IOP Conference Series: Materials Science and Engineering

PAPER • **OPEN ACCESS**

Cement Pavement Crack Identification Method Based on DFT Transformation and Crack Segment Splicing Method

To cite this article: Hong Ying *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **562** 012157

IOP Conf. Series: Materials Science and Engineering **562** (2019) 012157 doi:10.1088/1757-899X/562/1/012157

Cement Pavement Crack Identification Method Based on DFT Transformation and Crack Segment Splicing Method

Hong Ying, Shunxin Chen and Yukai Zhang

College of Architecture and Traffic Engineering, Guilin University of Electronic Technology, Guilin 541000, China
yinghongcq@tom.com

Abstract. The groove is the biggest interference factor in the identification of cement pavement cracks. In the process of restraining or eliminating the grooves, it inevitably reduces the contrast between the cracks and the background, at the same time weakens the cracks in the grooves and destroys the connectivity of the cracks. A large number of short crack fragments are mixed with noise, which increases the difficulty of subsequent identification. In order to solve these problems, a slot elimination method based on DFT transform and a splicing method based on grid voting method are proposed. Firstly, the image of cement pavement is transformed from DFT to frequency domain, and the characteristic of groove in frequency domain spectrum is obtained. On this basis, according to the periodicity of the groove in the spatial image, the position of the groove spectral peak in the frequency domain image is deduced, and a series of filters are designed to eliminate these spectral peaks in the frequency domain, and then the slot is eliminated by the inverse DFT transform in the spatial domain. Then, the global spatial image of cement pavement is binarized by Otsu method, and the noise is filtered after the square vote to realize the splicing of cracks so as to achieve the purpose of complete extraction of cracks. The experimental results show that the proposed method can eliminate the interference of the groove and keep the integrity of the crack after splicing.

1. Introduction

In recent years, with the rapid development of road image acquisition equipment, the use of image technology to manage the cracks in the road network has been gradually favored by people. Although the custody unit hopes to achieve the above management and maintenance model by image processing, in reality, the width of the new crack is very small. In the high-resolution image, there is only a width of 1~2 pixels, and the grooved image which causes great interference is generally 5 pixels wide, the intensity of the noise exceeds the image intensity of the crack, and the surface groove is very dense. The adjacent groove has only 20 pixels, and the crack is divided into small segments with a height of less than 20 pixels (corresponding to the actual road surface size of 20 mm), and it is very difficult to extract these small fragments in complex strong noise. The current road image recognition technology mainly focuses on asphalt pavement, and these methods are not suitable for cement pavement. Therefore, it is necessary to study efficient and accurate image recognition technology for new cracks on cement pavement, which will greatly reduce the workload of maintenance personnel on daily inspections. Managers provide the latest, fastest and most valuable road conditions, which will bring huge economic and social benefits to the maintenance of the freeway network.

The groove appears as a very dense horizontal line with strong edge features in the image. Its width and gray information are similar to the crack. When mixed with other noise, it is difficult to extract the crack from the dense groove. The literature[1] first uses the Canny algorithm to calculate the overlapping edge image of the groove and the crack, and then uses the Hough transform[2] to remove

IOP Conf. Series: Materials Science and Engineering **562** (2019) 012157 doi:10.1088/1757-899X/562/1/012157

the groove according to the straight line feature of the groove, and finally obtains the crack segment image, but because the crack segment is too small, it is easily confused with other noise; The literature[3] uses two-dimensional wavelet transform to suppress the groove in the high-frequency horizontal subgraph to achieve the purpose of weakening the groove, but this method causes serious interference to the identification of the lateral crack; In addition, the LoG[4] with direction enhancement suppresses the groove, and also has the problem of weakening the transverse crack. However, the one-dimensional wavelet transform method[5] using horizontal projection, although the calculation speed is fast, is incapable of the case where the groove has a declination. Based on the periodic characteristics of the groove, this paper starts from the frequency domain characteristics of the cement road image, deduces the position of the peak in the frequency domain, and eliminates the groove peak by designing a series of filters. In the process of grooving, the problem of weakening the integrity of the crack is weakened, and the crack splicing is carried out by the square voting method, and the purpose of complete crack identification is finally realized.

2. Power Spectrum Characteristics of Cement Pavement Images.

The cement concrete pavement groove has a periodic feature in the image. Using the periodicity of the groove in the longitudinal direction, it is a very typical stripe removal method to eliminate or suppress it in the frequency domain. Fourier transform is the basis of image analysis in frequency domain. It has been widely used in many fields of mathematics, science and engineering. It performs discrete Fourier transform on image function g(x, y) with size M×N:

$$G(u,v)=\frac{1}{MN}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}g(x,y)e^{-j2\pi(ux/M+vy/N)} \tag{1}$$

Similarly, given G(u,v), the original function can be obtained by inverse Fourier transform:

$$g(x,y)=\frac{1}{MN}\sum_{u=0}^{M-1}\sum_{v=0}^{N-1}G(u,v)e^{j2\pi(ux/M+vy/N)} \tag{2}$$

The power spectrum of the image is:

$$P(u,v)=\left|G(u,v)\right|^2=R^2(u,v)+I^2(u,v) \tag{3}$$

R(u, v) and I(u, v) represents the real and imaginary part of the G(u, v) respectively.

When processing, it is often necessary to multiply the original input image by $(-1)^{(x+y)}$ so that the origin of the power spectrum is at the center of the image. The groove of the cement pavement is constrained by the uniform standard in the construction process. Its width and spacing are roughly fixed on a certain section. The groove is approximately horizontal straight line running through the whole image in the road image. The arrangement of the grooves is equally spaced, the range of gray scale changes is basically the same, and there is obvious periodicity in the vertical direction. In the power spectrum image, near the v-axis, there are some equally spaced peaks, which are arranged in a straight line. The energy of the peak near the origin is large. As the distance from the origin is reduced, the peak energy is gradually attenuated. The peaks appearing in these periods are the periodic representation of the groove. Aiming at this feature, a series of notch filters can be designed to eliminate the periodic peaks near the v-axis in the frequency domain of the original image, and obtain the non-grooved road image by inverse transformation.

3. The Position of the Groove Peak in the DFT Power Spectrum

Frequency domain filtering is a typical periodic stripe interference removal method[5]. The difficulty lies in the determination of the spectral peaks corresponding to the periodic fringes. The periodicity of the cement pavement in the vertical direction can be simplified into one-dimensional sequence analysis. The pavement gray scale sequence f(n) is expressed as:

$$f\left(n\right)=\sum_{c}\left[f_1\left(n-cT\right)+f_2\left(n-cT\right)\right],n=0,1,...,N-1 \quad (4)$$

In this equation, $f_1\left(n\right)=\begin{cases}A, & n=0,1,...,p-1\\ 0, & n=p,p+1,...N-1\end{cases}$ indicates the grooved gray scale sequence, the p is groove width , the A is gray scale , and the N is the length of the sequence; $f_2\left(n\right)=\begin{cases}B, & n=p,p+1,...,p+q-1\\ 0, & n=p+q,p+q,...,N-1\end{cases}$ Indicates the groove interval gray scale sequence, the q is groove interval, the B is gray scale; T is the gray scale change period formed by the groove and the groove interval, T= p +q; f(n) is the result of the extension and truncation of f1(n) and f2(n) with T as the period, that is, the superposition after the cyclic displacement, so the discrete Fourier transform of N points for f(n), according to the discrete Fourier The time domain cyclic displacement property can obtain the amplitude F(k) of the pavement gray sequence:

$$\begin{aligned}\left|F\left(k\right)\right|&=\left|\sum_{c}\left[F_1\left(k-cT\right)+F_2\left(k-cT\right)\right]\right|\\ &=\left|\frac{\sum_{c}W_N^{kcT}}{\sin(\frac{\pi k}{N})}\right|\left|A\sin(\frac{\pi kp}{N})+BW_N^{kT}\sin(\frac{\pi kq}{N})\right|,k=0,1,...,N-1\end{aligned} \quad (5)$$

In this equation, $W_N=e^{-j\frac{2\pi}{N}}$; When each value is 1, there is a distinct peak, and the position of the peak is k=N/T and its octave. Since the pavement groove may have a small angle with the horizontal axis, the two-dimensional pavement The position of the groove peak in the frequency domain image is located near the v-axis N/T and its multiplier. The peak position can be found by searching for the peak in the vicinity of (0, ik) to obtain the peak position (ui, vi). The value of the maximum i is determined by the height N of the image.

4. DFT Transform Groove Elimination

After finding the peak position (ui, vi), the series filter Hi can be designed to suppress the vicinity of the peak to achieve the purpose of eliminating the peak. The series filters are as follows:

$$H_i\left(u,v\right)=\begin{cases}\dfrac{1}{1+\left[\dfrac{D_0^2}{D_i^2\left(u,v\right)}\right]^2}, & D_i\left(u,v\right)\neq 0\\ 0, & D_i\left(u,v\right)=0\end{cases} \quad (6)$$

$$D_i\left(u,v\right)=\left[\left(u-u_i\right)^2+\left(v-v_i\right)^2\right]^{\frac{1}{2}}$$

Filter G(u,v) with a filter of the transfer function Hi(u,v) to get:

$$K\left(u,v\right)=\frac{1}{n}\sum_{i=1}^{n}H_i\left(u,v\right)G\left(u,v\right) \quad (7)$$

In this equation, K(u,v) is the filtered result, n is the number of peaks, and the inverse Fourier transform is used to obtain the image without pavement. As shown in Fig. 3, the groove in the original road image disappears, and Longitudinal repair cracks and oblique new cracks are retained.

5. Square Voting Method

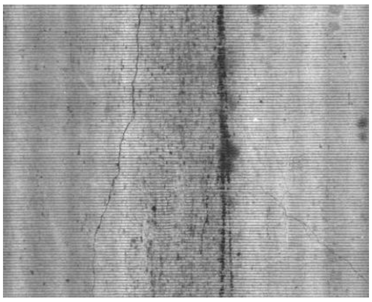
After the groove is eliminated, the global image can be binary processed by Otsu method, and the mend crack in high resolution image can be shielded by combining the recognition result of repairing crack in low resolution image. In this case, several discontinuous images of crack fragments can be obtained, which is due to the fact that the cracks are divided into several segments at the same time the slots are eliminated by frequency domain filtering, and the crack segments need to be spliced together. Crack segment splicing has always been a difficult problem in crack image recognition. Geometric, square and morphological methods[6] are usually used. The square method is a simple and easy method for splicing and extracting crack fragments. Its basic idea is: firstly, the fragment image is square, each square is initialized to "0", and all the fragment pixels in the image are traversed, then "vote" on the squares to which the pixel belongs; After the traversal is completed, the number of "tickets" obtained for each square is calculated. When a certain threshold is exceeded, the square is marked as "1"; the square or 8-neighbor method is used to calculate all squares marked "1". Connectivity, if the number of square connections marked "1" exceeds a certain threshold, it is judged that the connected area is a crack.

6. Experimental Results

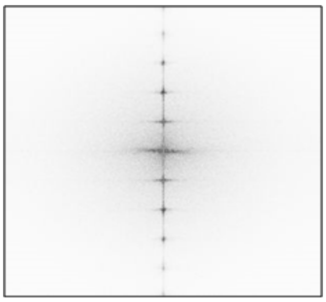
For the groove interference in the cement road image, using the frequency domain feature, firstly, the original image is Fourier transformed by the equation (1) to obtain the frequency domain image G(u, v). figure 1 (a) is a screenshot of a cement concrete pavement, and figure 1 (b) is a power spectrum image. It can be seen from the power spectrum that the power spectrum is oddly symmetrical, and the portion near the origin is the low-frequency component of the original image, corresponding to the image. In the background part, the main energy is concentrated near the origin; the part far from the origin is a high-frequency component, corresponding to cracks and grooves in the image.

In the vicinity of the v-axis N/T and its multiplication in G(u,v), the position series (ui, vi) of the peak formed by the groove is searched. G(u,v) is filtered according to the equation (7) using the series filter Hi(u,v) to eliminate the groove peak, and the frequency domain image K(u,v) is obtained; Then K(u,v) is inversely transformed into a spatial image by equation (2) to obtain the final noise-reduction enhanced image. As shown in figure 1 (c), the groove in the figure has completely disappeared, and the main target crack is still clearly visible.

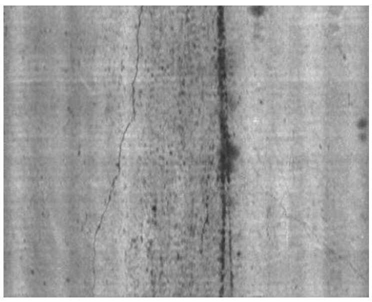
Then, the Otsu method is used for binarization, and the results shown in figure 1 (d) are obtained by chain code tracking. In order to facilitate observation, part of the image is intercepted on figure 1d. As shown in figure 1 (e), it contains a longitudinal new crack. The box in the figure is the circumscribed rectangle of each segment. The number indicates the number of each segment. The figure contains hundreds of segments. In addition to the crack segment, there is still a lot of noise fragment, and the crack fragments are not continuous. This is due to the weakening of the continuity of the cracks when using frequency domain filtering to eliminate grooves. In response to this problem, the splicing of crack segments is performed using the square voting method. figure 1f is the result of the extraction of the cracks in the square method, and the blue square in the figure is the larger connected area marked "1". On this basis, it is necessary to set the filter condition and delete the short branch at the red square in figure 1 (f), so as to obtain a relatively complete crack region.



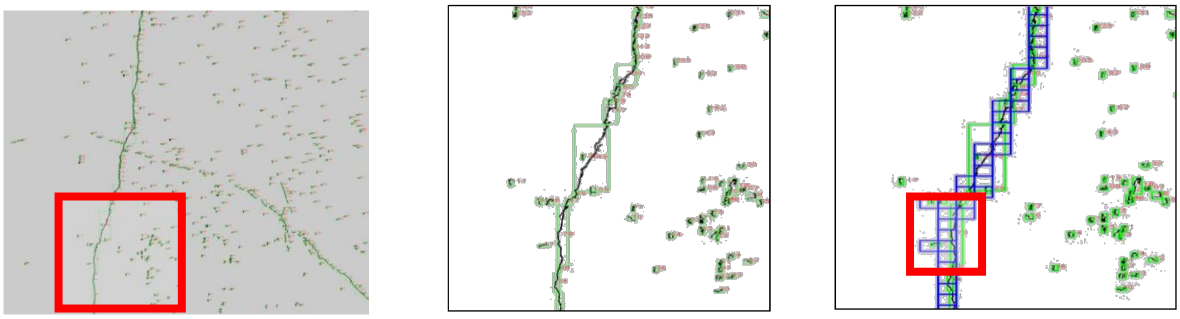
(a) Original image



(b) Power spectrum



(c) Eliminate the groove



(d) Otsu (e) Crack fragment (f) Splice

Figure 1. Experimental result

7. Conclusions

In this paper, a crack identification method for cement concrete pavement based on DFT transform and square voting method is proposed. The method has the advantages of good robustness, adaptability and easy promotion.

The periodicity of the groove is represented in the frequency domain image as a series of spectral peaks arranged at equal intervals, and the peak position is near the v-axis N/T and its multiplier. A series of filters Hi(u,v) are designed to eliminate the periodic peaks of the groove in the frequency domain. This achieves the elimination of grooves in the cement pavement image.

Aiming at the problem that the crack is broken at the groove by DFT, and it is difficult to identify with noise, after the binarization, the crack segment is spliced by the square voting method for the problem of crack discontinuity, which can effectively eliminate the influence of noise and extract the entire crack.

8. Acknowledgments

This work is supported by the Natural Science Foundation of China under No 51208130 and 51668012, Science and Technology Development Project of Guangxi Zhuang Autonomous Region under No 14124004-4-14.

9. References

[1] Jing R and Yu-li P 2012 *J. Journal of Highway and Transportation Research and Development*, Digital image Based Crack Detection of Grooved Cement Concrete Pavement, **29** 45-50

[2] Skingley Jand Rye A J 1987 *J. Pattern Recognition Letters*, The Hough Transform Applied to SAR Images for Thin Line Detection, **6** 61-67

[3] Jing R and Yu-li P 2012 *J. Journal of Beijing University of posts and telecommunications*, Image Based Crack Detection Algorithm with Application to Cement Concrete Pavement, **35** 121-124

[4] Bin G 2010 *J. Science Technology and Engineering*, An Improved Adaptive Anisotropic LoG Operator, **10** 2992-2996

[5] Weiwei C 2007 *Research on Stripe Noise Cancellation Method for Hyperspectral Images* (Xi'an: Northwestern Polytechnical University)