Analysis of cracks in structures and buildings

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Abstract. Analyzing and identifying cracks is the most vital step in the construction process. The manual crack detection process will take longer and will be subjectively assessed by the inspectors. This research provides a conceptual base for the image processing methodology for the automated identification and examination of cracks. This model uses the Gray Intensity Correction Method (i.e.) Min Max Gray Level Differentiation (M2GLD) for Image Improvement and the Otsu Image Binarization Process. The experimental result shows that the combination of the M2GLD method and the Otsu test will effectively detect crack defects in digital images. This model can therefore be a useful tool for building construction agencies and structural maintenance engineers.

Keywords: Cracks, Image processing, structural cracks, building cracks, causes of cracks

1. Introduction

Even as engineers, cracking on the top of the frame was also a big problem for building owners. That is because cracks may have a major effect on structural safety, reliability and serviceability [1-3]. The hypothesis is that as cracks are created and propagated, a bent is supposed to induce a decrease in the effective loading region resulting in increased stress and subsequent collapse of concrete or alternate structures[3]. Because concrete structures also have drawbacks and buildings deteriorate with time, cracking seems likely and all kinds of structures show as examples of concrete blocks, columns, slabs and brick walls[12]. The purpose of the shape, number, width and length of cracks on the structural surface indicates the earliest degree of degradation and the ability of the concrete frameworks to hold. Cracks are generally divided into two types[10]. There are [1-3, 13] concrete cracks and non-structural cracks. These non-structural cracks may occur due to internal pressure, poor workmanship, etc. Cracks can vary greatly in size. Widespread cracks vary in width (a) less than 1 mm, (b) medium—from 1 mm to 2 mm, (c) wide-more than 2 mm [1, 3, 4, 13]. Active fractures cause a great deal of discomfort and need careful treatment because they are structurally dangerous. Small cracks that look insignificant can also develop and can eventually lead to serious structural failure[9]. It is therefore important to consider the varieties of cracks, crack patterns and hence their causes, as well as the preventive steps to be taken to manage cracks[2]. Manual visual inspection is inefficient, both in terms of price and consistency, as required by the individual decision of the inspectors. Due to the inconsistent form and unusual scale of cracks and various vibrations, there are a host of problems within the image-based square tracking, such as odd light patterns, colors, blemishes, and bits of concrete within the obtained images. Due to its ease of operation, several
ways of detecting the operation of the image have been developed. There are many types of imaging techniques available. These include (a) IR based imaging techniques, (b) Ultrasound based imaging techniques, (c) Laser based imaging techniques, (d) TOFD based imaging techniques, etc [10, 11]. Though Crack detection using the Otsu process is a common technique, but it is unsatisfactory due to different reasons such as poor contrast, irregular light, concrete spall in images, etc. [5-8]. Photo retrieval, which is commonly used for text recognition and medical image analysis, is highly suitable for crack detection [14]. It’s because the text and fractures have identical features, and they have unique forms and curves. Image processing system that automatically identifies and analyzes the contents of the Otsu form. The Min-Max Gray Level Discrimination (M2GLD) Image Improvement Algorithm is proposed as a pre-processing step to improve the Otsu binarization procedure, followed by a shape analysis to increase crack detection performance [7, 14]. The examples of cracks are mentioned in Figure 1 and Figure 2.

![Figure 1. Crack occurred on Structure](image1)

![Figure 2. Crack occurred on Lintel](image2)
2. Description of area
The study on the investigation of the causes and solutions to cracks in buildings was undertaken in various buildings, located in Kalasalingam Academy of Research and Education, Krishnankoil, Tamil Nadu. We chose some buildings inside the University campus according to their age of construction and collected the crack samples from the buildings. The names of the buildings are listed below in Table 1.

| S. No | Name of the Building       | Year |
|-------|---------------------------|------|
| 1     | Block – 1                 | 1985 |
| 2     | Block – 3,4               | 1992 |
| 3     | Controller of Examinations| 1996 |
| 4     | PG Hostel                 | 2000 |
| 5     | G.D. Naidu Block          | 2005 |
| 6     | Srinivasa Ramanujam Block | 2010 |
| 7     | Visveshwaraya Block       | 2015 |

3. Objectives
- To identify the type of crack occurred in the buildings and come up with a solution to serve for the society.
- To identify the severity of cracks using Image Processing Technique.

4. Methodology
Identification of Cracks and their Causes:
In reconnaissance survey, the building inspection was performed to diagnose the cracks inside the building, by looking at the entire building from a distance, walking around the building, and inspecting each room to identify the cracks, and measuring each crack in detail, and their position in the building[1, 2]. The building was broken down into two pieces. (A) Internal building floor, (b) External building floor. We produced a table to indicate in a particular location the crack occurred. In Table 2 we listed the table generated here.

| S. No | Location of Crack | Vertical Crack | Horizontal Crack | Inclined Crack | Seepage Attack | Patches | Crack occurred on Structure | Crack Occurred on Wall |
|-------|-------------------|----------------|------------------|----------------|----------------|---------|-----------------------------|------------------------|
| 1     |                   |                |                  |                |                |         |                             |                        |

Cracking is an essential sign of structural breakdown. Crack detection is usually expected at the maintenance point of the house. In fact, structural quality checks aided by crack analyzes have been important for the service life assessment of structures[14].

Since this manual crack measuring process is extremely time-consuming for large-scale structures (e.g. high-rise buildings and bridges), some researchers have developed models focused on image recognition.
that offer a quicker and more accurate way to quantify cracks on concrete surfaces[14, 15]. The structure for these models as seen in Figure-3.

![Diagram of image processing](image)

**Figure 3. General Process of Image Processing**

After installation, the model is used to identify and inspect cracks on the surface of a range of building materials, such as concrete columns, slabs, doors, walls and a mortar-covered brick wall.

### 4.1 Otsu Method for Image Binarisation:

The Otsu approach is widely used for thresholding pictures [8, 14]. The fundamental idea of the Otsu approach is to categorize the pixels of a visual image into two groups: the point of significance and the background. The separate entity displays $\omega_0$ and $\mu_0$ which are the ratio of the pixel number and hence the average gray color. Likewise, the background of the image also has the two parameters of $\omega_1$ and $\mu_1$. The overall mean of the gray level of the picture is thus defined as follows.

$$\mu = \omega_0(t)\mu_0(t) + \omega_1(t)\mu_1(t) \quad ... (1)$$

where $t$ denotes a gray level of the image.

The image is optimally binarized if the following optimization function $f_s(t)$ is maximized.

$$\text{Arg Max } f_s(t) = \omega_0(t)(\mu_0(t) - \mu)^2 + \omega_1(t)(\mu_1(t) - \mu)^2 \quad ... (2)$$

The upper level gray value admires the maximum value of $f_s$, as the threshold value for binarization of the image[5] is selected. If there are two separable peaks in the gray-level histogram of the image, the Otsu method can correctly determine the optimum value of the top position between these two peaks. The maximum value of $f_s$ is admired by the top gray level, as the threshold value for image binarization[5] is selected. If the gray-level histogram of the picture contains two separate peaks, the Otsu method can accurately determine the optimum value of the top position between these two peaks. However, in cases of unimodal and near-unimodal image histograms, this approach may encounter difficulties in determining the reasonable value of the tip. The building is exposed to a variety of factors, including lighting, bleaching, shade, etc. These requirements are not fulfilled by the current Otsu method. This thesis must be accompanied by an updated Otsu method for the analysis of cracks in buildings and structures.

### 4.2 Min-Max Gray Level Discrimination:

Owing to the unique crack features that involve distinguishable lines and curves, the gray-scale value of the crack is usually the minimum region inside the image[15]. The brightness of the image in the background is not constant. In comparison, the building surfaces often feature low visibility, intermittent
lighting and extreme noise disruptions. In order to reverse this phenomenon, a protocol must be implemented to boost crack detection performance\cite{11}. To divide the image pixels into crack and non-crack classes, a simple technique called Min-Max Gray Level Discrimination (M2GLD) is used as an image pre-processing step before the Otsu method is used for image binarization\cite{15}. The layout configuration of the image processing technique was clearly illustrated in Figure 4.

![Figure 4. Model Structure](image)

5. Result and Discussion
The proposed crack detection and analysis program is being checked with a series of test images. The program parameters are set empirically as follows.
The adjusting ratio: RA = 2
The margin parameter: \(\tau = 0.5\).
Results of crack detection are shown from figure 5 to figure 9. The crack pixels detected by the proposed method are smoother and well separated from the structure compared to the Otsu method in all the test images. In addition, cracks detected by the proposed system mimic the actual crack structures within digital images. We can therefore assume that the newly constructed software could be a great tool for the sensible implementation of crack detection in the building structure.
Figure 5. Testing Image 1

Figure 6. Testing Image 2
Figure 7. Testing Image 3

Figure 8. Testing Image 4

Figure 9. Testing Image 5
5.1 SURVEY FORMAT
Survey conducted in Srivilliputtur village has been photographed. The following questions have been raised and the answers for the questions by the engineers and peoples of Srivilliputtur are enclosed below.

| QUESTIONS                                                                 | ANSWERS                                                                                                                                   |
|-------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|
| Why cracks are formed?                                                  | Cracks are formed due to the Subsidence, Settlement, Heave, Sway, Vibration and so on.                                                   |
| What are the reasons behind the formation of cracks?                    | Poor construction materials, foundation movements and settling of buildings, changes in temperature and climate, etc…                       |
|                                                                        | Plastic shrinkage concrete cracks. Expansion concrete cracks.                                                                             |
|                                                                        | Heaving concrete cracks.                                                                                                                  |
|                                                                        | Settling concrete cracks.                                                                                                                  |
|                                                                        | Concrete cracks caused by premature drying.                                                                                               |
|                                                                        | Permeability of concrete, corrosion of reinforcement, moisture variation, temperature variation, poor construction practices, poor structural design and specifications, elastic deformation, creep, chemical reaction, foundation movement & settlement of soil, growth of vegetation, |
| What are the types of cracks occurred in buildings?                     | Reduce Water Content in Concrete:                                                                                                         |
|                                                                        | Proper Concrete Mix Design and use of Quality Materials.                                                                                  |
|                                                                        | Finishing of Concrete Surface. Proper Curing of Concrete.                                                                                  |
|                                                                        | Proper Placement and Vibration of Concrete.                                                                                               |
| What are the factors influencing the formation of cracks in buildings and structures? | Yes                                                                                                                                       |
| What are the preventive measures you’ve taken to minimize cracking?     | Reduce Water Content in Concrete:                                                                                                         |
|                                                                        | Proper Concrete Mix Design and use of Quality Materials.                                                                                  |
|                                                                        | Finishing of Concrete Surface. Proper Curing of Concrete.                                                                                  |
|                                                                        | Proper Placement and Vibration of Concrete.                                                                                               |

6. Conclusions
This theory establishes an image processing system to detect crack defects on the surface of the building structure. The software uses the Min-Max Gray Level Discrimination (M2GLD) Image Improvement Algorithm as a pre-processing step to improve image quality. For picture binarization, the well-known Otsu technique is used to reveal fractures that occur on the surface of the structure. The M2GLD strategies adopted by the Otsu methodology mentioned in the present work are also clearly integrated into multiple crack detections and possible categorization models. The reason for this is that the procedure is capable of delivering effective crack detection output as unquestionable in laboratory experiments. As crack surfaces are removed from the sense of development, there is far more reliable work into these detected cracks.
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