ISSN: 2230-9926

Available online at http://www.journalijdr.com

IJDR

International Journal of Development Research
Vol. 10, Issue, 09, pp. 40172-40174, September, 2020
https://doi.org/10.37118/ijdr.19994.09.2020

RESEARCH ARTICLE

OPEN ACCESS

A MULTI-SCALE CANNY DETECTION TECHNIQUE FOR AUTOMATIC ASSESSMENT OF FATIGUE CRACKING USING MORPHOLOGICAL OPERATORS

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ARTICLE INFO

Article History:
Received 22nd June 2020
Received in revised form
17th July 2020
Accepted 04th August 2020
Published online 29th September 2020

Key Words:
Fatigue Cracking; Digital Image Processing; Canny Detection; Logarithmic Transform; Morphological operators; Bilateral Filtering:

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ABSTRACT

The maintenance of existing pavements with a good quality is one of the key challenges to the pavement engineers. The pavement condition monitoring and evaluation is a complex task to proceed for making decisions regarding the appropriate maintenance strategies. Generally, the Pavement Condition Evaluation involves in measuring the roughness, skidding index and pavement distresses. The fatigue cracking is one of the major distresses occurring in flexible pavements. The present research study focused on detecting the fatigue cracking using the Digital Image Processing (DIP). The image preprocessing techniques like linear-smoothing technique and bilateral filtering were used for removing the noise and background non-uniform illumination. Later, Canny's detection technique and morphological operators were used for enhancing the detection-accuracy. Finally, the resultant output was obtained via python programming and concluded that the proposed algorithm showed better results compared to the techniques without morphological operators.

Citation: ***Sai Suman, P., Venkata Ramana, N. and Sashidhar, C.* 2020.** "A multi-scale canny detection technique for automatic assessment of fatigue cracking using morphological operators*", International Journal of Development Research*, 10, (09), 40172-40174.

INTRODUCTION

Generally, the pavement distress assessment is important step in Pavement Management System. The pavement distresses can be evaluated directly or indirectly using manual or automatic methods respectively. The present study focused on evaluating the fatigue cracking. The fatigue cracking mainly occurs due to stiffer asphalt layers during the cold climates. The pavement is subjected to fatigue failure during its middle or late service life. It is necessary to recognize the microcracks or low-intensity fatigue cracking in order to reduce the cost of maintenance works. The concepts of image processing have been extensively used in automated pavement condition assessment. The previous studies adopted different techniques using curvelet, beamlet, ridgelet, wavelet transforms. The present study focused on detecting the fatigue cracking with the help of canny detection technique and morphological operators (dilation and erosion).

THE STUDY METHODOLOGY

The present study involved in a series of algorithms for detecting the pavement cracks. Firstly, the images were collected using the line-scan cameras mounted on Network Survey Vehicle (NSV). Secondly, the collected BGR-colored imageswere converted in to gray scale images. Thirdly, the gaussian filtering technique was adopted for removing the background noise. Later, the logarithmic transform and bilateral filtering techniques were performed for achieving the uniform illumination. In addition to them, the Canny detection method was used for detecting the pavement cracks. Finally, the morphological closing operator was utilized to increase the performance of detecting the cracks and the resultant images were presented and conclusions were made.

Image Acquisition System: In this study, Hawkeye-2000 Network Survey Vehicle (NSV) developed by Indian Road Survey Management was used for collecting the pavement surface. This vehicle captured the images at an interval of 10m and a width coverage of 8m. The images were captured by using three front cameras mounted on NSV. The image of NSV used for present study is shown in following Figure 2.

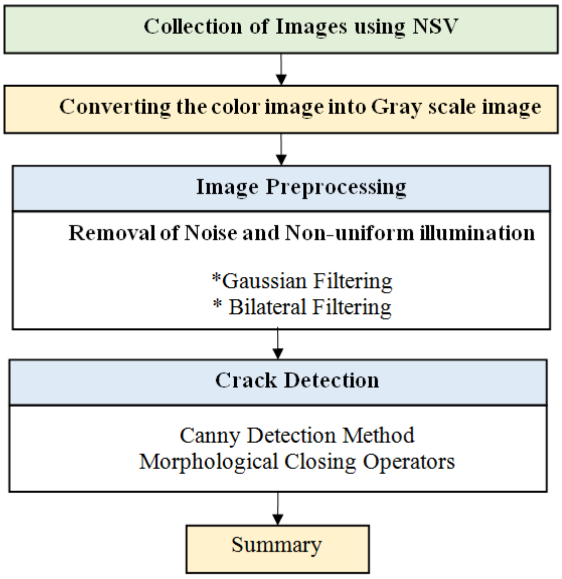

Figure 1. The study approach for detecting the fatigue cracking

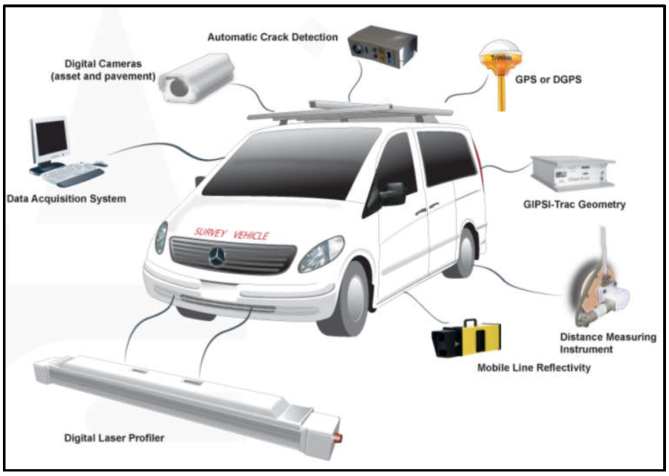

Figure 2. The Hawkeye 2000 Network Survey Vehicle

Image Preprocessing: A total of 80 images were selected for assessing the fatigue cracking. In the image preprocessing step, the colored images were converted in to gray scale images.

Linear Filtering with Gaussian Blur: The following Gaussian blur transform with linear filtering was adopted for initial denoising purpose.

$$GB[I]_{\mathbf{p}} = \sum_{\mathbf{q}\in S} G_{\sigma}(\|\mathbf{p}-\mathbf{q}\|)\, I_{\mathbf{q}},$$

Where,
P represents the center position;
$G_{\sigma}|p\text{-}q|$ represent the distance between center position and adjacent position considered
GB is Gaussian Blur;
$G_{\sigma}$is 2-dimensional Gaussian Kernel and is defined by following equation

$$G_{\sigma}(x) = \frac{1}{2\pi\,\sigma^2}\exp\left(-\frac{x^2}{2\,\sigma^2}\right)$$

Bilateral Filtering: The Bilateral Filter (BF) is also defined in terms of weighted average of pixels as similar to the Gaussian Blur. This filter is important in considering the variation in intensities and takes it into account for preserving the edges. Bilateral filtering is based on principle that "if two pixels occupy nearly spatial location and have similarity in photometric range, then that two pixels said to be close to each other". The bilateral filter is defined as follows:

$$BF[I]_{\mathbf{p}} = \frac{1}{W_{\mathbf{p}}}\sum_{\mathbf{q}\in S} G_{\sigma_s}(\|\mathbf{p}-\mathbf{q}\|)\, G_{\sigma_r}(I_{\mathbf{p}}-I_{\mathbf{q}})\, I_{\mathbf{q}}$$

Where,
W_P is defined normalization factor as given below:

$$W_{\mathbf{p}} = \sum_{\mathbf{q}\in S} G_{\sigma_s}(\|\mathbf{p}-\mathbf{q}\|)\, G_{\sigma_r}(I_{\mathbf{p}}-I_{\mathbf{q}})$$

Where, $\sigma_s$andσ_r are used for measuring the amount of filtering $G\sigma_s$and $G\sigma_r$ are spatial and range Gaussians respectively.

Canny Detection and Morphological closing: The Canny detection method was developed by Canny in 1986. It is a multi-stage algorithm used for detecting the several edges in given images. The canny detection algorithm mainly composed of following five stages:

- Denoising,
- Measurement of Gradient,
- Non-Maximum Suppression,
- Dual Thresholding,
- Tacking the edge

In this study, a 5 by 5 kernel was used for canny detection and morphological closing. Generally, morphological operation involves in two stages such as dilation and erosion. The closing morphology was adopted for enhancing the accuracy in detecting the fatigue cracks. The input and resultant images are shown in following Figure 3.

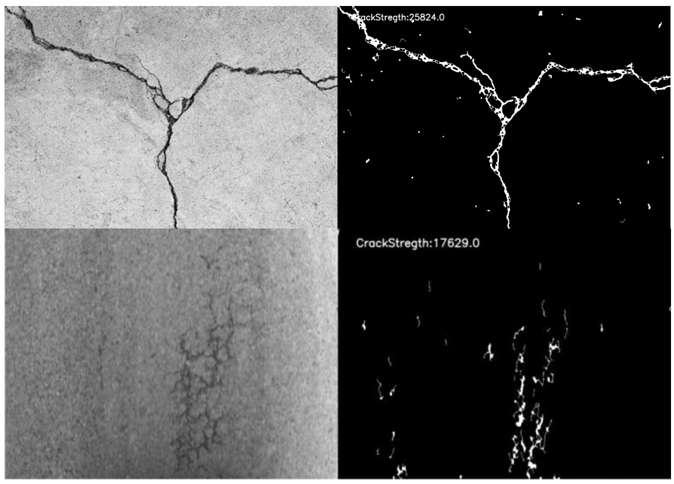

Figure 3. The input (left side-image) and output images (right side)

In this study, a total of 80 images were tested and the corresponding accuracy was computed. The collected 80 images composed of the images with fatigue cracking (60 images) and without fatigue cracking (20 images). The results of proposed algorithm are shown in following Table 1. The accuracy was determined by using following equation:

$$Accuracy = \frac{\text{Total number of images correctly predicted}}{Total\ number\ of\ images\ tested} \times 100$$

$$Accuracy = \frac{58 + 19}{60 + 20} \times 100 = 96.25\%$$

Table 1. The results of detecting the fatigue cracking

S. No	Images with Fatigue	Images without Fatigue
Detected Correctly	58	19
Detected Wrongly	2	1
Total	60	20

Summary

The results showed that the enhanced accuracy in detecting the fatigue cracking as compared to the Canny detection without morphological closing operator. In this study, a total of 80 images were tested and the fatigue crackings were detected with an accuracy of 96.25%.

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