ICCEPM 2022
The 9th International Conference on Construction Engineering and Project Management
Jun. 20-23, 2022, Las Vegas, NV, USA

Image-based Extraction of Histogram Index for Concrete Crack Analysis

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Abstract

The study is an image-based assessment that uses image processing techniques to determine the condition of concrete with surface cracks. The preparations of the dataset include resizing and image filtering to ensure statistical homogeneity and noise reduction. The image dataset is then segmented, making it more suited for extracting important features and easier to evaluate. The image is transformed into grayscale which removes the hue and saturation but retains the luminance. To create a clean edge map, the edge detection process is utilized to extract the major edge features of the image. The Otsu method is used to minimize intraclass variation between black and white pixels. Additionally, the median filter was employed to reduce noise while keeping the borders of the image. Image processing techniques are used to enhance the significant features of the concrete image, especially the defects. In this study, the tonal zones of the histogram and its properties are used to analyze the condition of the concrete. By examining the histogram, the viewer will be able to determine the information on the image through the number of pixels associated and each tonal characteristic on a graph. The features of the five tonal zones of the histogram which implies the qualities of the concrete image may be evaluated based on the quality of the contrast, brightness, highlights, shadow spikes, or the condition of the shadow region that corresponds to the foreground.

Keywords: concrete analysis, crack, histogram, structural condition, tonal zone

1. INTRODUCTION

The structural health evaluation is critical because it ensures the structure's integrity and safety during human occupancy [1]. In the past, structural inspections were conducted manually [2]. However, the quality of visual inspection is dependent on both the usage of appropriate equipment and the visual inspector's expertise. With human intervention the analysis often restricts the quality of inspection due to the limitations of human vision in image analysis, the abstract of understanding or concepts of analysis are frequently subjective instead of being objective; these concepts are based on the inspector's experiences. Apart from these disadvantages, the human eye is physically restricted in size, which limits its light-gathering ability. Additionally, the eye's frequency response is restricted by its capacity to perceive just visible wavelength electromagnetic radiation [3]. Further, the eye is incapable of storing images for later use. Aside from the various parameters that affect the human-based assessment, poor adaptability illumination conditions and stains on the concrete are some of the added issues to the human assessment method [4].

In general, a machine vision assessment is one of the solutions that may be used to ensure objective outcomes in an evaluation [5]. The system comprises an image capture equipment, a computer, and image processing software. The image processing techniques is capable to provide significant information on structures especially monitoring for monitoring purposes [6]. The proposed concept in this paper is to develop an automated image-based concrete technique that can be used to assess the condition of the concrete. The features and qualities of these concrete images, can correspond to the many aspects of the image such as edges, brightness, contrast, etc [7]. Computer-based assessments provide significant benefits, particularly in terms of image identification and classification. Computer vision can outperform human vision because computers can analyze and detect the different variances of colors, as well as distinguish them accurately.

2. HISTOGRAM ANALYSIS

An image histogram is a fundamental tool for assessing the amount of information contained in an image. In image-based analysis, an image histogram is commonly used in computer vision. An image histogram is a special form of the histogram that displays a graphical representation of the tonal distribution in an image. It plots the pixel value for each tonal value in the range. The x-axis is used to indicate the gray level intensities, while the y-axis is used to show the frequency. By viewing the histogram for an image, a viewer can quickly assess the whole tonal distribution of that image. The second purpose of the histogram is to determine the brightness of an image which has a wide application in image processing. In addition, not only in brightness but also in adjusting the contrast of an image can help to equalize an image. Furthermore, it can be utilized in image thresholding.

Image processing techniques are used to provide significant properties by extracting some key attributes of the concrete to identify its conditions. The following are some of the existing research studies that are relevant to the proposed study. Studies [8-9] used image processing techniques to characterize the concrete sample image that also identifies surface cracks. Research work [7] uses thermal imaging techniques and image processing tools to assess the health condition of a concrete structure. Other previous studies [10-11] performed a digital image analysis to determine the presence of cracks in concrete using a histogram of the oriented gradient.

In this study, other external factors such as the effects of dust, even smudges on the concrete image, as well as light reflection and shadow concerns, are eliminated. The non-cracked dataset was excluded from the image segmentation because it had no significance in terms of identifying the cracked concrete. The histogram features will aid the analysis since it provides a simple summation of pixel information for arbitrary positions on a given axis of an image. The graphical presentation provides the sum of the number of appearances of features extracted from the image enhancement provided by the image processing techniques such as contrast, brightness, and other color features which shows a statistical representation of an image in a given data distribution.

3. PROPOSED METHODOLOGY

As shown in Figure 1, the proposed methodology of this work comprises the description of the acquired dataset, the image processing techniques used, histogram extraction, and the assessment of the image being evaluated.

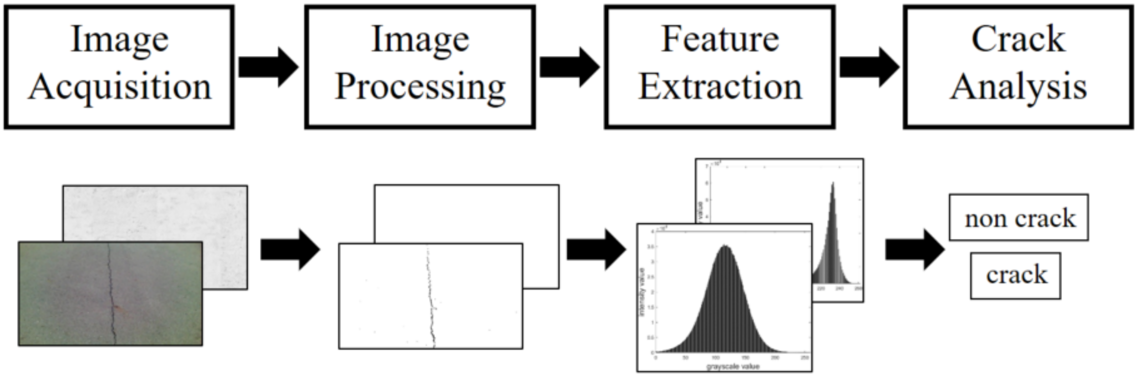


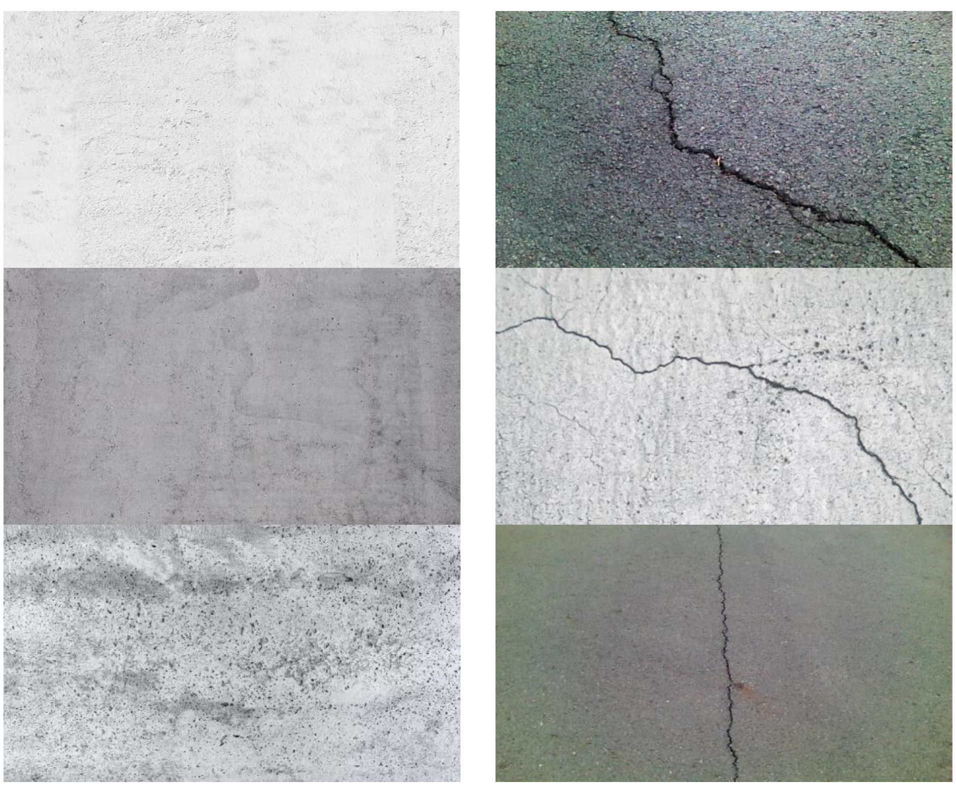
Figure 1. The proposed methodology of histogram extraction assessment.

3.1. Dataset

The proposed concept used a set of non-crack and surface cracked concretes. The dataset is composed of 3,000 images taken from various structures across Daegu City, Republic of Korea. Table 1 shows the summarized contents of the dataset. Figure 2 shows samples of the images that were used in this study.

Table 1. Summary of the dataset.

Non-crack images	Cracked image	Total number of images
1200	1800	3000



(a) (b)

Figure 2. Sample images of the dataset: (a) non-crack concretes; (b) cracked concretes.

3.2. Image Processing Techniques

After utilizing the resizing and filtering preprocessing techniques, all images subjected to preprocessing, the image segmentation algorithm is employed on cracked images only, converting them into a more manageable to analyze. Using multiple k-means values in image segmentation will provide either minimize or increase the variation of colors in an image, which can also help reduce or enlarge the size of the file. After thorough experiments, we discovered that setting k to 4 produces more relevant results for further image processing. The objective of the grayscale level on an image is used to eliminate the hue and saturation content from the image while keeping the luminance. In this study, changing an image to grayscale better changes its aspect, because it alters the depth of contrast at a pixel value, resulting in a more noticeable appearance. The image binarization procedure then replaces any values greater than a globally defined threshold with 1s and all other values with 0s, transforming the image to a binary image. The Otsu method is used to limit the variation of the threshold black and white pixels [12]. Finally, the edge detection approach is utilized to identify the most essential edge aspects of an image and serves as a filter to improve the image.

3.3. Histogram extraction

To avoid selecting inadequate features which can sometimes degrade the classification performance. In this paper, the proposed scheme is to use different feature extractions for texture classification using a histogram used as features for an image. Normally, when an image is used as a graphical representation, it conveys various information, including color space, picture features or objects in various stages of condition inside the image, coded data, and temperature mapping. The aim of this study is to use histogram features extraction of an image to classify them into two classes (cracked and non-crack concrete). In addition, the histogram tonal zone provides the characteristics of the object contained in a certain image. Figure 3 shows the five histogram tonal zones of a certain image.

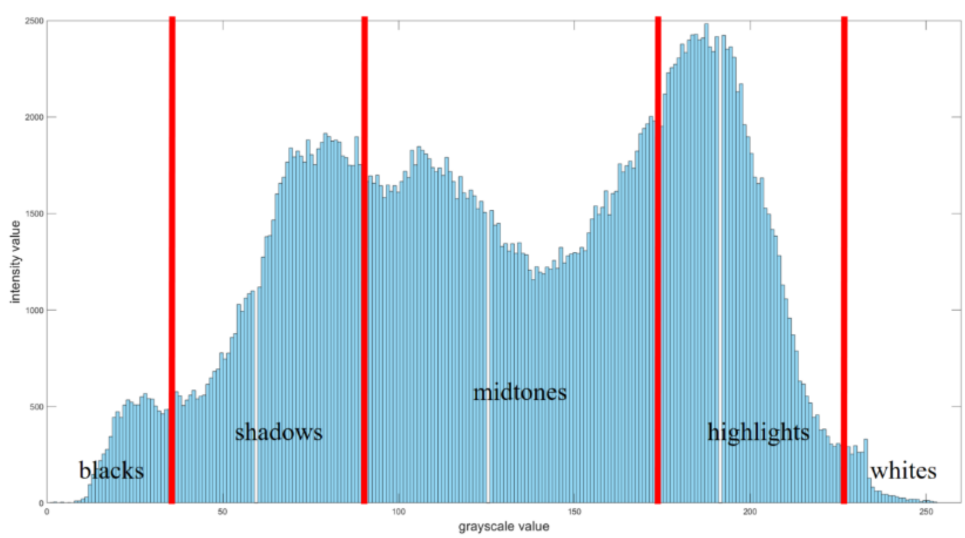


Figure 3. The five tonal zones of a histogram.

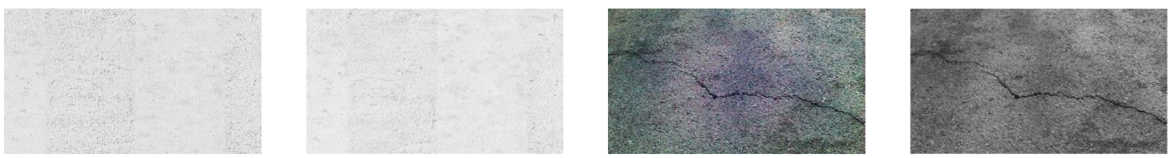
4. RESULTS AND DISCUSSIONS

Figure 4 shows the iterative output after providing the image processing techniques on the dataset.

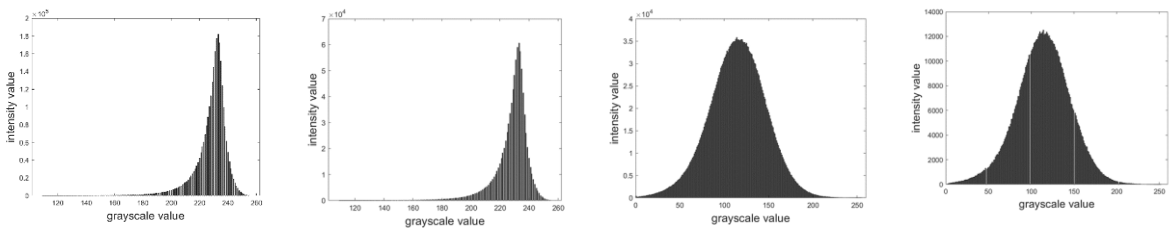
(a) (b) (c)

Figure 4. Sample of a cracked concrete image. (a) raw sample image; (b) grayscale output; and (c) the filtered image.

As shown in Figure 5, it shows that a non-cracked image provides a left-skewed histogram mode while the cracked image demonstrate demonstrates most likely a normal distribution histogram.



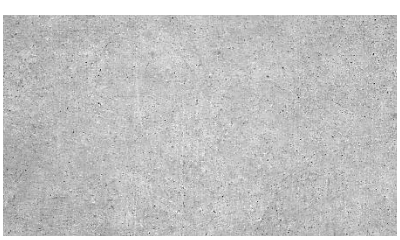
(a) (b) (c) (d)



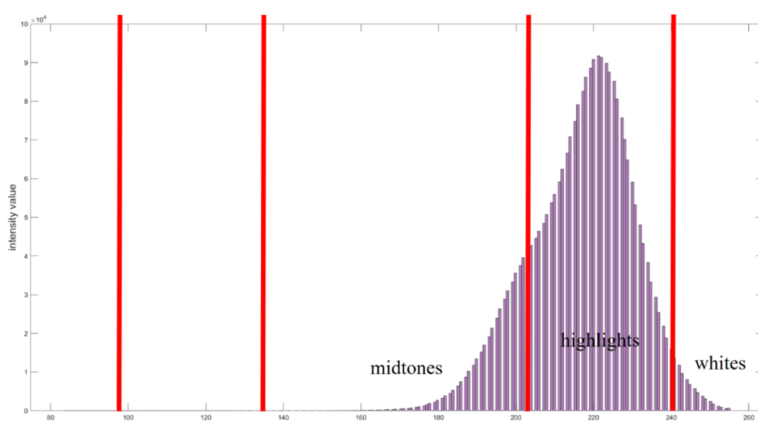
(e) (f) (g) (h)

Figure 5. Feature extraction using the histogram method. (a) raw sample image of a non-cracked concrete; (b) grayscale transformation of (a); (c) sample raw image of a cracked concrete; (d) grayscale transformation of (c); (e) to (h) are the corresponding histogram of (a) to (d), respectively.

Figures 6 and 7 show sample results using the five tonal zones of the histogram.



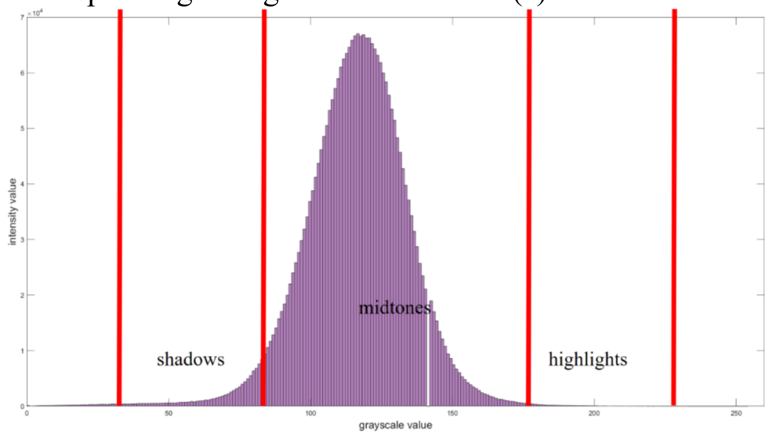
(a)



(b)

Figure 6. Histogram tonal zone extraction of a non-cracked concrete. (a) sample of a non-crack concrete; (b) corresponding histogram tonal zone of (a).

(b)



(b)

Figure 7. Histogram tonal zone extraction of cracked concrete. (a) sample of a non-crack concrete; (b) corresponding histogram tonal zone of (a).

Figure 8 shows different sample images and their corresponding histogram. It can clearly view that a non-cracked concrete image always has a left-skewed feature while the cracked concrete image provides an almost normal distribution histogram.

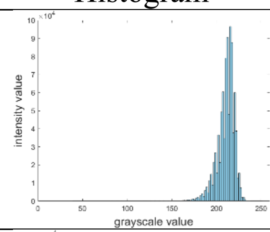
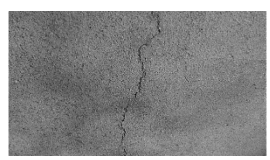
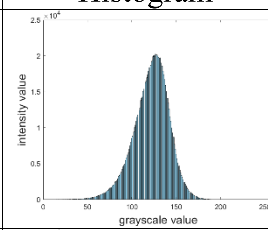
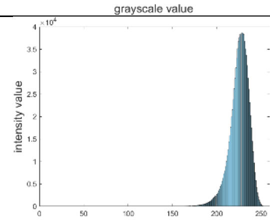
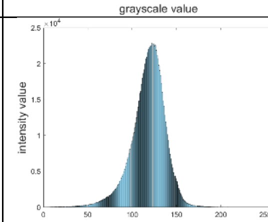
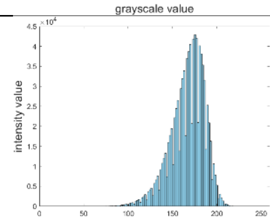
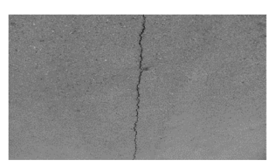
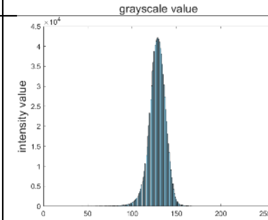
non-cracked concrete		surface cracked concrete	
Image	Histogram	Image	Histogram
			
			
			

Figure 8. Sample results using the histogram extraction of both the cracked and non-cracked concrete images.

In this paper, only two histogram characteristics are revealed. First, the image characteristics in graphical representation illustrate that, if a non-crack image is used for the extraction, the histogram result shows a left-skewed distribution. The majority of the number of data/information values are emerge on the right side whereas the remaining portion of the data values appears on the left side. In addition, from the five tonal zones of the histogram, no black and shadow region have occurred. The majority of the information contents are in the zone of the highlights region, with sideband information located on both midtones and white tonal zones.

On the other hand, when the extraction process is used on the cracked concrete image, the results in the graphical representation of the histogram appear to be in a normal distribution pattern. The distribution points appear on either side of the histogram, most likely identical in terms of the average value. Also, in a normal distribution, the mean, median, and mode are all in an equal scenario. Further, the tonal zone coverage as shown in the result, most of the information is concentrated in the midtones section, and the sideband information covers both regions of the shadows and highlights portion only.

5. CONCLUSION

This paper intends to provide a non-human intervention and an image-based assessment approach for structural monitoring by extracting the histogram feature from the acquired concrete images. Based on the simulated results, it shows a non-cracked concrete image has a left-skewed histogram mode in which the peak leans toward the right side, and has a tail on the left side of the histogram. Further, it demonstrates that a cracked concrete image exhibits a normal distribution in its tonal zone which encompasses the majority of the midtones region, and contains identical sideband information.

In the future, crack width estimation is necessary to specifically identify the health condition of the structure.

ACKNOWLEDGMENTS

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korean government (MSIT) (No. NRF-2018R1A5A1025137).

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