = cr^{\gamma} \tag{7}$$

The GAMMA curve in Figure 7 shows how it works. It can be found that when $r < 1$, GAMMA transform can stretch the lower gray level of the image and compress the higher gray level of the image.

ISSN 2616-5775 Vol. 6, Issue 1: 83-98, DOI: 10.25236/AJCIS.2023.060113

When $r \geq 1$, GAMMA transform can stretch the higher gray level part of the image and compress the lower gray level area, so that the enhancement of pavement crack image can be completed by GAMMA transform under various conditions.

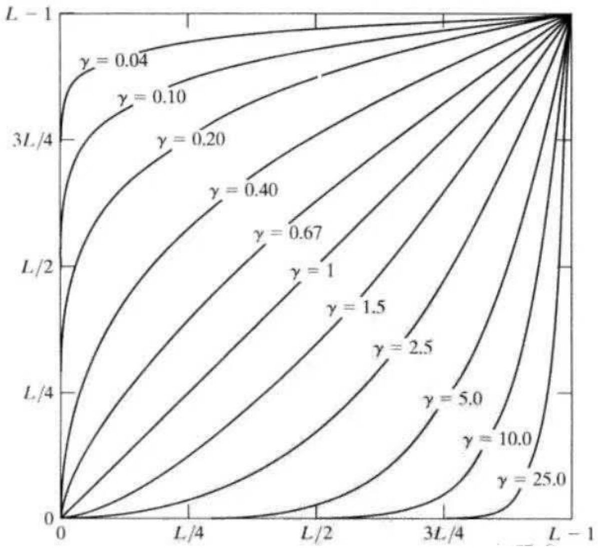


Figure 7: GAMMA transformation principle.

(4) Image smoothing and denoising

The last step of crack image preprocessing algorithm is systematic smoothing and denoising. In the shooting process of the road crack image acquisition vehicle and the information transmission process of the image, due to the influence of climate factors and transmission conditions, the crack image will inevitably produce a lot of different *degrees* of noise. Systematic smoothing and denoising of crack images is an important prerequisite for extracting crack features and segmenting crack images [13]. The median filtering algorithm has been mentioned above, so the paper focuses on two smooth denoising methods of crack image, namely mean filtering and bilateral filtering.

Mean filtering is also known as linear filtering. The basic principle of linear filtering is to replace the original pixel value of each pixel in the original image with the mean value filtering, which can save processing time and facilitate algorithm processing [14]. The processing results of mean filtering on crack images are shown in Figure 8.

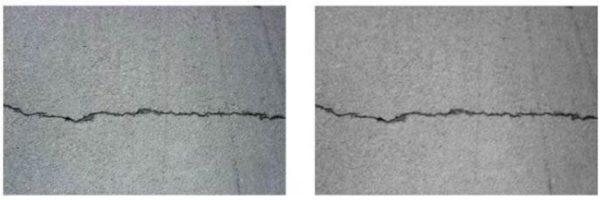


Figure 8: Crack original gray image and mean filtering results.

At the same time, the mean filtering itself has inherent defects, that is, it can not protect image details well, while the mean filtering also destroys many details of the image, and cannot remove noise points perfectly [15].

Bilateral filtering is a nonlinear filter, which can remove noise points in pavement crack images more effectively than mean filtering [16]. The expression of the filtering algorithm of the bilateral filter is:

$$g(x, y) = \frac{\sum_{i,j} f(i, j)\omega(x, y, i, j)}{\sum_{i,j} \omega(x, y, i, j)} \tag{8}$$

After bilateral filtering processing, the filtering result in Figure 9 can be obtained

Figure 9: Crack original gray image and bilateral filtering results.

It is not difficult to see from the comparison processing results that the bilateral filtering results have a better preservation effect on the high-frequency information of the crack edge, and can improve the noise removal effect on the premise of effectively protecting the edge and crack information, and the effect is better than the mean filtering.

3.2 Image Segmentation Method

(1) Threshold based segmentation method

The processing principle of the crack image is to use several thresholds to segment the crack image into several different areas. In most cases, the normalized gray value is used to segment the crack image. In general, the threshold value is called T, if the pixel of the current pavement crack image is (i, j), the gray value of the crack image pixel is $f(i, j)$, and the feature of the area around the pixel point is $H(i, j)$, then the threshold value T can be expressed as:

$$T = F\left[(i, j), f(i, j), H(i, j)\right] \tag{9}$$

The definition formula of the processed pavement crack image is:

$$g(i, j) = \begin{cases} 1, & f(i, j) > T \\ 0, & f(i, j) \le T \end{cases} \tag{10}$$

When the threshold is represented as a function only related to $f(x, y)$, T is the global threshold, that is, only one threshold is needed to segment the crack image. When the contrast between the crack image and the background is uneven, the threshold is correlated with (x, y), $f(x, y)$ and $H(x, y)$. Therefore, the size of the threshold should be dynamically selected through the neighborhood coordinates around the pixel point, and T is called the adaptive threshold at this time. When the distribution of pixels in the crack image is uneven, the crack image needs to be divided into several sub-regions with balanced gray values, and a global threshold is selected for each sub-region. In this case, T is called the local threshold [17].

Through the comparative analysis of various parameters, it is obvious that the threshold based segmentation algorithm can flexibly segment the crack image, so as to obtain the crack feature part that this paper aims to extract, which is conducive to deeper recognition and analysis of the pavement crack image [18].

(2) Edge based segmentation method

The crack edges of pavement crack images can be effectively detected from images or even dynamic videos by using the edge based segmentation method. The edge of the crack image usually has a lot of blurred pixels, and in many cases the color and brightness values of the crack edge are completely different from those of the surrounding pixels. The main features of the crack image can be reflected through the edge-based segmentation, which greatly reduces the amount of calculation of crack parameters [19].

When there is less noise at the crack edge of pavement crack image and the gap between the crack edge and the surrounding pixels is large, the first step degree operator can be used to complete the edge segmentation of pavement crack image well. The expression of the first step degree operator is:

$$\nabla f(x, y) = \frac{\partial f}{\partial x} i + \frac{\partial f}{\partial y} j \tag{11}$$

ISSN 2616-5775 Vol. 6, Issue 1: 83-98, DOI: 10.25236/AJCIS.2023.060113

By comparing each pixel of the crack image with the threshold value of the region, the edge position of the crack with less noise can be determined, so as to complete the segmentation of the image.

When feature extraction of crack image needs to be operated simultaneously under the condition of image gradient transformation, the second-order gradient operator is used for edge segmentation of crack image. The second order gradient operator can be expressed by the following formula:

$$\nabla^2 f(x,y) = \frac{\partial^2 f(x,y)}{\partial x^2} + \frac{\partial^2 f(x,y)}{\partial y^2} \quad (12)$$

Sobel operator is also a common operator in edge-based crack segmentation algorithm. When four different directions of Sobel operator are applied to extract the edge of pavement crack image, the edge information of crack can be extracted more effectively than the traditional single Sobel operator, and the edge image of crack can be strictly separated from the pavement background. It also greatly improves the efficiency of crack image processing. The flow chart of Sobel algorithm in four directions is shown in Figure 10.

3.3 Image Feature Extraction and Parameter Calculation Method

After the segmentation and gray-scale processing of pavement images are completed, the image projection analysis method is used to extract features and calculate parameters of pavement cracks. The projection method has few calculation steps and simple crack parameters, so it is widely used in the field of highway image processing [20]. In the recognition and calculation of projection method, since the image containing pavement crack has now become a binary crack image, that is, the target crack with pixel value of 0 and the pavement background with pixel value of 1, the horizontal and vertical projections of pavement crack image can be taken respectively, denoted as X and Y[21]. This gives us an expression for X and Y:

$$X(i) = \sum_{j=0}^{M} f(i,j) \quad i = 1,2,L,N \quad (13)$$

$$Y(j) = \sum_{j=0}^{N} f(i,j) \quad j = 1,2,L,M \quad (14)$$

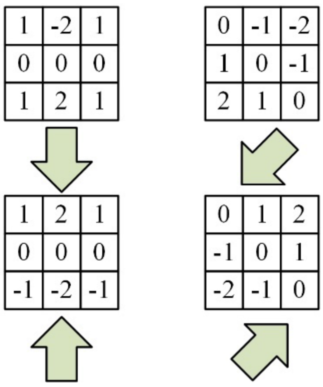


Figure 10: Sobel algorithm flow.

Therefore, it is more convenient to analyze the characteristics of crack from the projection of crack X and crack Y. For the unidirectional transverse pavement crack, its projection is very uniform in the horizontal direction, and there will be obvious crest in the vertical direction. For the one-way longitudinal pavement crack, its projection in the vertical direction is very uniform, and the wave crest appears in the horizontal direction. For massive or irregular network cracks, obvious crests can be seen in both directions at the same time [22]. Based on the conclusions obtained by the research, the maximum difference between the X direction and the Y direction can be calculated:

$$x_{\max} = \max\{X(i+10) - X(i)\} \quad (15)$$

$$y_{\max} = \max\{Y(j+10) - Y(j)\} \quad (16)$$

ISSN 2616-5775 Vol. 6, Issue 1: 83-98, DOI: 10.25236/AJCIS.2023.060113

Among them,

$$i = 1, 2, L, N - 10 ; \; j = 1, 2, L, M - 10 .$$

The type of fracture can be more clearly analyzed by the maximum difference value of X and Y directions: the maximum value of X is smaller than the maximum value of Y; The Y maximum value of longitudinal fracture is smaller than the X maximum value. The maximum X and Y values of massive and reticular fractures are very small.

The parameter calculation of crack mainly lies in calculating the length and width of pavement crack. In the parameter calculation process of projection method, if the key parameters of the crack image currently processed are to be calculated, it is necessary to determine the edge position of the pavement crack first. In the relatively regular pavement crack image, finding the centroid coordinates of the crack in the X and Y directions is the first step of parameter calculation. The coordinates of the center of mass can be expressed by the following formula:

$$x_{cen} = \frac{1}{sum} \sum_{f(i,j)=1} j \tag{17}$$

$$y_{cen} = \frac{1}{sum} \sum_{f(i,j)=1} i \tag{18}$$

Where, sum is the number of all pixels contained in the pavement crack image. The left and right positions of the cracks in the horizontal direction and the up and down positions in the vertical direction can be determined by the obtained centroid position. Therefore, the transverse length L_x and longitudinal length L_y of the pavement cracks can be obtained by subtracting the coordinates of the two. Finally, the actual length of the entire pavement crack is the product of the transverse length and longitudinal length of the crack image respectively and the size d of the actual pavement length represented by an image pixel. That is, the actual length L of pavement crack is $L_y \times d$, and the actual width W is $L_x \times d$.

4. The GUI Realization of Pavement Crack Detection

4.1 Image Preprocessing

In image preprocessing, grayscale processing, smoothing and denoising processing and enhancement processing should be carried out for different types of cracks. The gray image of pavement cracks can be loaded into Matlab through the loading image program of GUI interface, which can realize the first step of image preprocessing. The overall GUI program operation interface is shown in Figure 11.

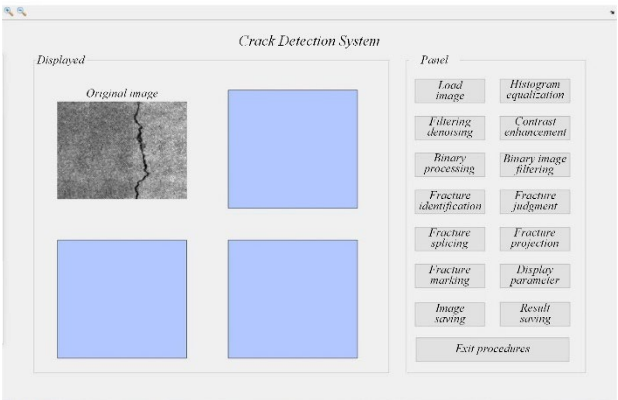


Figure 11: GUI for crack detection system.

The first step of the actual experimental operation process requires loading the crack image file in the GUI interface, and the corresponding code can realize the first step of the operation. The part of the

ISSN 2616-5775 Vol. 6, Issue 1: 83-98, DOI: 10.25236/AJCIS.2023.060113

program code that loads the image file into the GUI program is shown in Figure 12.

```
[filename, pathname] = uigetfile({' *. jpg;*. tif;*. png;*. gif' ,' All Image Files' ;...
    '*.*',' All Files'}, 'Load Image',...
fullfile(pwd,'images'));
I = imread(fullfile(pathname, filename));
Result = Process_Main(I);
handles.File = fullfile(pathname, filename);
handles.Result = Result;
guidata(hobject, handles);
InitAxes(handles)
axes(handles. axes1); imshow (handles.Result.Image); title('Original Image');
```

Figure 12: Load the image file code.

Histogram equalization algorithm is used to enhance the pavement crack image. As for the enhancement results of histogram equalization, the original grayscale images of several pavement cracks and the contrast images after enhancement are shown in Figure 13, 14, 15 and 16.

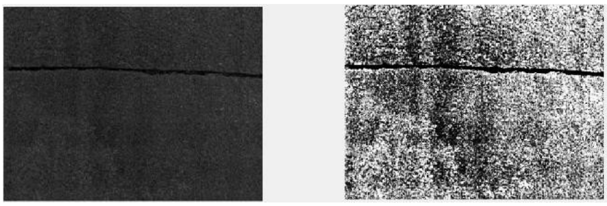


Figure 13: Horizontal crack gray image histogram equalization processing results.

Figure 14: Histogram equalization enhancement results of longitudinal crack gray image.

Figure 15: Histogram equalization enhancement results of block-crack gray image.

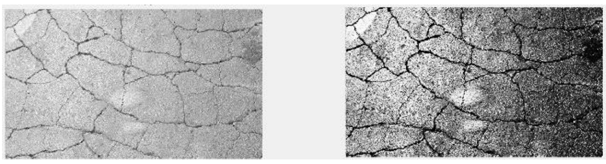


Figure 16: Histogram equalization enhancement results of gray-scale mesh crack images.

For histogram equalization processing of crack image, the program in the GUI interface is shown in Figure 17.

```
function pushbuttonHisteq_Callback (hObject, eventdata, handles)
% hObject    handle to pushbuttonHisteq (see GCBO)
% eventdata reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
if ~isempty (handles.Result)
    axes (handles. axes1); imshow (handles. Result. Image); title('Original image');
    axes (handles. axes2); imshow (handles. Result. hist); title('Histogram equalization image');
end
```

Figure 17: Histogram equalization file code.

ISSN 2616-5775 Vol. 6, Issue 1: 83-98, DOI: 10.25236/AJCIS.2023.060113

The last step of image preprocessing experiment is to smooth and denoise the gray-scale pavement crack image. In the experiment process, the denoising processing algorithm of median filter is selected in this paper, and the pre-processing results of pavement crack gray image are shown in Figure 18, 19, 20 and 21.

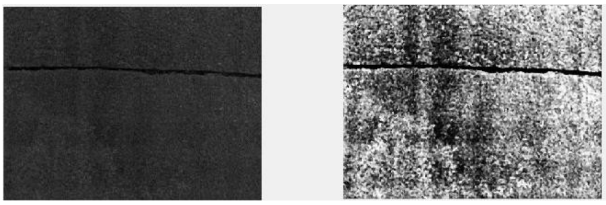


Figure 18: Image denoising by transverse crack median filtering.

Figure 19: Image denoising by longitudinal crack median filtering.

Figure 20: Image denoising by block crack median filter.

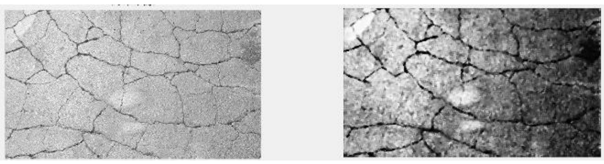
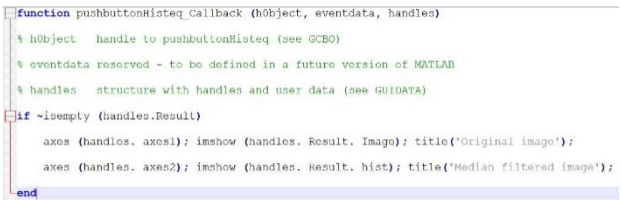


Figure 21: Image denoising by mesh crack median filtering.

The experimental results show that the image smoothing and denoising using the median filter algorithm can effectively remove the influence of imaging equipment and external noise interference in the transmission process of crack image, improve the overall quality of crack image to a large extent, and avoid the influence of noise on crack identification. The median filter processing of crack image in the GUI interface is shown in Figure 22.



```
function pushbuttonHisteq_Callback (hObject, eventdata, handles)
% hObject    handle to pushbuttonHisteq (see GCBO)
% eventdata reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
if ~isempty (handles.Result)
    axes (handles. axes1); imshow (handles. Result. Image); title('Original image');
    axes (handles. axes2); imshow (handles. Result. hist); title('Median filtered image');
end
```

Figure 22: Median filter denoising program code.

4.2 Segmentation of Image

For the image segmentation experiment, this paper adopts the crack image binarization processing and binary filtering processing, and uses the improved Sobel operator based on four different directions and the threshole-based segmentation algorithm to carry out the segmentation processing. The segmentation processing results of various types of crack images are shown in Figure 23, 24, 25 and 26.

ISSN 2616-5775 Vol. 6, Issue 1: 83-98, DOI: 10.25236/AJCIS.2023.060113

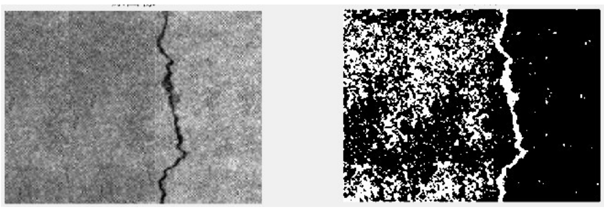


Figure 23: Transverse crack segmentation image based on four different directions of Sobel algorithm.

Figure 24: Longitudinal crack segmentation image based on four different directions of Sobel algorithm.

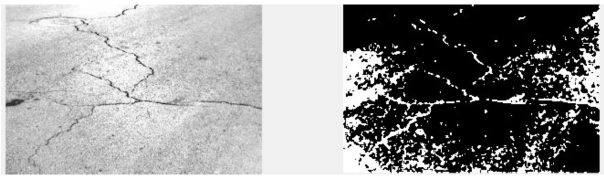


Figure 25: Block crack segmentation image based on four different directions of Sobel algorithm.

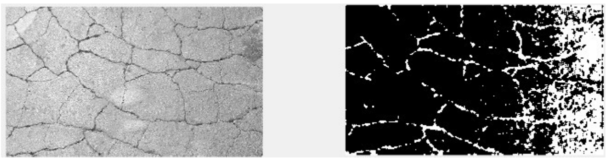


Figure 26: Network crack based on four different directions of Sobel algorithm segmentation image.

From the results of image segmentation processing, Sobel algorithm intercepts relatively complete crack image information, but in the process of image segmentation, many noise points are not effectively removed, and the expected crack image segmentation results are not achieved. Therefore, this paper uses another method to re-segment the crack image. The processing results of the image segmentation method based on threshold value for the crack image are shown in Figure 27.

The experimental results show that the image segmentation algorithm based on threshold value can flexibly segment the crack image effectively, and remove unnecessary white noise points, so as to obtain the crack feature part that we want to focus on in this paper, with good processing results.

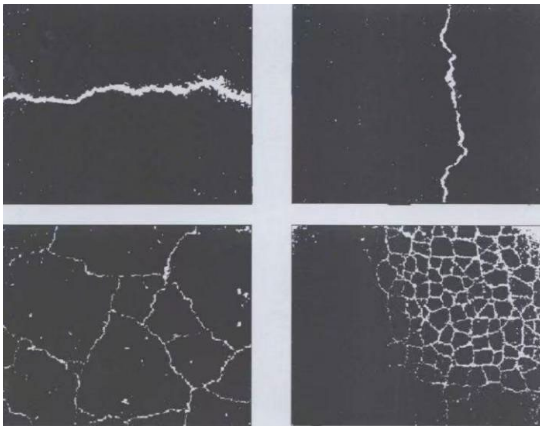


Figure 27: Several types of crack based on threshold segmentation algorithm processing image.

4.3 Image Feature Extraction

The last step of pavement crack detection and recognition algorithm is feature extraction of crack image. Taking massive crack as an example, feature extraction was carried out on its image in this paper. First of all, crack recognition and judgment should be carried out on the GUI interface for crack feature extraction. If there is discontinuity between cracks, crack image stitching can be carried out on the GUI interface, and finally the feature projection of cracks can be displayed. Figure 28 shows the feature extraction results after crack image recognition and judgment.

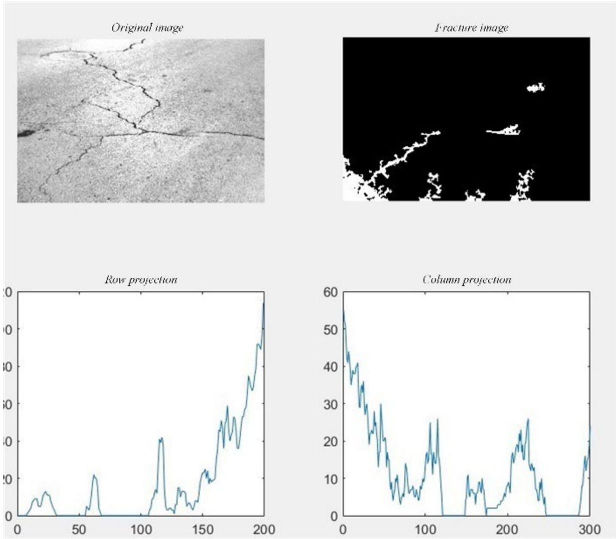


Figure 28: Feature extraction results of crack image.

The experimental results show that through the analysis of horizontal and vertical crack projections, the massive crack has obvious wave peaks in the X and Y directions, which verifies the above conclusions of feature extraction of crack images based on image projection analysis, and then the maximum difference values in the X and Y directions can be calculated respectively, which effectively completes the determination of crack types.

After the crack feature extraction is completed, the crack image after feature extraction is usually marked to facilitate the subsequent crack image processing. Taking longitudinal crack as an example, the marking results after feature extraction of crack image are shown in Figure 29 on the GUI interface.

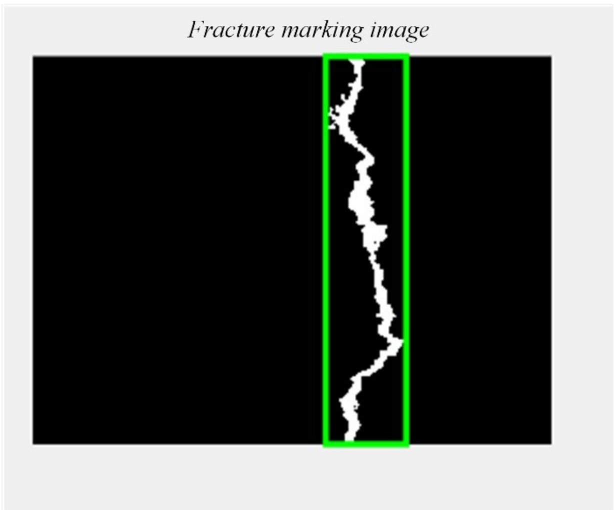


Figure 29: Crack marking image.

As can be seen, crack images can be clearly marked through the crack marks on the GUI interface, effectively improving the efficiency of crack detection. Part of the GUI interface used in the process of crack feature extraction and labeling is shown in Figure 30.

ISSN 2616-5775 Vol. 6, Issue 1: 83-98, DOI: 10.25236/AJCIS.2023.060113

```
if ~isempty(handles. Result)
    axes (handles. axes1); imshow (handles. Result. Image); title('Original image');
    axes (handles. axes2); imshow (handles. Result. BwFilter); title('Binary filtered image');
    axes (handles. axes3); imshow (handles. Result. CrackRec); title('Fracture identification');
    axes (handles. axes4); imshow (handles. Result. CrackJudge); title('Fracture judgment');
end
% --- Executes on button press in pushbuttonCrackLoc.
function pushbuttonCrackLoc_ Callback(hObject, eventdata, handles)
% hObject   handle to pushbuttonCrackLoc (see GCBO)
% eventdata reserved- to be defined in a future version of MATLAB
% handles   structure with handles and user data (see GUIDATA
if ~isempty (handles. Result)
    axes (handles. axes1); imshow (handles. Result. Image); title('Original image');
    axes (handles. axes2); imshow (handles. Result. CrackJudge); title('Fracture image');
    axes (handles. axes3); imshow (handles. Result. CrackJudge); title(handles. Result. str);
    axes (handles. axes4); imshow (handles. Result. CrackJudge); title('Fracture marking image');
    hold on;
    rectangle('Position', handles. Result. rect, 'EdgeColor', 'g', ' Linewidth', 2);
    hold off;
end
```

Figure 30: Crack marking and feature extraction file code.

The crack image parameters can be calculated after the crack mark recognition is completed. For the crack image in Figure 4.18, the parameter calculation results of the crack are displayed in the GUI display interface, as shown in Figure 31.

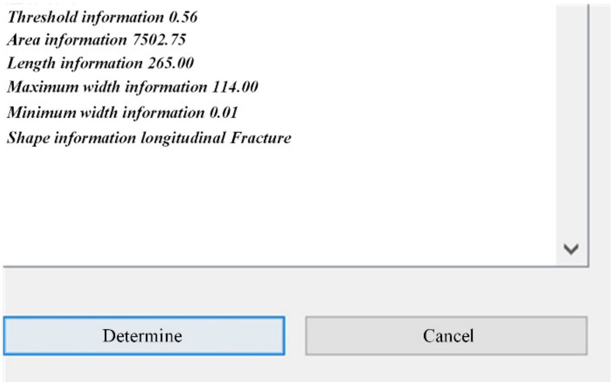


Figure 31: Fracture parameter calculation results.

On the GUI display interface, you can see the threshold information, area information, length information, maximum width information, minimum width information and other parameters of the crack, which reflects the characteristic value of the crack in a more comprehensive way. Part of the GUI program code for crack parameter calculation is shown in Figure 32.

```
if ~isempty(handles. File)
    raw = [];
    xlsfile = fullfile (pwd,' Result/result. xls');
    if exist(xlsfile, 'file')
        [num, txt, raw] = xlsread(xlsfile);
    end

    F =[];
    F{1, 1} = 'File name';
    F{1, 2} = 'Threshold information';
    F{1, 3} = 'Area information';
    F{1, 4} = 'Length information';
    F{1, 5} = 'Maximum width information';
    F{1, 6} = 'Minimum width information';
    F{1, 7} = 'Shape information';


    F{2, 1} = handles. File;
    F{2, 2} = handles. Result. BwTh;
    F{2, 3} = handles. Result. BwArea;
    F{2, 4} = handles. Result. BwLength;
    F{2, 5} = handles. Result. BwWidthMax;
    F{2, 6} = max(handles. Result. BwWidthMin, 0.01);
    F{2, 7} = handles. Result. str;

    F = [raw; F];
    xlswrite(xlsfile, F);
    msgbox('Save the result successfully!','Information prompt box');
    end
catch
```

Figure 32: Crack parameter display file code.

In order to verify the accuracy of the pavement crack detection and recognition system in this paper, the algorithm processing and parameter calculation are carried out on various types of crack images. The parameter recognition results of 10 crack images randomly selected from the recognized crack images are shown in Table 1.

After many validations, it can be seen that although there are many interference of image quality factors and transmission quality factors, the accuracy rate of pavement crack image recognition and calculation of the system can still reach 80%, and the algorithm program developed is relatively feasible. However, the recognition accuracy of massive cracks still has some deviation, so the algorithm program has some improvement.

ISSN 2616-5775 Vol. 6, Issue 1: 83-98, DOI: 10.25236/AJCIS.2023.060113

5. Conclusion

The main work of this paper is to use pavement crack detection and recognition algorithm to efficiently identify and process road crack images. The main work process is as follows:

(1) This paper summarizes the formation reasons and types of pavement cracks and expounds the application of pavement crack detection and recognition algorithm and the basic working principle of pavement crack recognition.

(2) Using Matlab to collect the pavement crack image image preprocessing, image segmentation and feature extraction process, the pavement crack image gray processing, smooth denoising, enhancement processing, image segmentation based on several different algorithms, based on the parameter calculation of binary image projection, compared the advantages and disadvantages of several mainstream image processing algorithms. Through the recognition and parameter calculation of a variety of different types of crack images, it is verified that the accuracy of the threshold segmentation algorithm and the binary image projection analysis method for crack recognition and parameter calculation, the recognition rate can reach more than 80%, which is better than the processing results of Sobel algorithm. However, there are still defects in the recognition of massive cracks, which need to be improved in the future.

Table 1: Crack image parameter identification results

Image sequence	Fracture type	Type of identification	Fracture length	Cracks area	Crack threshold
1	Longitudinal fracture	Longitudinal fracture	540.00	20058.00	0.54
2	Reticular fissure	Reticular fissure	366.45	8809.82	0.55
3	Transverse fracture	Transverse fracture	432.06	5500.32	0.54
4	Longitudinal fracture	Longitudinal fracture	441.09	7633.14	0.56
5	Massive fracture	Reticular fissure	386.26	9655.40	0.55
6	Reticular fissure	Reticular fissure	444.47	5925.79	0.56
7	Transverse fracture	Transverse fracture	327.94	6988.60	0.54
8	Massive fracture	Massive fracture	559.68	7605.00	0.53
9	Reticular fissure	Reticular fissure	290.02	3607.25	0.56
10	Massive fracture	Reticular fissure	455.00	8849.66	0.54

References

[1] Jiayi H. Research on Pavement crack Detection Algorithm based on OpenCV [D]. Harbin: Harbin Engineering University, 2017.
[2] Weiye W, Xianfu Y. Urban road construction quality standardization management [M]. Hangzhou: Zhejiang Gongshang University Press, 2018.
[3] Baoan H, Rong C. Research on pavement crack image recognition algorithm [J]. Digital Technology and Applications, 2015(1): 127.
[4] Shao B. Research on image detection algorithm of asphalt pavement crack [D]. Xian: Chang 'an University, 2008.
[5] Peng B, Jiang Y S, Pu Y. Pavement Crack Detection Algorithm Based on Bi-Layer Connectivity Checking [J]. Journal of Highway & Transportation Research & Development, 2014, 8(4): 37-46.
[6] Zedong Q. Research on automatic crack recognition Algorithm of Asphalt pavement based on intelligent image processing [D]. Nanjing: Southeast University, 2014.
[7] Aijun X. Research on common diseases and maintenance treatment technology of highway asphalt pavement [J]. Heilongjiang Communications Technology, 2012, 35(1): 11-12.
[8] Yu X. Research on key algorithms in vehicle detection [D]. Shanghai: Shanghai Jiao Tong University, 2009.
[9] Wanli W. Research on road defect detection and recognition algorithm [D]. Wuhan: Wuhan Institute of Technology, 2015.
[10] Changrong X. Design and research of pavement crack detection system [D]. Xian: Chang 'an University, 2008.
[11] Dejin Z, Qingquan L, Ying C, et al. An asphalt pavement crack detection method based on spatial aggregation characteristics [J]. Acta Automatica Sinica, 2016, 42(3): 443-454.
[12] Hang Z. High-resolution No.1 remote sensing image segmentation method based on full convolutional network [D]. Taian: Shandong Agricultural University, 2018.
[13] Bin Q, Zhenmin T, Xiaobo S, et al. Pavement crack detection based on multi - feature manifold

ISSN 2616-5775 Vol. 6, Issue 1: 83-98, DOI: 10.25236/AJCIS.2023.060113

learning and matrix decomposition [J]. Journal of Scientific Instrument, 2016, 37(7): 1639-1646.
[14] Yingping W. Research on Improved Face recognition Algorithm based on compressed sensing [D]. Hanzhou: Zhejiang University of Technology, 2017.
[15] Na L. Urban pavement crack detection based on image processing technology [D]. Fuxin: Liaoning Technical University, 2015.
[16] Ke Z. Research on Pavement crack image Automatic recognition System [D].Xian: Chang 'an University, 2009.
[17] Xinghan Q. Research on Pavement Crack detection and recognition based on image segmentation [D]. Chongqing: Chongqing Jiaotong University, 2012.
[18] Xu H. Research on image - based pavement crack detection technology [D]. Tianjin: Hebei University of Technology, 2016.
[19] Meilin H, Li W. Design of pavement crack detection and recognition system [J]. Naval Electronic Engineering, 2020, 40(8): 151-154.
[20] Chong Z. Pavement crack detection and analysis based on MMS image [D]. Beijing: Beijing University of Civil Engineering and Architecture, 2017.
[21] Bo P, Yangsheng J, Yun P. Automatic pavement crack classification algorithm based on digital image processing [J]. China Journal of Highway and Transport, 2014, 27(9): 10-18.
[22] Henrique O, Paulo L C. Identifying and retrieving distress images from road Pavement Surveys[J]. IEEE, 2008: 57-60.