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A Study of Crack Detection Algorithm

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Abstract—***As an emerging computer technology in the field of intelligent crack detection van, crack detection technology is also an important aspect of digital image processing. After giving the characteristics of the crack image and the environment of the project for crack detection, this paper shows the key technologies and core algorithms in crack detection, makes detailed description of image pre-processing, crack extraction, crack connection algorithm.***

Keywords-crack image, pre-processing, crack extraction, crack connection

I. INTRODUCTION

Science and technology promote the development of detection technology to the age of automation, intelligent crack detection vehicle arise at the historic moment. As an important sub-system of intelligent crack detection vehicle, crack detection system can be divided into two parts in accordance with the composition of the entity. One is the hardware part of the detection system which can get the road or tunnel surface image information at a certain speed through car camera, signal processors and other devices, the other is the software part of the crack detection system which can detect cracks to the acquired images. Therefore, crack detection is one key technology of smart crack detection vehicle. Currently, how to extract the crack detection under complicated background accurately is a research hotspot in the field of intelligent crack check-out car development [1].

II. CRACK IMAGE PRE-PROCESSING

The Environmental difference of crack image detection is remarkable, and the environment has strong noise interference to the result of crack image detection. Road pavement texture characteristics, uneven illumination, noise in the environment, tunnel test environment from the illumination, stains, seepage and inherent effect of the joint surface of the tunnel lining, the particularity of tunnel interface all will influence the final detection result. Therefore, we should do some preprocessing to crack image so as to be well prepared for the extraction of cracks. In this part, we will introduce some pre-processing algorithms which are often used.

A. Graying arithmetic

Generally speaking, the image captured by cameras is colorized. These color images include large color information which not only occupy large storage overhead, but also reduces the processing speed of system. Each pixel of the image has three different color components containing many unrelated identify information, which are not convenient to further identify work. Therefore, before us marching image recognition processing, it is very necessary to transform color image into grayscale images. By doing this, we can greatly accelerate the speed of image processing.

Grayscale image only contains brightness information, and doesn't contain chromaticity information. Graying means converting color image containing brightness and chromaticity into grayscale image process. Gray is essential in the image processing, whose result is the foundation of subsequent processing, so looking for a suitable grayscale algorithm is very important. Colors are seen as variable combinations of the so-called primary colors red(R), green (G) and blue (B). Gray process is making the values of these primary colors equal. Because the value ranges of these components are 0 to 255, gray levels only have 256 levels.

Currently, gray processing methods mainly have three kinds which are the peak measurement, the mean value and the weighted average method [2]. The peak measurement method means the final RGB values equal to the maximum of them. The mean value method means the final result equal to the average of the sum. The weighted average means the result is the weighted average of the three components whose weight given by their significance or other index.

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B. *Image denoising*

Image filter can be divided into spatial filtering and Filter frequency two kinds. Generally speaking, the image noise spectrum is located in the high area of spatial frequency, and frequency component of the image is in the low spatial frequency domain. In order to eliminate the noise, we often adopt the spatial lowpass filtering. Spatial filtering mainly includes the local average method, the median filtering method. In this paper, we mainly introduce the median filter who is a nonlinear image smoothing method [3].

Median filter usually uses a sliding window containing an odd number of points, and it replaces the value of the center pixel with the median of neighboring entries. If the window includes an odd number of elements, the grey of neighbourhood center pixel is just the middle value after all the entries in the window are sorted numerically.

If the window includes an odd number of elements, the grey of neighbourhood center pixel is the average of the two middle values after all the entries in the window are sorted numerically.

C. *Image enhancement*

The purpose of cracks image enhancement mainly have two: one is to improve the visual effect of image, improve the sharpness of the image elements; the other is to make the image more conducive to the processing of compute.

Image enhancement does not consider the reason for decline in image quality, only outstands the interested image characteristics and decay the unneeded characteristics. By doing this, we can improve the intelligibility of the image [4].

At present, there is no general measure of quality of image enhancement. From the scope of enhancement processing, image enhancement can be divided into spatial domain and frequency domain methods. Spatial domain processing is based on image spatial domain information, that's to say, the information of the image itself. It mainly directly disposes each of the pixels in the image, in the space domain of image pixel gray value directly for processing. Spatial domain method can divide into two types; One is the local operations in the spatial domain of pixel neighborhood. The other is point operation which does point by point operations to the image. Processing can be linear or nonlinear, can use index, logarithmic, ratio.

III. CRACK EXTRACTION ALGORITHM

A. *Image edge detection*

The margin of the image is the basic characteristics of the image. Margin, also called boundary or edge, refers to the collection of pixels which have step change or rooftop change. Edges are widely exists between objects and objects, object and background. Therefore, the edge is the important features of image segmentation.

Edges in the image are mainly reflected by gray discontinuity. Common edge detection method base on image gray level of each pixel in a certain field, using the change rule of the first or the second directional derivative near the edge for edge detection, this method is called local operator edge detection method. In this part, we will introduce several commonly used edge detection operator [4].

1) Robert operator

Robert operator use partial differential operator to find the edge. For the low noise image with characteristics of step response Robert operator is best, but for the image with major gray level gradient and noise, the effect is poorer, the speed is slower, the edge is not smooth, and the edge line is coarser.

2) Prewitt operator

Prewitt operator gets the image edge by calculating convolution. The default image edge direction is the horizontal and vertical directions on the edge, so every point in the image will be made with the two nuclear convolutions, taking the maximum as the final convolution output value.

Prewitt edge detection operator can get the edge image fast, and the effect for image with more gray gradient and noise is good. But because it does not have the properties of isotropic, the detected edge is not fully connected.

3) Laplacian operator

The Laplacian operator is a second order differential operator in the n-dimensional Euclidean space, defined as the divergence ($\nabla \bullet$) of the gradient (∇f).

Due to the Laplacian operator is the second derivative operator who is more sensitive to noise, so scattered broken edge pixels appear on the test results of some pixels.

In order to reduce the noise interference of edge detection, before undergoing Laplacian edge detection low pass filter is very necessary. The practice proved that choosing gaussian low-pass filter to smooth the image denoising is very effective. After Gaussian low-pass filter processing and then use the method of Laplacian edge detection operator to extract the image edge is known as the Laplacian of Gaussian (LOG) operator.

4) Canny factor

Canny operator is a kind of operator based on optimization algorithm. In the document of canny operator, canny point out the general criteria for edge detection includes：

a) Detection of edge with low error rate.

b) The edge point detected from the operator should accurately localize on the center of the edge.

c) A given edge in the image should only be marked once, and where possible, image noise should not create false edges.

The Process of Canny edge detection algorithm can be broken down to 5 different steps [5]:

a) Apply Gaussian filter to smooth the image in order to remove the noise

b) Find the intensity gradients of the image

c) Apply non-maximum suppression to get rid of spurious response to edge detection

d) Apply double threshold to determine potential edges

e) Track edge by hysteresis: Finalize the detection of edges by suppressing all the other edges that are weak and not connected to strong edges.

5) Sobel factor

The Sobel operator, is used in image processing and computer vision, particularly within edge detection algorithms, and creates an image which emphasizes edges and transitions. Technically, it is a discrete differentiation operator, computing an approximation of the gradient of the image intensity function [6].

At each point in the image, the result of the Sobel operator is either the corresponding gradient vector or the norm of this vector. The Sobel operator is based on convolving the image with a small, separable, and integer valued filter in horizontal and vertical direction and is therefore relatively inexpensive in terms of computations. On the other hand, the gradient approximation that it produces is relatively crude, in particular for high frequency variations in the image.

B. Mathematical morphological Image Processing

Mathematical morphology (MM) is a theory and technique for the analysis and processing of geometrical structures, based on set theory, lattice theory, topology, and random functions. MM is most commonly applied to digital images, but it can be employed as well on graphs, surface meshes, solids, and many other spatial structures.

Topological and geometrical continuous-space concepts such as size, shape, convexity, connectivity, and geodesic distance, were introduced by MM on both continuous and discrete spaces.

The basic morphological operators are dilation, erosion, opening and closing[7].

1) Dilation

For a given target image X and a structuring element S, when S moves on X, to each position of X, S [X] only has three states:

The first is S[X] is completely correlation with X, that's to say, S[X] is a subset of X ;

The second is S[X] is completely unrelated with set X, that's to say, S[X] is a subset of the complementary set of X;

The last one is S[X] is section-related with X. In other word, S[X] not only has intersection with X ,but also has intersection with the complementary set of X.

Among the three states, we call the set of the X which belongs to the completely correlation state as S's corrosion to the target graphical X.

In mathematical morphology, corrosion is used to eliminate the effect of edges, remove the smaller than the structural elements of the object, disconnect the tiny connected between two objects, and so on.

2) Erosion

If the dilation is regarded as contract every subset of target image X which are exactly equal to the structuring element S, then the opposite is expanding every point in X to S [X], this is the expansion of the morphological operations.

In mathematical morphology operations, the role of the expansion operation is to incorporate the point around an object to the object, when the distance between two objects are closer, erosion operation may lead to the two objects together, expanding operations is very useful in filling the void between objects.

3) Opening operation and closing operation

Based on the two basic operations, corrosion and expansion, we can construct two other very important morphological operator, opening operation and closing operation.

In mathematical morphology, opening is the dilation of the erosion of an image X by a structuring element S, while closing of an image X by a structuring element S is the erosion of the dilation of that set.

Both opening operation and closing operations are lossy operations, which means part information will be lost in the process of operation, that leads to the result is not equal to the original image. Open operation generally make the contour of the object more smooth, disconnect the narrow gap and eliminate small protrusions; Closed operation also makes the object contour more smooth, but contrary to open operation, its effect is to eliminate the narrow gap and a long thin gap, eliminate small holes and fill the contour line of fracture.

Extraction methods based on mathematical morphology can not accurately extract complete crack information, so this method must combine with other test methods. Such as the crack extraction method based on edge feature and mathematical morphology, this method preprocess crack image first, and then use edge detection algorithm to extract the edge crack. Finally, using closed mathematical morphology operation to make crack contour more smooth, eliminate the narrow gap and a long thin gap, eliminate small holes and fill contour line breaks. This method combine mathematical morphological operation with the characteristics of digital image so can greatly reduce the degree of fracture cracks.

C. Crack Detection Based on Wavelet transform

The main idea behind wavelet transform is after scaling, translating and other operations, the original signal is disassembled into a series of subband signals with different spatial resolution, different frequency and direction characteristics. These subband signals have good time-frequency features, and utilizing them can realize local

analysis of time domain and frequency domain of the signal[8].

At present, to achieve a more accurate and fast detection effect, most crack detection algorithm using wavelet analysis combine with a variety of other methods.

For example, based on wavelet analysis and mathematical morphology method to extract crack, the method by wavelet multi-scale decomposition to extract the texture clear and has different spatial resolution and the direction of the edge of graph, image transformation to the different direction of crack subband are extracted, and finally the wavelet decomposition with mathematical morphology method after the details of the image of a series of morphological operations, further eliminate the useless information and noise, to extract the crack.The method in the case of small noise extraction effect is good; The downside is slower, and when noise larger cracks extraction accuracy also decreases.

IV. COMMON CRACK CONNECTION METHOD

A. *Heuristic edge connection method*

The edge connection method proposed by Roberts, is the typical algorithms among many heuristic connection technique. In this algorithm, we need to check a 4x4 pixels block to test the edge gradient. If the amplitude of some point is greater than the threshold, then the gradient pixel with biggest value was named as a tentative edge point. The line in the four directions, south, east, west, north, whose length is five is used for fitting for the gradient near the edge of the data points. If the best fitting according to the fitting relationship between measurement and worst fitting ratio is higher than a second threshold, then the tentative edge point has been named as the edge of the legal point, and will it pointing in the direction for the best fit[9].

B. *Region-growing Crack Connection arithmetic*

Firstly, proceeding image denoising to the image after crack extraction treatment. Secondly, using the improved region growing algorithm to do crack connection, ensure the integrity of extract crack. The step of the region-growing Crack Connection arithmetic are shown as follows [10][11]:

1) Find seeds area, do division to binary chart, calculate the length of each region, compare with the minimum length of crack, and then select the maximum region as crack seed region.

2) Search adjacent areas, along the direction of the seed regions, center on the two endpoints of seed area to do respective sector search domain, search area within the scope.

3) Extend crack area, in either direction area, calculate the length and the area direction in all areas , begin with the largest length area, do direction consistent match with seed area, once the match is successful, no longer do judge for the rest region of the search field, the current match area is regard as fracture zone and connect with the seed area, and the whole area after connection act as the seeds of a new round of extension area, repeat 2) and 3), until no neighborhood can extend, means the end of a seed regional extension, namely the accomplishment of a crack extraction.

4) Lookup next seed area, remove the extracted crack area from the binary map, continue select the area greater than the maximum length as a new crack seed area, repeat2),3) and 4) until there is no greater than the area.

V. CONCLUSION

The study of crack detection system is a pioneering work. The following work is improving the above methods furthermore. Based on the analysis to their advantages and disadvantages, we can accumulate useful experience to the crack detection research on a certain environment.

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