A Novel Detection of Cracks in Concrete Structures Using Image Processing

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***Abstract*: Cracks on the concrete surface are one of the earliest indications of degradation of the structure which is critical for the maintenance as well the continuous exposure will lead to the severe damage to the environment. Concrete slabs and bridge decks experience early ages cracks mainly due to volumetric changes associated with moisture and temperature variations These cracks have detrimental effects on their durability and long-term performance. Manual inspection is the acclaimed method for the crack inspection. In the manual inspection, the sketch of the crack is prepared manually, and the conditions of the irregularities are noted. Since the manual approach completely depends on the specialist's knowledge and experience, it lacks objectivity in the quantitative analysis. Surface cracks in concrete structures are critical indicators of structural damage and durability. Manual visual inspection, the most commonly used method in practice, is inefficient from cost, time, accuracy, and safety perspectives. It is difficult to find cracks by a visual check for the extremely large structures. So, the development of crack detecting systems has been a significant issue. The scope of this project is to overcome the problem by using a technique so that end user can clearly view the images and detect the cracks easily by retaining the original content of images. A promising alternative is computer vision-based methods that can automatically extract crack information from images.**

***Keywords*: Gray Scale, Segmentation, Erosion, Dilation, Histogram Equalization, CLAHE.**

1. Introduction

Crack detection is the process of detecting the crack in the structures using any of the processing techniques. Safety inspection of concrete structures should be strictly carried out since it is closely related with the structural health and reliability The importance of safety in facility is increased as the construction of high-rise buildings, super long span bridges, and asymmetric buildings are popular. In past years, inspection of cracks has been done manually by careful and experienced inspectors, a method that is subjective and scarcely efficient. Besides, the poor lighting conditions in the tunnels make it hard for inspectors to see cracks from a distance. Therefore, developing an automatic crack detection and classification method is the inevitable way to solve the problem. By developing an effective infrastructure lifecycle management system through automation, it is possible to secure the stability of the facility, and reduce the number of inspectors, inspection, time, and maintenance cost. Moreover, we can judge the condition of the structural health objectively by acquiring and processing the data. Most of the infrastructures are composed of concrete. In these structures, the one of the ways in judging the structural health is to examine a crack on the surface of the structure. Since the condition of a concrete structure can be easily and directly identified by inspecting the surface crack, the crack assessment should be done on a regular basis to ensure durability and safety within its life-cycle The work presented herein endeavors to solve the issues with current crack detection and classification practices, and it is developed for achieving high performance in the following three aspects: Detection rate: it is the most important requirement for the approach, which means the crack detection and classification approach must guarantee that the vast majority of crack length in the original image is detected in the last output results. Detection accuracy: under the premise of a high crack detection rate, the crack detection accuracy must be acceptable, which means that the misidentified objects should be removed as much as possible. Detection efficiency: in practical application, thousands of images are collected, making the processing of so many images a huge task. Therefore, the image processing process must be fast and efficient. Algorithms with high computation complexity are not applicable in this situation. The above three requirements are the principles for developing the automatic crack detection and classification method. First of all, to guarantee high detection rate, the captured tunnel images should be able to present cracks as much as possible, thus the captured images should have acceptable resolutions.

2. Literature review

The Following literature review discusses methods of detection of cracks by using different operators and segmentation techniques are applied to a variety of test images.

Corr et al. (2007) proposed a technique to examine the bond between carbon fiber reinforced polymers (CFRP) and concrete substrates and to examine the interfacial transition zone (ITZ) of plain concrete, and the softening and fracture behavior of this region. For this, DIC allows for precise measurement of the surface displacements of the deforming materials. The resulting strain data are higher in resolution than is possible with other experimental techniques.

Shin et al. (2008) proposed self-calibrating surface wave transmission method which is a promising nondestructive technique for surface-breaking crack depth inspection of concrete. Determination of crack depth using the cut-off frequency in the transmission function (TRF) is difficult, however, in part due to the variability of the measurement data. The effectiveness of the proposed method is validated by comparing the conventional time-of-flight and cut-off frequency-based methods. The results show that spectral energy transmission has excellent potential as a practical and reliable in place nondestructive method for in-place crack depth estimation in concrete structures.

Maini and Aggarwal (2010) proposed a combined approach of gray level transformation algorithms, such as logarithmic transform and power law transform, with alpha rooting algorithm for contrast enhancement. Enhancement techniques such as alpha rooting operate on the transform domain whereas grey level transformations operate on individual pixel. However, these techniques bring about tonal changes in the images and can also generate unwanted artifacts in many cases.

Hoult et al. (2013) proposed an alternative technique for measuring strain using digital images called Digital Image Correlation (DIC) that allows for the measurement of 2-D strain fields. A series of tension tests on steel plates are conducted allowing measurements from the DIC technique to be compared to measurements from conventional foil strain gages. Using these solutions, it is possible to achieve mean strain errors of less than 5 $\mu\varepsilon$ when comparing DIC to foil strain gage measurements, which suggests that the DIC technique has the potential to replace conventional strain gages. Areas of future research are also introduced.

Rivera et. al. (2015) proposed a procedure for structural inspection that often requires application of non-destructive techniques for localization of damages, and for validation of the structural integrity. The proposed algorithm can be applied to datasets of the images generated at different loading levels for the purpose of producing a diagram that represents evolution of the crack distances with increasing load. It is illustrated using the experimental data obtained by the authors

Kim et al. (2017) proposed computer vision-based methods that can automatically extract crack information from images. They have focused on optimal parameter determination and comparative performance evaluation for five common binarization methods. Subsequently, comparative analysis is conducted using crack images with different conditions based on three performance evaluation criteria: crack width and length measurement accuracy and computation time.

Mohan and Poobal (2017) provide the collective survey of the different image processing techniques used for the detection of the cracks in the engineering structures. The main intention of this study was about to study and review the crack detection system based on image processing. Here they have taken 50 research papers for the review based on the crack detection and finalized review based on the analysis of the five features.

3. Research methodology

In this research work, firstly the image acquisition is done and after the image pre-processing will be done like rbg to gray scale, segmentation, histogram equalization and morphological operations. Finally, the parameters of the detected image will be measured.

Step 1: The image is input to the Matlab workspace i.e. Image Acquisition will be done-First of all the image will be acquired from the database and will be loaded in the Matlab workspace.

Step 2: Image preprocessing will be done- Contrast adjustment will be performed and image is converted from RGB to grayscale.

Step 3: Image Processing will be Performed-Image Processing includes Image Segmentation and Morphological Operations.

Step 4: The crack will be detected-In this step; the crack will be detected in the image.

Step 5: The Parameter Estimation will be performed-The actual length of crack will be determined

4. Flowchart

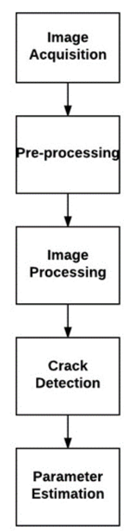

Fig. 1. Proposed flowchart

5. Experimental results

The proposed work has been implemented in MATLAB and the results are evaluated as presented below.

As illustrated in figure 3, file selector window opens where the image to be loaded can be selected. In the next step, Contrast Adjustment is performed. Contrast adjustment remaps image intensity values to the full display range of the data type. An image with good contrast has sharp differences between black and white.

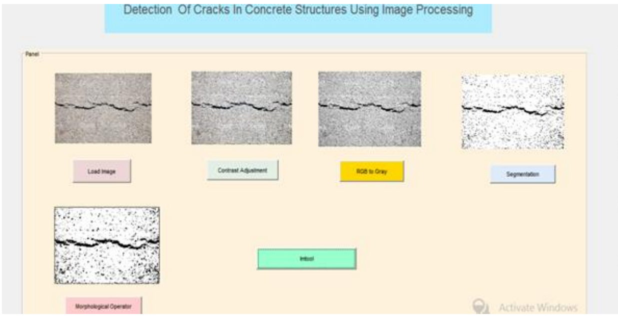

Fig. 2. Front panel of the project

Fig. 3. Image loaded

Fig. 4. Contrast adjustment

In the next step, RGB to Grayscale conversion is performed. I = rgb2gray(RGB) converts the truecolor image RGB to the grayscale intensity image I. The rgb2gray function converts RGB images to grayscale by eliminating the hue and saturation information while retaining the luminance.

Fig. 5. RGB to gray

In the next step, Segmentation is performed. In computer vision, image segmentation is the process of partitioning a digital image into multiple segments (sets of pixels, also known as super-pixels). The goal of segmentation is to simplify and/or change the representation of an image into something that is more meaningful and easier to analyze.

```
I = imread('crack.jpg');
level = 0.50;
Ithres = im2bw(g,level);
imshow(Ithres)
```

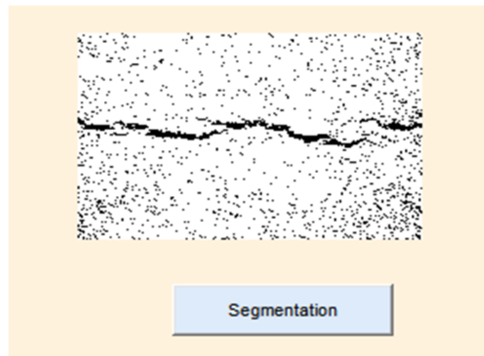

Fig. 6. Segmentation

Morphology is a broad set of image processing operations that process images based on shapes. Morphological operations apply a structuring element to an input image, creating an output image of the same size. In a morphological operation, the value of each pixel in the output image is based on a comparison of the corresponding pixel in the input image with its neighbors. By choosing the size and shape of the neighborhood, you can construct a morphological operation that is sensitive to specific shapes in the input image.

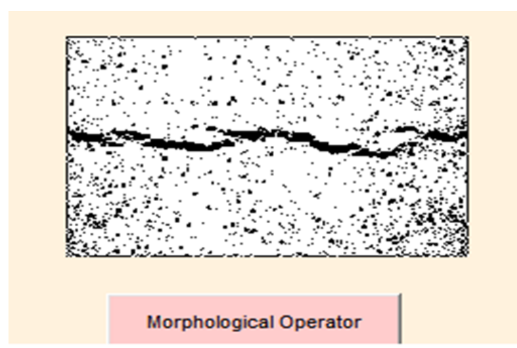

Fig. 7. Morphological operator

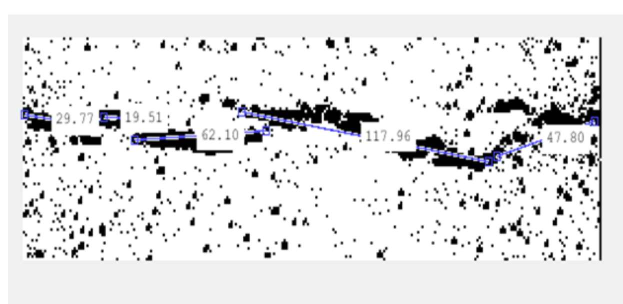

Fig. 8. Length of crack

In the last step, the length of crack is determined through imtool function in Matlab.imtoolopens a new Image Tool in an empty state. Use the *File* menu options *Open* or *Import from Workspace* to choose an image for display. imtool(I) displays the intensity image I.

6. Conclusion

Cracking can invite sudden failures of concrete structures. The crack detection during the manufacturing process is an important step for quality management of panel products. Traditional crack detection methods are subjective and expensive because they are performed by experienced human inspectors. Therefore, crack detection techniques for automated and accurate inspection are required. The project presents a procedure for crack identification using digital images of concrete elements. Various techniques used are Contrast Adjustment, RGB to Grayscale conversion, Segmentation and Morphological Operations. In an automatic manner, the proposed algorithm allows to determine coordinates of cracks and forward resulting data through a numerical procedure of crack spacing determination. The main contribution of this algorithm was realization of an automated crack detection system, which allows eliminating subjective judgment characteristics of the traditional expertise.

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