

## CONCRETE SURFACE CRACK DEFECT DETECTION BY USING IMAGE PROCESSING: A SHORT REVIEW

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### ABSTRACT

In the early stages of structural degradation, cracks in the concrete surface area are an important maintenance indicator as well as an environmental hazard owing to extended exposure. Manual inspections are a well-known crack assessment method. In the course of a physical examination, a fracture drawing is created by hand and the circumstances of the irregularities are recorded. The quantitative analysis lacks objectivity since the manual approach is completely dependent on the expert's knowledge and expertise. As a result, an alternative to image-based automatic fracture identification is provided. The study's primary goal was to examine and evaluate an image processing-based technique for identifying fractures and identifying the main problem in image processing for crack detection. Image processing may be used to locate cracks in a variety of methods, according to the literature. As a result, a review of 10 years period for image processing of crack analysis in concrete concluded that three main problems in image processing are undetected crack, long processing period and presence of interference object. Besides, the major image processing technique that is being used for crack analysis is the Otsu thresholding method, Sobel edge detection method and Canny method.

**Keywords:** *Concrete, surface crack, defect detection, image processing*

### 1.INTRODUCTION

A crack is the result of the splitting or fracturing of concrete into two or more sections, whether the separation is complete or not. Buildings, bridges, roads, pavements, railroad tracks, vehicles, tunnels, and aeroplanes, to name a few, all have surfaces that are susceptible to cracking over time. Active cracks and dormant cracks are the two main classifications of cracks that exist. The direction, breadth, and depth of active cracks fluctuate over time, whereas dormant cracks remain the same. Passages for moisture penetration exist in both active and dormant cracks. If not repaired, this can lead to further deterioration. Transverse, longitudinal, and other cracks, as well as crocodile, and reflection cracks are only a few of the many currently active fractures. In nature, dormant fractures are extremely fine, and they gradually mend on their own with time. When it comes to cracks, the different sorts are classified depending on their structure. These include microcrack and sealed-crack varieties as well as mixed-crack and line-like-crack varieties. It is important to perform precise fracture detection by measuring the size of the cracks to ensure dependability. The human visible inspection is time-consuming and slow, automatic crack detection technologies are increasingly being used since their processing speed is faster than that of human inspection. The use of image-based crack detection is becoming increasingly popular. The image processing techniques in crack detection has several advantages over manual approaches; the most

significant of which is the accuracy of the findings [1]. However, the defects, fractures, abnormalities, and disturbances in images, image-based detection presents some other challenges faced in image processing [2]. Image-based fracture identification for non-destructive inspection is gaining popularity as a non-destructive inspection technique. Certain problems in detecting irregular cracks and noises such as uneven lighting conditions, shadowing, imperfections, and concrete spall on pictures are caused by random fracture shapes and irregular crack sizes in the obtained images of the detection system. Many of the image processing detection methods have been presented because of their simplicity in terms of processing time.

The complexity in processing a picture in fracture detection is proportional to the size of the image. Deep learning algorithms are those algorithms that are derived from artificial intelligence and have been refined through time. Therefore, 17 research articles on crack detection were selected and evaluated, with the results of the study being used to inform future research. After a brief introduction, the arrangement of this review article moved on to camera-based image processing, followed by unmanned aerial vehicle and phone-based image processing, respectively. Additionally, the discussion and analysis section focused on a typical challenge in crack identification by image processing, and an analysis based on image processing techniques was included.

### ***1.1 Camera-based Image Processing***

Yiyang et al. [3] have Proposed a digital image processing technology crack detecting technique. They gathered information about the crack picture by pre-processing, image segmentation and feature extraction. After the approved picture was smoothed, the threshold segmentation approach was applied. To evaluate their picture, The roundness index's surface area and perimeter have been calculated. Then, the crack's presence in the picture was assessed through comparison. Although many commercial images processing approaches simply mandate preprocessing, several techniques are focused on the integration algorithm for the extraction of features, which is a key component of feature extraction.

The image processing scheme's overall efficiency might be affected by the filtering techniques used in it. Salman et al. [4] the technique suggested to automatically differentiate cracks in Gabor filtering digital images. The high-potential Gabor filter allows multi-directional fracture identification. The Gabor filter is a powerful multi-direction fracture detecting method. The Gabor filter function image analysis was closely connected to the manual visual perception. The fractures aligned to various directions will be discovered once the filtering has been completed. For their approach, they have a detection accuracy of 95%.

In image processing for the detection of fractures in concrete structure pictures, a novel technique has been described by Talab et al. [5]. Three stages are taken in the methodology: First, convert the image to grey with the picture edge, then apply Sobel's approach to produce an image using the filter from Sobel to identify fractures. Then they are classified into the front and background picture using the appropriate binary threshold image of the pixel. Sobel filtering has been utilized for the removal of remaining noise once the pictures are classified. Cracks were discovered utilizing the Otsu technique after the enormous filtering process of the picture. In certain situations, the sober filter has been substituted with the multiple median filtering.

Nguyen et al. [6] Their technique has been built on the detection of noisy 2D images of concrete fracture surfaces. You have seen the fractures as a topology of the tree. Based on the Phase Symmetry-Based Crack Enhancement Filter (PSCEF), non-cracking components were removed. After separation, the threshold filter or morphological dilution method were binarized for fracture central line estimate. The centerline of the cubic divisions was then established. The edge is related to the continuous cracking edge. The surface of the crack was reached from the crack edge. The findings of the application of the process to concrete surface pictures showed that their technique could detect weak fractures correctly and minimize the noise from unwanted items substantially. In addition, the approaches provided might be expanded to calculate the fracture width in cross-section profiles from edge points. Their proposed image processing approach was intended to improve the efficiency and cost-effectiveness of crack inspection.

Lins et al. [7] proposed the automated crack measuring operations a system based upon ideas that have been built. Only one camera was used in the image sequence for estimating the fracture size. The hue–saturation–value (HSV) and red, green, and blue (RGB) model algorithms were then used to identify fractures by cracking image sequences. The input and output of the proposed technique are a fresh image with red particles on the detected fracture. The pixel positions of the particles were logged and transmitted as a vector to the crack technique. The technique calculates the number of pixels in a cross-section with pixel position and gives crack dimensions.

Wang et al. [8] suggested a picture-based crack detection approach and depending on its functioning define the crack. Four kinds were classed as the current frame-based fracture detection. The algorithms, morphology, percolation, and practice were all integrated. The shading was adjusted with an integrated algorithm. The technique of percolation was utilized to find the unclear prediction of crack. The fracture identification was made using a methodology of morphology to detect microcracks using the practical technique for extracting characteristics.

The present work [9] proposes a complete automatic fracture identification and crack kinematic measuring method for digital image correlation instrumented laboratory investigations (DIC). The suggested procedure uses well-recognized methods of image processing to extract the fracture pattern as skeletons. The given fracture identification process is based on the DIC concept of strain field. In contrast, the vast number of previous crack detectors, who used the pixel intensities of real pictures to extract break sites in dark pixels. The identified cracks were therefore immediately connected to the deformations recorded on the surface, allowing the removal of much finer cracks and more dependable fracture locations. The concepts and methods suggested offer novel applications, such as precise assessment of complicated crack behaviour in large-scale testing with various fracture inclinations, spacing and varied orientations.

As stated above in the literature study, numerous fracture detection approaches have been proposed on a variety of surface types in the past. Crack detection on all types of concrete surfaces cannot be accomplished with a single algorithm or technique. In this paper, [10] To find the best way for pre-processing of concrete cubes, various techniques were used and evaluated on various samples. This paper consists of a discussion of pre-processing and processing methods.

Filter pre-processing was employed for the removal of interferential items such as noises/dents on the under-observation surface. The filters are quite common, such as Gaussian, median, min-max etc. During noise removal, bilateral filters may maintain the strong edges. In a bilateral filter, the intensity difference function considers only pixels with values that are comparable to a centre pixel value. Due to the significant intensity fluctuation, the edges stay sharp, but the calculation time is substantially slower than with other filters such as the Gaussian filter. Image Subtraction is used to eliminate sounds as a pre-processing approach for improving the distinction between crack and non-crack images. A threshold operation is necessary to acquire or perform crack detection. It separates the crack and background portion of the image, which may be used to further analyze the crack and quantify crack length and breadth, etc.

A proposal was made for the novel percolation algorithm fusion and adaptive Canny operator technique for fracture identification [11]. Using the percolation approach, a binary image was created, and this binary image was referred to as Image A. The crack-grey image was processed further using the adaptive Canny operator to produce a binary image of a crack, and this binary image was referred to as Image B. This binary picture is a grey crack image, which means it has been cracked. Using wavelet processing, the low-frequency and high-frequency components of Image B are separated and analyzed separately. Both binary images have components with low- and high-frequency frequencies. When a fusion picture is created by superimposing high-frequency and high-frequency pictures, the inverse transformation is performed. This innovative crack-detection method combines the resilient continuity of the penetration technique with the exact edge locating capabilities of Canny's adaptive algorithm to provide a crack-detection system that is both accurate and fast.

Based on concrete crack photography technologies, an image preprocessing approach that includes many adaptive filters and improved contrast was presented to satisfy the crack detection picture satisfaction

requirement for fracture detection images. It enhances the removal of background noise and gathers vein information from tiny fractures, which is useful for vein identification [12]. The local adaptive algorithm for Otsu threshold segmentation was then created and combined with the modified Sobel operator for the removal of isolated noise locations, to extract information on crack edges, and enhance the crack border placement precision. In addition, the information results acquired from 10 crack pictures of the concrete surface collected on the test site for the advantages of verification of the efficacy of the algorithm for extracting fracture information after computation have been provided. This approach offers technological help to automatically detect bridge surface fractures in a non-destructive way. Finally, early findings suggest that the picture cracks generated are very compatible with actual ones, and the characteristic data calculation accuracy satisfies the demand for engineering detection. The enhanced system is, therefore, possible to automatically detect concrete bridge cracks in real-time.

A deep convolutional neural networks (DCNN) study was developed in three modes to identify the same split, to provide an exhaustive comparison between edge/ edge sensors and to offer a novel hybrid split detector integrating the DCNN and the edge detector [13]. The techniques of edge detection precisely detect 53-79% of broken pixels, however, the final pictures create residual noise. Far finer fractures than edge detection methods were also identified by DCNNs. DCNN time computations are shorter than the most efficient methods for edge detection without regard to the training procedure. These findings are promising for the future use of DCNN techniques for concrete picture-based damage analysis. Furthermore, the combination of DCNN with edge detectors was suggested to minimize residual noise. This approach decreased the Log Edge Detector's noise ratio from 2.4% to 0.11% and had a comparable impact on the other edge Detectors.

This paper [14] provides a quick and non-invasive fracture detection approach including the removal of the contour of the recorded item and an evaluation of a single edge line. There are five phases to the suggested crack detecting approach. In this case, pictures are captured in real-time with a pre-mounted camera on a conveyor system. Secondly, following the valley emphasis Otsu method the original picture is transformed into a binary image. The primary pixel group is extracted with a pre-defined grid picture by use of percolation-based form recognition. Then, the first detection of all suspected fracture regions is carried out. The windows of each suspicious area are finally upgraded to high resolution, to examine any possible cracks completely. The suggested image processing technology allows the sensing of surface cracks with steady capacity and high precision and performance on the pressed panel.

### ***1.2 Unmanned Aerial Vehicle Image processing.***

This paper [15] discussed the construction and application of a device that used image processing to detect cracks. The system features a graphical user interface for the device initialization, the observation of videos in real-time, images of a crack, width assessment and the analysis of the crack image. It was done by the Raspberry Pi 3 Model B. 10 surface photos with real crack and another 10 surface photos with no breakages were evaluated. The confusion matrix in this portion was used to visualize an algorithm's performance. The split was measured from 3 different distances to a maximum of 10 % inaccuracy. In the overall system, cracks may be detected, and the real width and length of the crack are measured and if it is safe or dangerous. The distance, however, limits the system's dependability. The distance between the crack and the gadget can be reduced to a minimum.

The suggested framework [16] includes unmanned air vehicles (UAVs), data gathering techniques, fracture identification and surface degradation assessment image processing. An excellent solution is being developed by the usage of fracture detection algorithms for Speed Up Robust Features (SURF) and Scale Invariant Feature Transform (SIFT). There are two elements to the suggested prototype. A quadcopter for picture capturing and MATLAB image analysis. The quadcopter's ultrasonic sensor ensures that it is always at some distance from the wall. The pictures will be processed using MATLAB. Then the pictures were transformed to greyscale and the recorded thresholded are divided into distinct textures. The existence of cracks is identified and differentiated if there are voids, a circle with centre and centre of the image are

presented. It is quite beneficial to utilize the suggested method of detecting and analyzing fractures on walls of concrete utilizing imaging techniques. Particularly in the building's most inaccessible areas.

A conducted by Sarker et al., 2017 to assess the feasibility of crack detection and measurement of a new cost-effective (ZED) deep-depth camera. The result of the experiment using the ZED camera and processing instruments used for the detection and investigation of crack is described in this article. In this procedure, an area with a defined crack was recorded, which was propagated in a 3D point cloud with the ZED depth viewer to the crack surface. Due to the simplicity and durability of the software, MATLAB was used for post-processing and picture analysis. The method allows for the differentiation between paint crashes and fractures created by evaluating their depth from a point cloud on the concrete surface. While ZED depth camera research potential is at its core, experimental processes offer huge promise for precise and robust identification and modelling of infrastructure.

This report [17] discusses the creation of a low-cost approach for the analysis of picture pavement distress which enables potholes and cracks to be identified. Fuzzy-CMeans (FCM) has been used to identify lengthy cracking and the pothole and the Spectral Theoretical Algorithm has been implemented. The framework has three steps, including picture capture, processing, and functionality extraction. On a moving vehicle, a digital camera (Gopro) camera with a holder is utilized to record pavement distress photos. In calculating characteristics and classifying longitudinal cracking or pothole, FCM classification and Spectral theory algorithms are utilized. When evaluating the viability of pavement distress in selected metropolitan regions of Bengaluru, India, the Matlab2016Ra image tool package is utilized. The results of picture assessment using a semi-computerized image management frame were around 80 % accurately showing the characteristics of longitudinal cracks and potholes. This system benefits from fast handling, ease of operation and convenience of usage. It may also determine the distressing aspect that is important for selecting maintenance measures.

### ***1.3 Phone-Based Image Processing***

Measuring and analyzing the concrete crack feature based on a digital image-processing methods (SADIPT) smartphone APP on android systems have been examined in this work (Ni et al. 2020). Seven smartphone product models from four brands were conducted in calibration studies. Three cracks width values were measured, and fifteen measurements were taken using a smartphone app. With the fracture width measuring equipment, the widths of these fractures have been measured. Three shooting distances and five magnifications were used in the measuring trials. The inaccuracies of smartphone APP might be  $\pm 10\%$  compared to the fracture width measurer equipment. This error was acceptable in the field of engineering. Engineers can satisfy the standards of detection by measuring concrete fractures with a smartphone zoom lens or lowering the shooting distance.

## **2. DISCUSSION AND ANALYSIS**

The evaluation of crack detection is based on a variety of variables, including performance-based evaluation, accuracy-level evaluation, error-level evaluation, and image processing techniques-based evaluation.

### ***2.1 Significant difficulties in concrete defect image processing***

A literature review reveals some shortfalls in the detection procedure that require improvement to ensure future work is error-free. Some of the difficulties are discussed further below. It is common practice to process digital images in a brute force manner, which involves examining all of their pixels regardless of how large or unnecessary they are. The sheer number of pixels in an image makes any sort of sequential

processing difficult, even for the fastest processors. This limits the complexity of visual tasks that can be completed. Table 1 shows the summary of difficulties in image processing for concrete defect detection.

Table 1: Summary of difficulties in image processing for concrete defect detection

| <i>PROBLEM</i>                             | <i>DESCRIPTION</i>   |
|--|--|
| <i>Interference object</i>                 | <ul style="list-style-type: none"> <li>• Cracks can be mistaken for shadows, watermarks, background lines, and dark paints.[18]</li> <li>• The uneven illumination on the concrete structure's surface can make it difficult to segment local images in addition to the interference information like stain and potholes. [16]</li> </ul>  |
| <i>Distance of the device</i>              | <ul style="list-style-type: none"> <li>• Further camera distance from the surface reduces crack resolution, affecting the conversion process and increasing the probability of errors. [15]</li> </ul>   |
| <i>edge break and unilateral detection</i> | <ul style="list-style-type: none"> <li>• the edge detection is sometimes incomplete. [11]</li> <li>• there is a phenomenon of unilateral detection. The above problems cause difficulty in the extraction of cracks. [8], [10]</li> </ul>  |
| <i>Processing time</i>                     | <ul style="list-style-type: none"> <li>• Crack detection takes a considerable time to complete, especially for large-size pictures of concrete. [8]</li> <li>• More orientations mean more computing time and complexity, both of which add to system performance disadvantages [19]</li> </ul>  |
| <i>Crack undetected</i>                    | <ul style="list-style-type: none"> <li>• It is hard to achieve a good line crack pixel as the crack pixels are not detected when the crack is large enough and the crack pixel values are equal to or greater than the concrete texture pixel values. [10]</li> <li>• Some microcracks in concrete pictures will go unnoticed because crack pixels are not accurately identified. [18].</li> </ul> |

The efficiency in image processing and computer vision techniques can be improved by the development of fast image processing and computer vision techniques that rely solely on software algorithms, rather than on specialized hardware. For the image processing and computer vision communities, this is one of the most pressing problems they are facing right now.

## **2.2 Image processing Techniques Based Analysis.**

The primary goal of digital image processing is to extract usable information from pictures. In an ideal world, this would be accomplished entirely by computers, with little or no human involvement. Image processing algorithms may be classified into three categories. Several approaches deal with the pixel values at the most basic level, including denoising and edge detection as suitable examples. Algorithms in the intermediate use low-level findings to power more advanced techniques like segmentation and edge linkage. The approaches that seek to derive semantic meaning from the information supplied by the lower levels are classified as being at the highest level. In this section, Table 2 shows the summary of concrete defect detection image processing, method, and performance in the engineering structures.

Table 2: Summary of concrete defect detection image processing, method, and performance

| <i>METHOD</i> | <i>APPLICATION OF METHOD</i> | <i>PERFORMANCES</i> | <i>ACCURACY LEVEL</i> | <i>ERROR LEVEL</i> |
|---------------|------------------------------|---------------------|-----------------------|--------------------|
|---------------|------------------------------|---------------------|-----------------------|--------------------|

|   |   |   |       |       |
|---|---|---|-------|-------|
| <b>MAMDANI'S FUZZY [20]</b>                     | Used to detect a crack position (crack position)  | <ul style="list-style-type: none"> <li>Besides concrete surfaces, it may also be used on a variety of other surfaces, such as painting cracks.</li> </ul>   | 99.2% | 1.95% |
| <b>OTSU THRESHOLDING [5], [8], [14], [16]</b>   | Applied to separate cracks from the background (contrast development)                                       | <ul style="list-style-type: none"> <li>an ideal image with a deep and crisp valley in the histogram between two peaks indicating cracks and the backdrop is most effective</li> </ul>   | N/A   | N/A   |
| <b>GABOR FILTER [4]</b>                         | Can be applied for multidirectional crack detection (position)  | <ul style="list-style-type: none"> <li>shown to be successful in achieving the lower constraint and performs optimally in the joint domain</li> </ul>   | 95%   | N/A   |
| <b>SOBEL EDGE GRADIENT DETECTION [12], [16]</b> | Indicator for detecting sharp changes in the pixel value and is thus called an edge. (Contrast development) | <ul style="list-style-type: none"> <li>Isolated noise regions can be eliminated, and cracked edge information retrieved to increase its quality.</li> </ul>   | N/A   | N/A   |
| <b>CANNY EDGE DETECTION [11], [16]</b>          | used to filter out parts of the image with specific colours. (Contrast development)                         | <ul style="list-style-type: none"> <li>More information about the fracture edges is retained, and no breakpoint or single edge detection is made in the picture.</li> </ul>   | N/A   | N/A   |
| <b>PERCOLATION-BASED METHOD [8], [14]</b>       | Can be used for unclear crack detection. (Contrast development)   | <ul style="list-style-type: none"> <li>Prevent interference from soil bubbles, dirt, stains, and shadows of various sizes.</li> <li>The percolation-based technique completely accounts for the connectivity of the nearby pixels and the shape information.</li> </ul> | N/A   | N/A   |
| <b>MORPHOLOGICAL APPROACH [8]</b>               | used to distinguish between cracks, holes, laterals, and joints (Contrast development)                      | <ul style="list-style-type: none"> <li>processing time is shorter</li> </ul>  | N/A   | N/A   |
| <b>PRE-PROCESSING METHOD [10]</b>               | Used to enhance the cracks appearance/visibility (contrast development)                                     | <ul style="list-style-type: none"> <li>Remove any impediments, such as sounds or dents, from the surface being seen.</li> </ul>   | N/A   | N/A   |

|  |  |   |     |     |
|--|--|---|-----|-----|
| <b><i>SKELETON METHOD [18]</i></b>       | Used to identify and extract the skeleton of multiple cracks (Multiple cracks) | <ul style="list-style-type: none"> <li>• reduce the cracks to single-pixel lines</li> </ul>   | N/A | N/A |
| <b><i>LAPLACIAN OF GAUSSIAN [13]</i></b> | useful in detecting cracks coarser than 0.1 mm (shape and size)                | <ul style="list-style-type: none"> <li>• Comparatively speaking, it was the most precise and efficient method of edge identification (Sobel, Prewitt, Butterworth and Roberts)</li> </ul> | 79% | N/A |

The primary goal was to review and evaluate a crack detection system that relied on image processing techniques. The review focused on several image processing and deep learning-based crack detection methods and assessed their results. This study presents a comprehensive review for fracture identification in engineering structures of the various image processing algorithms now in use. The discussion displays the accuracy and error-based analysis of the publications culled from the review of previous research. It also included the performance and the application of the method listed.

The research is divided into five categories depending on their accuracy levels: below 80%; 80–85%; 85–90%; 90–95%; and 95–100%. It shows that 2 research [4], [20] had achieved an accuracy level in crack detection of more than 90%. Besides, based on the review shows that research using the Gaussian method [13] have an accuracy of 79% in detecting crack on concrete surfaces. Here, it also provides the error level analysis based on the paper that has been reviewed. Based on the review, it shows that 1 paper,[20] has an error below 5%.

These findings show certain approaches are quick, but they're not as accurate as others; however, some ways have great accuracy but are slowed down by complicated computations. Great speed and high precision are both necessary for real-time processing. All methods were shown to be effective for detecting particular faults in the systems evaluated here. To sum up, no universal approach for identifying all kinds of surface cracks has yet been developed. According to the results of the study, increasing the depth of deep networks improves accuracy and recall.

### 3. CONCLUSION

Eventually, it demonstrates numerous frequent issues with fracture identification in image processing at concrete surfaces, such as interfering objects, undiscovered cracks, high processing times, and difficulty with the distances of devices. It is possible to conclude from this examination that image processing's inability to detect cracks accurately is due mostly to edge break and unliteral detection. Moreover, Otsu thresholding and percolation methods are frequently employed in crack detection image processing. For finding surface defects, digital image processing methods such as the Otsu, skeleton, and canny approaches, as well as median filtering and Gabor filter, are essential. As with everything, there are benefits and drawbacks from all the approaches.

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