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Comparative Study of Various Image Processing Techniques to Detect Cracks in Concrete Structures

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Abstract*— Studies in the past have used image processing techniques on quality crack images obtained from open-source databases. The results obtained by using these techniques on such images yielded convincing results. But in an ideal situation, the environment in which the image is captured is often complex and dynamic, which does not guarantee good quality crack images. This study aims to compare the performance of four different image processing techniques used to detect concrete cracks when any crack image taken from a standard camera is used. The image processing techniques that have been considered are namely Wavelet transform, Min-Max Gray Level Discrimination, Super Pixel Segmentation and Nine Element Matrix method. The Otsu segmentation method is used to binarize the image after the images are preprocessed using these techniques, followed by the use of morphological operations to remove noisy spots. It was observed that Min-Max Gray Level Discrimination performed relatively better than the other techniques.

***Index Terms*—binarization, cracks, image processing, pixels.**

I. INTRODUCTION

Monitoring of cracks plays a major role in ensuring the durability, serviceability and safety of the structure. Due to the existence of constraints in reinforced concrete structures, structures are subject to deterioration over time [1]. As a result, cracks seem unavoidable and occur in concrete walls, slabs, beams and brick walls. Manual crack inspection by professional inspectors has been the most common way to detect and analyze cracks. The inspection procedure is physically demanding and time consuming. It is also prone to human and measurement errors, as the accuracy and reliability of the results depend on the skill set and experience of the inspector. These problems demand an automated approach to detecting and analyzing cracks. Over the years, there have been several studies suggesting methods to automate crack detection using image processing techniques. An automated crack detection system can help in reducing the time and cost of maintenance. It also helps to inspect complex environments and inaccessible parts of the structure. Therefore, the accurate detection of cracks is an essential step to facilitate the quantification of cracks in the structure for further analysis.

II. LITERATURE REVIEW

There has been a significant increase in efforts to find an efficient and accurate crack detection system in recent years. Image binarization is a widely used image processing technique to distinguish between crack and non-crack regions [2]. In [3], the authors proposed an image processing scheme which included the use of adaptive filtering and contrast enhancement to remove background noise. This was followed by the use of Otsu threshold segmentation to binarize the image and a Sobel filter to remove noisy spots for isolating the crack. Xuhang Tong et al. [4] proposed a method to detect cracks in irregular light conditions and complex environments underneath bridges. Jonathan P. Rivera et al. [5] presented a procedure which involved preprocessing the images to minimize over exposure and shadows, followed by an edge detection algorithm and morphological operations to detect cracks and surface defects. B Y Lee et al. [6] proposed a new image processing technique which included morphological operations to correct non-brightness in the background. Enhanced binarization and shape analysis was used to improve the detection performance. Damage detection using wavelet transform is a modern research topic rapidly gaining interest. It performs a local analysis of signals using wavelets which makes it capable of revealing hidden information in the image that other techniques fail to detect [7]. In a comparative study of four edge detection techniques: fast Haar transform (FHT), fast Fourier transform, Sobel, and Canny, the results indicated that fast Haar transform was more reliable than the others [8].

Otsu method is a nonparametric and unsupervised technique used for selecting an optimal threshold based on discriminant criteria to maximize the separability of the two classes present in the gray image [9]. Nhat-Duc Hoang proposed a gray intensity adjustment method that is used as a preprocessing step on the image before it is binarized. The results showed that the proposed method enhanced the performance of the Otsu algorithm thereby improving the crack detection performance [1]. Anis Salaheddin Sury [10] developed a sophisticated edge detection algorithm called the Nine Element Matrix method which provided a better continuity of crack edge lines compared to other pre-existing algorithms in MATLAB. Catherina Vasanthalin Prabakar and Chella Kavitha Nagarajan [11], established a novel

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approach for automatic recognition and detection of cracks using super pixel segmentation.

III. METHODOLOGY

In this comparative study, four different image processing techniques have been considered. The techniques include Wavelet transform, Min-Max Gray Level Discrimination, Super Pixel Segmentation and Nine Element Matrix method. They have been chosen on the basis of their applications and performance in previous studies. The Otsu segmentation method is used to binarize the image after the images are preprocessed using the above mentioned techniques. This is followed by the use of morphological operations to remove noisy spots. Each technique is applied to crack images obtained from an open-source database [12] and it is observed that all the techniques performed well in detecting the cracks. But when a crack image captured on a 16MP phone camera is used, all the techniques fail to detect the crack accurately. The general framework of this study is depicted in figure 2.

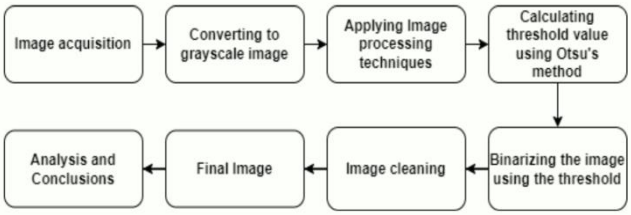

Figure 2: Framework of the study

The objective of this study is to compare four different image processing techniques used to detect concrete cracks. Studies in the past have used these techniques on standard quality crack images obtained from publicly available databases. The results obtained by using these techniques on those images yielded convincing results. But in an ideal situation, the environment in which the image is captured is often complex and dynamic. So, obtaining an image matching the standards used in previous studies is not guaranteed. Therefore, the comparative study done will be based on the accuracy of the results produced when any crack image taken from a standard camera is used.

MATLAB is used as the programming environment for the study. Images from two different sources are taken up for analysis. One source is an open-source database of crack images, and the other is a 16 MP phone camera. Images obtained from the sources are in RGB format. They are converted into a grayscale image using an inbuilt MATLAB function called rgb2gray, following which image processing techniques are used on the grayscale image. Wavelet Transform and Superpixel segmentation tools are available in MATLAB whereas, for Min-Max Gray Level Discrimination and Nine Element Matrix method, the algorithms were obtained from the studies of Hoang N-D [1] and Anis Salaheddin Sury [10] respectively.

IV. BACKGROUND

Wavelet Transform minimizes the unwanted textures that occur naturally or due to varying surface conditions such as moisture content, surface roughness, temperature etc [13]. Since the work deals with only 2-D images, discrete wavelet transform is used. Unwanted texture, also known as background noise, is removed by wavelet transform leaving behind finer details. In Superpixel segmentation, the image gets divided into a number of non-overlapping superpixels. Superpixels are a group of pixels having similar colors and textures. An image which is made up of a huge number of pixels gets reduced to a relatively small amount of superpixels, which makes this method computationally efficient [11]. Min-Max gray level discrimination technique increases the gray level intensities of potential non crack pixels and decreases the intensities for potential crack pixels [1]. As a result, the non-crack pixels appear lighter than the crack pixels. This enhances the performance of the Otsu Method as it is easier to find a threshold intensity which separates the two classes of pixels. In the Nine element matrix method, four differences in luminance are calculated around a pixel. The basic idea behind the previous step is that one of the differences will definitely be a fairly large value if a crack is present. As a result, no matter what the orientation of the crack edge is, this method will be able to detect it [10].

Otsu method is a commonly used image thresholding technique. The basic idea of the approach is to separate the pixels into two classes. MATLAB has an inbuilt function called graythresh which employs the Otsu method, to obtain the threshold gray level value. The threshold value obtained is then used to binarize the image using an inbuilt function called imbinarize. Following the binarization process, the image is cleaned using some morphological operations. Morphological operations are used on binary images to remove imperfections in the structure of the image. The application of morphological operations is illustrated in figure 3.

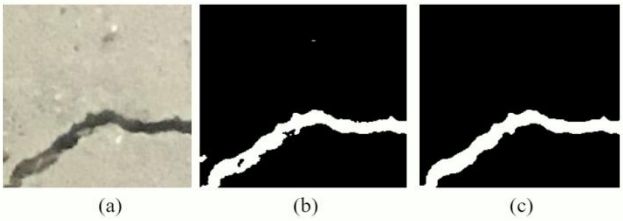

Figure 3: (a) Original image, (b) Binarized image and (c) Image Post morphological operations

V. RESULTS AND OBSERVATIONS

This section focuses on testing the image processing techniques that have been considered for this study. For this purpose, one image from each source has been used. As mentioned earlier, one source is a publicly available database of crack images while the other is a 16MP camera using

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which an image of crack on a brick wall has been captured. The images considered are shown in figure 4.

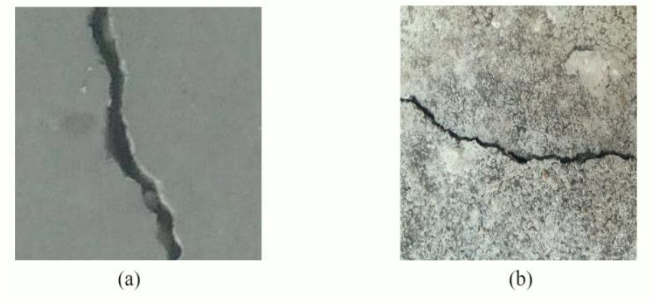

Figure 4: (a) Database image and (b) 16MP mobile camera image

The images obtained by following the methodology discussed above are shown below. Figure 5 contains the results of Wavelet transform method, and Figure 6 contains the results of the Nine element Matrix method, figure 7 contains the results of super pixel segmentation method and figure 8 contains the results of the Min-Max Gray level discrimination method.

Figure 5: Result of Wavelet Transform

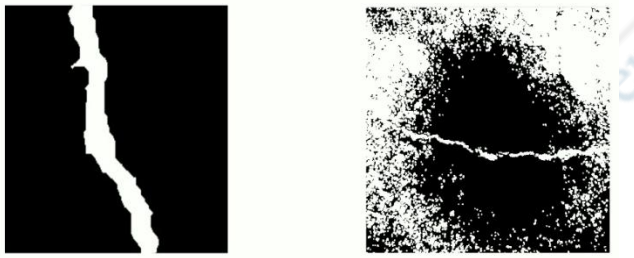

Figure 6: Result of Nine Element Matrix Method

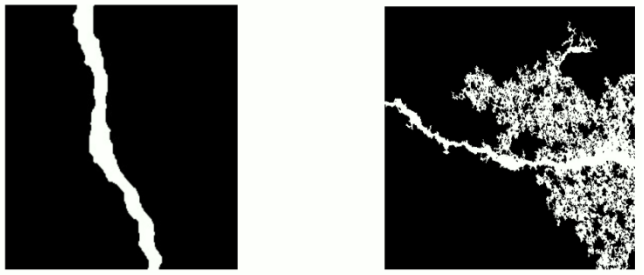

Figure 7: Result of Super Pixel Segmentation

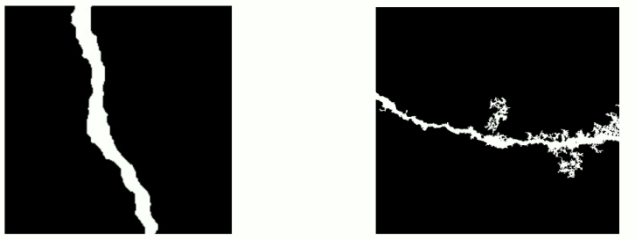

Figure 8: Result of Min-Max Gray level Discrimination

By analyzing the results, it is observed that all the image processing techniques used in the process of detecting cracks perform well when the database image is used. In the case where the Nine Element matrix method is used, it is observed that the crack gets detected correctly but the structural aspect of the crack is not retained. Also, this method worked accurately only when the crack spans the entire image. When an image captured using a 16MP camera is used, it is observed that all the methods have identified non-crack pixels as cracked. Among these, the method using Min-Max Gray level discrimination performs relatively better by misidentifying fewer pixels. Overall, the accuracy has decreased for all the methods when an image from a different source is used. Therefore, improvements are needed for the existing methods to make them viable for automating crack detection in the construction industry.

This discrepancy can be attributed to the fact that previous studies had performed their analysis using an image, primarily taken from the database, which had uniform illumination, a zoomed-in view of the crack, smooth and uniform surface surrounding the crack which makes the crack much more distinguishable from the rest of the surface. On the other hand, the image taken by the 16MP camera had an irregular surface which was also weathered by forces of nature. The comparison of the methods using the above-mentioned image processing techniques is illustrated in Table 1.

Criterias\Techniques		Wavelet Transform	Nine Element Matrix Method	Super pixel segmentation	Min-Max Gray level Discrimination
Accurate detection of crack	Database image	Yes	Yes	Yes	Yes
	16 MP - camera image	No	No	No	No
Structural aspect of crack maintained		Yes	No	Yes	Yes

Table 1: Comparison of various techniques

In an ideal inspection site, a zoomed-in view of a crack with uniform illumination cannot be obtained consistently. Moreover, the effect of weathering on the surface makes it difficult for these techniques to distinguish between the two classes of pixels. In other words, the image processing techniques considered could not reduce the background noise to the extent required for accurate detection.

VI. CONCLUSIONS

This study compared four image processing techniques which are commonly used in the process of detecting cracks. The techniques used are as follows, Wavelet transform, Nine element matrix method, Super pixel segmentation and Min-Max gray level discrimination. Images from two different sources, one being a publicly available database and other being a 16MP camera, were used to analyze the performance of the techniques. Most studies in the past had utilized this database for their experiments. It was observed that when an image from the database was used, all the techniques could detect the cracks accurately in most cases. On the other hand, when an image from the other source was used, none of the methods could detect the cracks accurately. This is because the digital image captured by the 16MP camera features various difficulties like low contrast, uneven illumination, surface roughness and texture variations due to weathering. The techniques could not help distinguish the crack and non-crack pixels in the presence of the difficulties mentioned above. As a result, there is a variation in the performance of the techniques when images from different sources are considered.

On a relative scale, when Min-Max gray level discrimination technique was used, there was a minimal misidentification of non-crack pixels as cracked. Therefore, it can be concluded that the Min-Max Gray level discrimination technique gave the best results among the ones considered. However, it fails to detect some comparatively thin cracks.

Therefore, there is a need to explore sophisticated techniques that help to tackle the difficulties like low contrast, uneven illumination etc. in the digital image for distinguishing crack and non-crack pixels more accurately.

REFERENCES

[1] GHoang N-D (2018) Detection of Surface Crack in Building Structures Using Image Processing Technique with an Improved Otsu Method for Image Thresholding. Advances in Civil Engineering 2018:10. doi:10.1155/2018/3924120

[2] Chaki N, Shaikh SH, Saeed K (2014) Applications of Binarization. In: Exploring Image Binarization 218 Techniques. Springer India, New Delhi, pp 65-70. doi: 10. 1007/978-81-322-1907-15

[3] Yun Wang et al., "Research on Crack Detection Algorithm of the Concrete bridge based on Image Processing" , 8th International Congress of Information and Communication Technology, ICICT 2019

[4] Xuhang Tong et al., "A New Image-Based Method for Concrete Bridge Bottom Crack Detection".

[5] Jonathan P. Rivera et al., "Automated Detection and Measurement of Cracks in Reinforced Concrete Components", ACI Structural Journal, V. 112, No. 3, May-June 2015, MS No. S-2014-084.R1, doi: 10.14359 /51687424.

[6] Bang Yeon Lee, Yun Yong Kim, Seong-Tae Yi Jin-Keun Kim (2013) Automated image processing technique for detecting and analyzing concrete surface cracks, Structure and Infrastructure Engineering, 9:6, 567-577, DOI: 10.1080/ 15732479.2011.593891

[7] Shuncong Zhong and S Olutunde Oyadiji, "Crack Detection In Simply Supported Beams Using Stationary Wavelet Transform Of Modal Data".

[8] Ikhlas Abdel-Qader et al., "Analysis of Edge-Detection Techniques for Crack Identification in Bridges", https://doi.org/10.1061/(ASCE)0887- 3801(2003)17:4(255)

[9] N. Otsu, "A threshold selection method from gray-level histograms," IEEE Transactions on Systems, Man, and Cybernetic, vol. 9, no. 1, pp. 62–66, 1979.

[10] Digital Image Processing For The Study Of Concrete Beam Cracks by Anis Salaheddin Sury, B.E.Sc (1999)

[11] Catherina Vasanthalin Prabakar and Chella Kavitha Nagarajan, "A novel approach of surface crack detection using super pixel segmentation", https://doi.org/10.1016/ j.matpr.2020.12.114

[12] C¸.F. Ozgenel, Concrete crack images for classification, Retrieved from, https://doi. org/10.17632/5y9wdsg2zt.2, 2019.

[13] Shahid Kabir and Patrice Rivard, Damage classification of concrete structures based on gray level co-occurrence matrix using Haar's wavelet transform, Computers and Concrete, Vol. 4, No. 3 (2007) 243-257.