Research on Image Processing Methods in Pavement Crack Extraction

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Abstract. Since the acquired road images are affected by weather and lighting factors, a large amount of noise information is contained. Therefore, it is necessary to denoise the image. Based on the acquired large number of images, the best method is selected through comparison to three image compression methods; after compressed, the image gray-scale processing method based on YUV is selected through comparison; then, the image enhancement processing method based on the frequency domain transformation is selected, and the image denoising process is performed by comparing three denoising methods, the best effect is for median filter; finally, the two image stretching methods are compared, by using the custom function adjstra method, the better image stretching effect can be achieved. So, the image processing method selected by the invention can enlarge the useful information of the image more effectively, and simultaneously, the influence of image noise is greatly reduced.

1. Introduction
In the process of image acquisition, due to the influence of various factors such as weather, lens distortion and so on, the collected road surface image contains a large amount of noise information independent of crack extraction. These noises not only affect the visual effects of pavement disease images, but also bring great difficulties to the feature extraction and disease analysis of subsequent cracks. It is an important preliminary work that image preprocessing can aim to improve image quality, enhance the contrast between image background and target information, and highlight the objects of interest. Thus, it can reduce the amount of image noise information and improve the image quality and improve the accuracy of information [¹].

Digital image processing is a method and technology for removing noise, enhancing, and restoring, segmenting, extracting features and so on [², ³]. The rapid development of remote sensing technology, computer technology and mathematics has led to the rapid development of digital image processing, which has been widely used in agriculture, animal husbandry, forestry, environment, military, industry and medicine. In agriculture, Prabira kumar sethy et al mainly used image enhancement technology to eliminate image noise in the detection of plant leaf disease [⁴]. Anita kinnikar et al. used the color histogram to identify and detect soybean seed disease images, and based on the enhancement of image processing to increase contrast and smoothness to detect plant infection [⁵]. G nagalakshmi mainly uses median filter for noise reduction of shrimp species image [⁶]. In the engineering field, Bin lei et al use
UAV image processing to identify and detect bridge cracks [7]. Because of the poor contrast and serious noise of UAV images, image enhancement and filtering techniques are used to reduce the noise effect [8]. S. Chandran, m. using image enhancement and image segmentation methods [9]. V. Ganeswar Rao uses image processing technology for face recognition, in which binarization and filtering techniques are used to suppress noise [10]. In the military field, K. A. Ghani and others use image processing technology to identify battle tanks and armoured personnel carriers [11].

Although it is used in many fields, it is seldom used in pavement image crack extraction. In this paper, many image processing techniques are used to remove noise and improve image quality based on pavement image.

2. Image Compression
In order to further improve the efficiency of image processing and save storage space, the processing efficiency is reduced because the resolution of images collected by road surface acquisition equipment is too large, so in order to further improve the efficiency of image processing and save storage space, in order to further improve the efficiency of image processing and save storage space, the road image needs to be compressed. In Matlab, the function `imresize()` is used to compress the processed image[12]. Optional values of parameters method are three commonly used image pixel compression methods: nearest neighbor interpolation method, bilinear interpolation method and bicubic interpolation method. Of course, the effect of bicubic interpolation pixel compression method is preferable, but the operation process is complicated, and if the number of images to be processed is large, more calculation time is consumed.

3. Image Gradation
The collected images of pavement cracks are usually color or luminance images. In order to reduce the amount of computation, the cracks in the images are extracted by digital image processing technology, and each color component of the image needs to be processed separately. To improve efficiency, color images must be converted to gray images [13]. The process of converting color images to grayscale images is usually called grayscale processing. The gray value of pixels in grayscale image is in the range of 0-255. There are generally two methods for graying color images: (1) The average value of (R, G, B) with each pixel point in the image is calculated, and which is taken as the output value of the corresponding pixel point after gray processing. (2) In the space of YUV (Y represent luminance, U and V represent chroma), it is graying the image through the transformation relation, we can obtain the conversion relationship between the Y component and the (R, G, B) component. Through the experiment contrast, we choose the second method to carry on the grayscale processing.

4. Image Enhancement
In either way, the original images are noisy to some extent. These noises make the image quality decline, which seriously affect the visual effect, but also bring great difficulties to the extraction and analysis of the crack information in the image. Therefore, it is necessary to process these noisy images. Image enhancement is a very effective processing method. The purpose of image enhancement is to enhance the desired features while weakening or removing some noise information. The main content of image enhancement is to improve the intelligibility of the image. Image enhancement is mainly divided into two categories: one is to enhance the object of interest in the image by processing information other than the attenuated target; the other is to keep the noisy image as close as possible to the original image by changing the factors causing the degradation of image quality. According to the difference of processing space, the methods of image enhancement are divided into two kinds: spatial domain and frequency domain. Spatial domain method is based on image pixels, while frequency domain method is based on Fourier transform. The spatial domain method can be defined by Eq. (1):

$$g(x,y) = T[f(x,y)]$$  \hspace{1cm} (1)

Among them, $f(x, y)$ and $g(x, y)$ input images and processed images respectively. $T$ is an enhancement operation. According to the definition range of $T$, $T$ is divided into point operation and
template operation. If $T$ is defined on each point coordinate in the image, then $T$ is a point operation; if $T$ is defined on a certain region of the image, then $T$ is a template operation.

4.1. Frequency Domain Enhancement Method

After the image is processed in the image transform domain, the indirect processing method is transformed back to the spatial domain. Where: $f(x, y)$ and $f(U, V)$ are the original image and the result of positive transformation respectively. $H(U, V)$ is a modified coefficient, $g(U, V)$ is the result of the correction, $g(x, y)$ is $g(U, V)$ through inverse transform to enhance the image after processing.

1) Low-pass filtering method: firstly, the image in the original image space is transformed to other space by some transformation, and the image is processed to a certain extent by the special properties of these spaces. Finally, the image is transformed into the original space by the transformation relation, and the effect of image enhancement is achieved.

2) Wavelet enhancement method: wavelet analysis is the key of Fourier analysis, which can reduce the influence of low-pass filter on crack information in pavement disease image.

4.2. Histogram Equalization

By changing the gray value of the luminance image or the index image, the contrast between the background and the target of the image is increased, thus the accuracy of the recognition and extraction of the crack features in the image is improved. Histogram equalization principle and implementation steps is as following:

1) The frequency of each gray level in the image is counted and stored in the array hist.cs;
2) Establish the corresponding mapping table and store it in the array ys: 1st, the number of pixels in the statistical image is less than or equal to a certain level, and stored in the variable $t_{sum}$; 2nd, the mapping value of the corresponding gray level is obtained by Eq. (2);

$$T_s = T_{sum} \times \frac{255}{h \times l}$$

Where $h$ and $l$ are the pixel sizes about the row and column of the image respectively. $Ts$ is corresponding to the mapping value of the gray level.

3) Using the mapping table in array ys to make a new mapping of the pixel value of the original image. We will apply mathematical Eq. (3) to describe histogram equalization:

$$f(x, y) = INT\left(\frac{g(i)-g_{min}}{1-g_{min}} (L - 1)\right)$$

Where: $f(x,y)$ is the gray value of changed image, $I$ is the gray value of image before transformation, $g$ is the frequency of gray distribution, $g_{min}$ is the minimum value for the frequency of gray distribution, INT is taken as the total number of possible grayscale levels in the image, usually is 256.

Histogram equalization has obvious effect on the image with too bright background or too dark background, and the equalization is intuitive and reversible.

5. Image Denoising

In process of collecting, transmitting and processing images, because of the influence from weather, camera lens distortion and other factors, a lot of noise interference is produced, which seriously affects the image quality and characteristics of cracks in the image. In order to extract image features efficiently and eliminate these noises as much as possible. We construct and analysis image denoising methods include Wiener adaptive filtering\cite{14}, median filtering, mean filtering\cite{15} and so on.

5.1. Wiener Adaptive Filtering

Wiener adaptive filtering is the most basic but most commonly used modern filtering method with the minimum mean square error as the optimal standard. By analyzing the autocorrelation between the input random signal and the noise, the Fourier transform is used to obtain the optimal estimation of the original signal. Wiener filtering belongs to a self-adjusting smoothing filtering method. Principle of algorithm: assuming that the useful signal in the image is $y(x)$, useless signal is $n(x)$, $w(t)$ is as Wiener
filter, after \( w(t) \) filtering, the signal \( n(t) \), is reduced and the real signal \( y(t) \) is regained and restored. The optimal criteria to be followed for the resulting signal, ideally it is Eq. (4):

\[
h(t) = \hat{y}(x) = h(x) \times (y(x) + n(x))
\]

Where \( \hat{y}(x) \) is estimated value, Wiener adaptive filtering adapts to a widely used, but the operation requires all the observation data, and the conditions are difficult to satisfy. Meanwhile, it cannot be used in the case of non-stationary stochastic process and vector.

5.2. Median Filtering

Median filter is a kind of nonlinear signal processing technology based on ranking statistics theory, which can effectively suppress noise. It is simple and fast. It shows excellent performance in filtering superimposed white noise and long tail superposition noise.

\[
g(x, y) = median\{f(x-i, y-j)\} \quad (i, j) \in W
\]

In the Eq.(5): \( f(x-i, y-j) \) and \( g(x, y) \) are pixel gray values of input and output respectively, \( W \) provides template windows of \( 3 \times 3, 5 \times 5 \) and \( 7 \times 7 \) respectively. In a neighborhood with a pixel as the center, the gray value of each pixel is sorted, and the median filter takes the sorted intermediate value as the new gray value to the pixel in the center of the neighborhood. Some random noises in the image can be eliminated by median filtering. The general processing steps are divided into five steps: (1) A window containing odd pixels is generally selected;(2) Find the location of moving center pixel through window movement and record it;(3) Sort according to the gray value of pixel in the window;(4) Find the intermediate value in the sequenced gray value sequence;(5) Take the intermediate value as the new gray value of the window center pixel.

By comparing and analyzing the processing results of different templates from Fig.1, it is found that only a small part of noise is removed by using the median filter of \( 3 \times 3 \) template, and that the median filter with \( 7 \times 7 \) template is enhanced in the ability of denoising. But it is easy to cause the crack edge blur, and the \( 5 \times 5 \) template not only removes most of the noise, but also protects and strengthens the crack edge, so it is most appropriate to use \( 5 \times 5 \) template to process the median filter.

(1) Original image (2) 3 \times 3 median filter (3) 5 \times 5 median filter (4) 7 \times 7 median filter

**Figure 1.** Several median filter templates

5.3. Mean Value Filtering

Mean value filtering is also called linear filtering, that is, using the average gray values of several different pixel points as the new grayscale values for these pixels. Mean filter can suppress noise effectively, but it is easy to cause image blur, which is not conducive to crack extraction.

\[
g(x, y) = \frac{1}{M} \sum_{m, n \in S} f(x, y)
\]

Where \( S \) is the set of \( (x, y) \), \( M \) is the sum of points within \( S \), \( f(x, y) \) is the original noise image with \( m \times n \) pixels and \( g(x, y) \) is the image after domain operation. Different templates are selected according to different needs in image processing (e.g. \( 3 \times 3, 5 \times 5, 7 \times 7 \)). The effect of crack image processing is different by using different size templates. By Eq.7, the original image with noise is treated as the new gray value of a pixel, which is with the average of gray value among the pixel and its surrounding pixel. So that the noise can be removed and the function of smoothing can be achieved. So the mean filter has better smoothing effect. Under the same conditions, the above three methods can reduce the
noise to the minimum to a certain extent, but there are some differences between the conditions and corresponding effects of three methods. Therefore, it is necessary to select the best algorithm for pavement disease detection and treatment according to the specific situation.

The smaller the mean square error of Wiener adaptive filtering is, the better the denoising effect is. Median filter not only denoises but also protects the edge of the image. From the filtering effect, it can be found that the road surface crack image after median filtering achieves the goal of both protecting edge and removing noise. The mean filter algorithm is relatively simple and has a good effect in removing noise from the point, but it also weakens the useful information. Using mean value filtering to process images of road diseases can blur tiny cracks in the map. Compared with the above several denoising methods, mean filter and Wiener filter. Not only attenuate the noise, but also blur the edge of the image, and the median filter is better than other filters in image denoising and smoothing. And the effect on edge ambiguity is small, which accords with the visual characteristics of human eyes. In this paper, 5 × 5 median filter is used for image denoising.

6. Image Stretching

The image processed by median filter eliminates the isolated noise points, but weakens the image features and edges. Therefore, it is necessary to further enhance the image after median filtering [16].

6.1. Imadjust Function

Matlab provides a color matrix function that adjusts the brightness or color of a grayscale image that is imadjust(). The grammatical structure is: Image_in=imadjust (I,[l_in h_in],[l_out h_out],gamma)

The brightness value in the image I is remapped to the image in by processing, that is, the value between l in and h in is processed to map between l_out and h_out, that is to say, the value less than l_in is mapped to l_out, the value larger than h_in is mapped to h_out, the parameter gamma is used to specify the shape of the brightness value for mapping image I, if less than 1, the output is higher, and if greater than 1, the output is lower.

6.2. Custom Function Adjgamma

In this experiment, the custom function adjgamma () is used to further process the image. The basic principles are:(1) A new image matrix I1 is obtained by subtracting the image matrix from the minimum value of the matrix(Eq.(7)); (2) Each value in I1 is divided by the maximum value in I1 to obtain a new matrix I2(Eq.(8)); (3) It is determined by judging the number of input parameters n, when n is equal to 2, then g is 2, when 0 < n < 2 and when n < 0, it exits operation(Eq.(9)).

\[ I_1 = I - \text{min}(\text{min}(I)) \]  
\[ I_2 = I_1 / \text{max}(I_1) \]  
\[ I_3 = I_2 \wedge (1/g) \]

In this paper, I is image processed by median filter/. and . are point multiplication operation in an array or matrix. Compared with Fig.2 and Fig.3, the custom function adjgamma () can effectively improve the contrast between the target and the background information compared with the imadjust function.

**Figure 2.** adjgamma processing results

**Figure 3.** imadjust processing results
7. Conclusion
In this paper, the method of image processing is compared and the image compression, image graying, image enhancement, filter removal and image stretching have been carried out before the pavement crack information was extracted, so that the noise information of image is greatly reduced, and the image crack information is smoother, it is a solid foundation laying for the next step information extraction.

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