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Determination of Optimal Parameters of Image Binarization Methods for Concrete Crack Identification

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ABSTRACT

Digital image processing has been introduced for automated identification of concrete cracks from images captured using digital imaging devices such as cameras and video recorders. Image binarization is a key process in the crack identification, which is to distinguish crack and background pixels based on statistical properties of pixel groups. Image binarization results highly depend on binarization parameters of window sizes and sensitivities, which prevent an objective and unbiased determination of crack information. Furthermore, the binarization parameters suggested in the literature are tailored to text detection, while optimal ones for crack information identification have been unexplored. This study presents a systematic way of selecting optimal binarization parameters for crack identification using the most commonly used methods developed by Niblack (1985) and Sauvola and Pietikäinen (2000). The optimal parameters of each method are determined by comparing crack information from a set of various crack image obtained using a DSLR camera and an optical microscope.

1. INTRODUCTION

Civil infrastructure suffers from a variety of loadings such earthquakes, typhoons, floods, winds, traffics, and service loads. These loadings induce structural damages and even failures, which result in national, social, and economical losses. To efficiently maintain civil infrastructure, a research field of structural health monitoring (SHM) has been emerged and extensively studied in recent several decades. Crack monitoring is one of the essential items in the condition assessment process for concrete structures, which is generally done by visual inspection in practice. Although having been used as a standard process in practice, the visual inspection inevitably depends on inspector's opinions, which can possibly produce biased observations.

Digital image processing has been introduced as an alternative to the visual

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inspection, which is possible to measure crack information from images captured by using digital imaging devices such as cameras and video recorders. Among the diverse methods for extracting crack information from the captured images, image binarization-based methods have a strong potential to effectively distinguish cracks and backgrounds based on statistical properties of the grayscale images. A wide variety of image binarization methods have been developed primarily to identify texts using the user-based input parameters of window size and sensitivity. Niblack [1] proposed an equation to determine a threshold considered the local mean and standard deviation. Sauvola and Pietikäinen [2] improved Niblack's method to compute a threshold by adding the dynamic range of the standard deviation. Because the targets of text detection and crack identification have a similar properties of a relatively dark color and shape of the line, image binarization is considered as a viable way to detect cracks in images.

In the crack identification using the image binarization, the most important issue is to choose appropriate binarization parameters such as a window size and a sensitivity value. Because the performance evaluation of text detections is generally conducted by using optical character reader (OCR), the thickness of detected text does not significantly affect the evaluation result. However, the thickness of measured cracks can be overestimated or underestimated according to the designated window size and sensitivity in case of crack identification. Thus, a research for deciding a proper window size and sensitivity of each binarization method should be studied to calculate an accurate crack information.

This study presents a systematic way of selecting appropriate image binarization methods with optimal parameters for the crack identification. A digital camera and an optical microscope are used to capture crack images in different conditions, such as working distance, crack direction, size, length, and width, and concrete surface. Subsequently, the optimal parameters of Niblack's and Sauvola's method are determined by analyzing the minimum root mean square (RMS) of crack information measured from camera and microscope.

2. METHODOLOGY FOR SELECTING OPTIMAL PARAMETERS

Because image binarization methods highly depend on the user-based input parameters of window size and sensitivity, the determination of optimal parameters is a key process for a practical crack identification. To determine an optimal window size and sensitivity, the comparisons of crack widths measured by an optical microscope and a digital camera are used as a criterion to select optimal binarization parameters. The flowchart of proposed methodology is shown in Fig. 1

To decide an optimal window size and sensitivity, the crack information measured by a digital camera and an optical microscope are compared. A digital camera and an optical microscope are used to acquire a wide variety of crack images in different conditions such as illuminances, working distance, crack widths, lengths, directions, sizes, and concrete surfaces. The captured images from digital camera are converted to grayscale; and image binarization methods with diverse parameters are conducted to generate binary images. Subsequently, non-crack elements removal is employed to the binary images for deleting noises using the eccentricity and actual number of pixels in the region; and the crack widths in pixels at specified locations are calculated, and these values are converted to metric by using the following camera pinhole model [3]:

$$W_r = D_p W_p = \frac{D_w}{10 P_c L_f} W_p \tag{0}$$

where W_r is the real crack width in metric (mm), D_p is the resolution of the imaging system, W_p is the obtained crack width in pixel, D_w is the working distance in mm, P_c is the pixels per centimeter of the used camera sensor, and L_f is the focal length of the camera in mm. Afterwards, these calculated crack widths are compared with measured crack widths of an optical microscope to select optimal parameters of each binarization method.

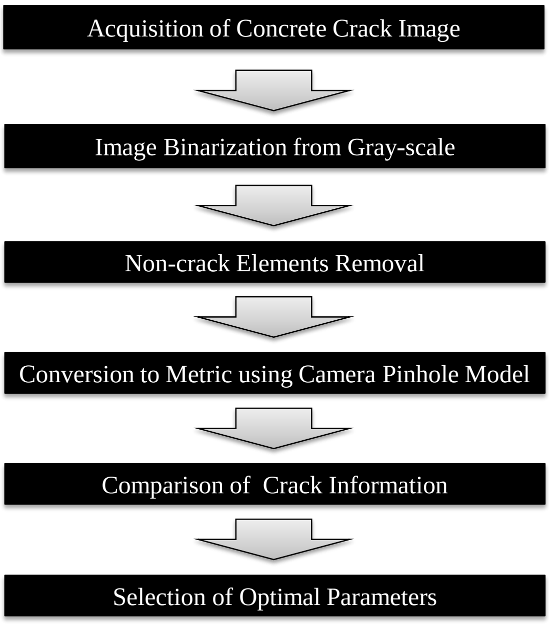

Fig. 1 Flowchart of proposed methodology

3. EXPERIMENTAL RESULTS

The proposed method is applied using collected sample crack images to determine optimal parameters. The crack widths calculated from image binarization methods are compared with the ones from the optical microscope. A different images of cracks with different conditions, including concrete textures, working distances, crack sizes, lengths, widths, patterns, and directions are captured by using a digital camera, and these images are used to calculate crack widths in the specified locations after image binarization methods. The color targets of post-it notes are attached to the concrete surface for identifying the specified locations compared with the results of an optical microscope. The true crack widths in pixels are manually measured using an optical microscope in a horizontal target line, a wide variety of binarization parameters is used to calculate crack widths in pixels based on image binarization methods. Subsequently, the true crack widths measured by an optical microscope are converted to metric using the pixel calibration, and the calculated crack widths calculated by a digital camera are converted to metric using the camera pinhole model.

The RMS results of crack widths are presented in Figure 2 as a 3D plot according to the selected boundary of sensitivity and window size. The boundary of sensitivity is in the range of -0.5 to 0.5 determined based on the default value of Niblack and Sauvola method, and the window size of all methods is in the range of 10 to 200. The simulation time of image binarization methods is closely related to the selected window size, a smaller window size is better than a larger window size in terms of the processing time. From the results, optimal sensitivity and window size of Niblack's and Sauvola's method are -0.22 and 101 and 0.06 and 111, respectively.

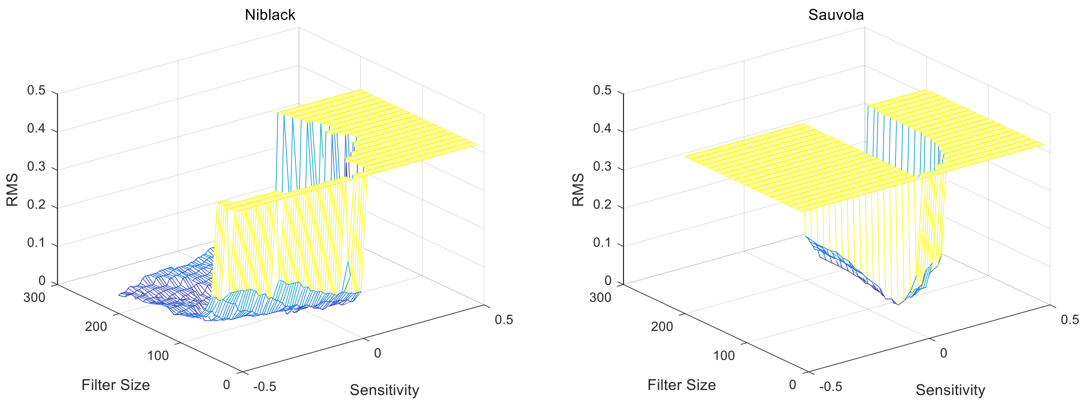

Fig. 2 RMS results of Niblack's and Sauvola's method

4. CONCLUSION

Digital image processing has been introduced as an alternative crack identification method instead of visual inspection, which is possible to conduct the automated identification of concrete cracks from images. Image binarization is a key process in the crack identification, which is to distinguish crack and background pixels based on statistical properties of the pixel group. However, crack identification results using image binarization methods highly depend on the user-based input parameters of window sizes and sensitivities, which prevent objective determination of crack information. This study presents a systematic way of selecting appropriate image binarization methods with optimal parameters for the crack identification. In the experiment, the optimal parameters of Niblack's and Sauvola's method are successfully determined by comparing crack information from a set of various crack image obtained using a digital camera and an optical microscope.

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