Journal of Theoretical and Applied Information Technology
29th February 2012. Vol. 36 No.2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

AUTOMATIC DETECTION OF CRACKS IN PAVEMENTS USING EDGE DETECTION OPERATOR

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ABSTRACT

Crack detection in pavements and objects has been a constant field of research in pavement management. Conventionally, humans were engaged to detect cracks in the pavements and they used to present report sheets based on their assessment. But, this process was a time consuming one and was costlier too. So, researchers were trying for some alternate method that would detect cracks, hence minimizing the human involvement and at the same time detecting the cracks precisely. This gave way to numerous automated techniques for the detection of cracks. In this paper, an automated technique to detect cracks in pavements by means of digital image processing is proposed. This technique detects the horizontal, vertical and diagonal cracks on buildings, pavements, soils, roads, objects, etc. Some conditions such as complex texture, bad illumination, and non-uniform background in images may influence the accuracy of the automatic system. So, a lot of work has been made to overcome these hardships and to provide a well-organized method for crack detection. First, the images are processed by gray scale morphological processing. Subsequently, the final result is obtained by filtering the images (Butterworth filter) and then applying the edge detection operators (canny). By visual inspection, contented detection results are obtained through this method.

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Keywords: *Butterworth Filter, Automated Crack Detection, Canny Edge Detection Operator, Gray Scale Morphology*

1. INTRODUCTION

A crack is the separation of an object or material into two, or more, pieces under the action of stress. Depending on the substance which is cracked, the crack reduces the strength of the materials in most cases, e.g. building walls, roads, etc. At the beginning, humans were used in detecting these cracks. However, detecting a crack manually is a very intricate and time consuming process. With the advance of science and technology, automated systems with intelligence were used to detect cracks instead of humans. By using the automated systems, the time consumed and the cost for detecting the cracks reduced and cracks are detected with more accuracy. The accurate detections of minute cracks has enabled for the better design for critical projects. These automated systems features overcomes manual errors providing better outcome comparatively. Numerous algorithms have been proposed and developed in the field of automated systems, but the proposed algorithm improves the efficiency in the detection of cracks than the previous developed techniques. Implementation is much simpler than the techniques proposed so far.

The paper is organized as follows. In Section 2, the related works that were done on crack detections are discussed. In Section 3, the methods and the flow of operations used on the images to

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

detect cracks are explained with a detailed description. Proposed flow work is given in section 4. The experimental results and the conclusions are given in Section 5.

2. RELATED WORKS

Up till now, some studies about the automatic crack detection have been done. Several methods using neural networks, SVM and digital image processing have been proposed. In some cases, the quality of the images may also have an effect on the obtained output. In this case, the texture and shape descriptors are taken in to account while detecting cracks [1]. In this paper, to eliminate uneven elimination and irregular textures, six texture features and two translation-invariant shape descriptors were used.

In [2], crack detection based on neural networks was also proposed. In this, the thresholds that were used to separate the crack pixels from the background were fixed using the neural networks. After that, Hough transforms were used to detect cracks.

Other methods for crack detection include various techniques such as wavelet-based transform [3], fuzzy set theory [4], SVM [5] and GLCM features [6].

In this paper, we use filters and edge-detection methods for crack detection. The experimental results on images from Google show that the proposed approach is effective and feasible.

3. METHODS AND MATERIALS

The proposed crack detection technique involves various stages: image acquisition, image preprocessing, image enhancement, image restoration and image segmentation. Each stage performs meticulous operation on the image to proficiently detect cracks present in the images. The sequences of stages are discussed in detail.

3.1 Image Acquisition

Images required are obtained from various search engines like Yahoo, Google images, Bing etc. Images obtained for processing are digital images captured by means of digital camera. These acquired images are color images; comprising combination of the primary color model (RGB).The RGB color model consists of amalgamation of 8-bit array of Red, Green and Blue.

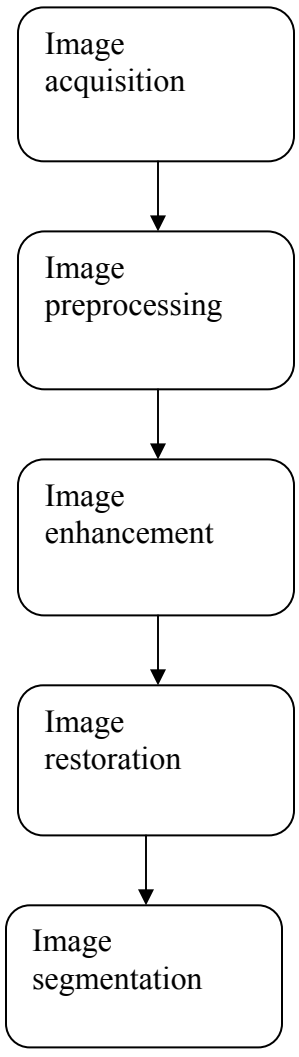

Figure 1: Proposed flow work

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

3.2 Image Preprocessing

Images obtained for crack analysis ought to be preprocessed. Acquired images may be of different dimensions. Image resizing algorithm is applied on the images, which in turn convert them into a square image. Image resize algorithm uses various interpolation techniques to obtain an image of the desired dimension. Resizing algorithm adds the specified number of rows and columns in the given image and scales them to the required size. The algorithm by default computes the required number of rows and columns to preserve the aspect ratio of the image if the rows and columns are not specified.

3.3 Image Enhancement

For accurate crack detection, the visual appearance of the images needs to be developed. To achieve this image enhancement is done. The resized color images obtained from the preprocessing technique comprise combination of three 8-bit arrays. The 8 bit array symbolizes brightness of these colors which ranges from 0(black) to 255(white). The brightness level of the color image can be manipulated to obtain a gray scale image. Gray scale image conversion is achieved by retaining luminance and by eliminating hue and saturation. Quality of the images is not affected when true color images are gray scale converted. Gray scale images are more compatible when compared to colored images. They become compact and so, the efficiency of transmission and reception of these images increases enormously. During the acquisition or transmission of the images, unnecessary noise appends with the original image which brings down the efficiency of detecting cracks in the image.

3.4 Image Restoration

Images can be affected by noise; the noises can be categorized under two sections, periodic noise and random noise. The noise which may be appended to the original image must be removed before processing the image to detect cracks. They may affect the process reducing the efficiency of detecting cracks in the image. To remove superfluous noise, images are passed through filters. These filters remove the unwanted noise attached to the original image and retrieve the original image from the noisy image.

3.4.1 Filters

Filters are electrical network that alters the amplitude or phase characteristics of a signal with respect to the frequency. Filters are often used in electronic systems to emphasize signals in certain frequency ranges and reject signals in other frequency ranges. Such a filter has a gain which is dependent on signal frequency.

Whenever a noisy image is passed through the filters, the gain of the original signal is retained and that of the noise is removed. Various filters are available like spatial filters which are used to remove random noise. Filters using frequency domain technique remove periodic noise. Frequency domain filters' behavior is mathematically described in terms of its transfer function. Ability to determine transfer function at each frequency enables us to determine how well the filter can distinguish a particular frequency from other unwanted frequency. Filters based on the output can be classified into five basic types

Basic filter types are:

- Low pass
- High pass
- Band pass or (notch)
- Band reject
- All pass

In this paper Butterworth filter with band-pass mode is used. It exhibits flat pass band with no ripple. The general equation for Butterworth filter is

$H(\omega) = 1/[1+(\omega/\omega_0)^{2n}]$

ω is the frequency of the filter

n is the order of the filter

Band pass response is in which the response curve has a constant gain within the pass band and zero gain outside the pass band. Band pass is used to separate signal at one band of frequency from other frequencies.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

3.5 Image Segmentation

Segmentation technique is to distinguish objects from background. Segmentation is classified into four popular categories: threshold techniques, edge-based methods, region-based techniques, and connectivity-preserving relaxation methods [7].

3.5.1 Threshold techniques: This technique makes decision based on local pixel information and is effectual when the intensity levels of the images fall squarely outside the range of levels in the background [2].

3.5.2 Edge-based methods: This refers to the process of identifying and locating sharp discontinuities in an image. The discontinuities are abrupt changes in pixel intensity which exemplify the boundaries of objects in a scene. Their weakness in connecting together broken contour lines make them prone to failure in the presence of blurring.

3.5.3 Region-based techniques: In this method the image is partitioned into connected regions by grouping neighbouring pixels of similar intensity levels. Adjacent regions are then merged under some criterion involving perhaps homogeneity or sharpness of region boundaries.

3.5.4 Connectivity-preserving: This method also known as active contour model. It detects the outlines of the noisy image. Key idea is to begin with initial boundary shape represented in the form of spline curves, and iteratively modify it by applying various shrink/expansion operations according to some energy function. Local minimum is a drawback which must be taken into consideration.

In this paper edge based segmentation technique is used. The classical edge segmentation technique convolves the image with an operator. The operator decides the orientation of the edge; the operator can be optimized for a particular edge. There are lot of edge detection techniques and canny is one among them and also very effective technique. Canny detection technique can detect minute edges. This method follows three major criteria. First it must have low error rate, second the edges must be localized and third, each edge must be detected only once. In order to detect edge precisely in this detection technique, the image is filtered using Gaussian filter. After the completion of the smoothing and filtering of the image, the strength of the edge is detected by taking gradient of the image. Gradient is estimated in both the orientations. Direction of the edge is determined by the formula Theta= inverse of tangent (ratio of gradient of y to that of gradient of x). After the estimation of the direction of the edge the sequence of the edge is traced. Direction in which the edge is traced can be right, acute or obtuse angled. Non maximum suppression is applied to further intensify the edge detection, changing the pixel value of the images. Hysteresis is used to eliminate streaking. Streaking is breaking of the edge contour due to fluctuation of the output.

4. PROPOSED ALGORITHM

The algorithm proposed is implemented in Matlab. Its implementation is discussed in detail below:

Step 1: The first and the foremost part of the algorithm is image acquisition. The image is obtained from various sources. Images acquired can be of any format and orientation.

Step 2: Obtained image has to undergo various modifications such that it is suitable for performing the operations on them. Image is cropped to the necessary dimensions such that it is a square image. Cropped image is then converted to gray scale image such 3-dimensional images is converted into 2- dimensional images.

Step 3: Resulting 2-dimensional image might be a noisy image. Image is then filtered to remove the unwanted noise. Various filtering techniques were applied in the image. Spatial filters, frequency domain filters and adaptive filters were applied on the image, since periodic noise was predominant compared to other noise present in the image. Frequency domain filters were singled out.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Butterworth filter in band pass type proved to be most efficient filter. The threshold of the filter is dynamically chosen by the filter based on the image. Threshold varies from image to image depending on the image intensity, major factor deciding the threshold of the image is the variation of intensity between the foreground and the background image.

Step 4: The final process in the algorithm is edge detection, once the image is filtered, a pure sample from which crack has to be detected is obtained. The edge detection algorithm is applied on the sample. Numerous edge detection algorithms are available. Canny edge detection algorithm is best suited among the available edge detection methods; it is used to detect minute cracks present in the image, providing the maximum number of cracks present in the image.

5. RESULTS AND CONCLUSION

Sample images were taken from various search engines and the cracks were detected. Here an example is shown. This example image was obtained from Goggle and is shown in figure 2. The original size of the image was 640 x 480 which was cropped to 256 x 256 and it was enhanced using gray scale morphological processing as shown in figure 3. In figure 4, Butterworth filter was applied to remove noise. Then the final image is obtained by edge detection methods and the cracks are detected accurately which is shown in figure 5.

It can be seen that development in area of automation has helped in effective crack detection. The method displays promising result of detecting cracks in every feasible direction. The end result of the system was accomplished by integrating image processing algorithms. These algorithms process the images in sequential manner and provide sequence of images like binary image, filtered image and cracks in image. The system achieves distress quantification more effectively when compared to the traditional methods.

Figure 2: Original image of pavement cracks

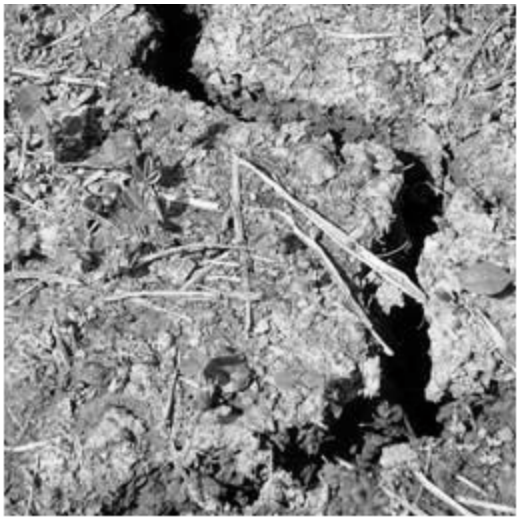

Figure 3: Image after pre-processing and enhancement

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Figure 4: Image restoration using Butterworth filter

`**Figure 5:** Final image after segmentation with the cracks

This proposed automation model gets the input image from any data source and automatically detect the cracks and display it on the screen. Even hairline crack can also be detected efficiently by this proposed method. In this algorithm, adaptive threshold technique is used to detect all kinds of cracks in all the substances which make it inimitable from other algorithms. The limitations of this algorithm are that the given image has to be pre-processed to obtain a grayscale image with square sized dimensions for further processing. These limitations will be removed in the upcoming works.

In future, detailed comparison analysis with the pervious algorithms with respect to performance metrics will be discussed. Techniques to determine the depth and intensity of the cracks using soft computing methods will also be proposed in the future work.

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