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APPLICATION OF BOTTOM HAT ALGORITHM FOR FISSURE DETECTION

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ABSTRACT

Conventionally, humans are engaged to detect defects in surface and they used to present report sheet based on their assessment. But this process is time consuming and expensive. Inspection system to replace human inspectors should be capable of detecting flaws such as cracks. Since the human inspection approach completely depends on the person knowledge and experience, but there will be deficiencies in quantitative analysis. The replacement for this problem is automatic image-based crack detection. The crack detection is the process of detecting crack by using image processing algorithms. This paper presents a crack detection algorithm based on bottom-hat transformation technique to obtain surface crack image by making use of pre-processing, image segmentation, feature extraction on the crack image.

Keywords: crack detection, thresholding, bottom-hat, median filtering, image thinning, crack length.

1. INTRODUCTION

The method to perform some operations on an image to get an enhanced image or to extract some useful information from image is called image processing. At present, processing of digital images is one of the rapidly growing technologies which includes the following three steps:

i. Acquiring the image through image acquisition tools;
ii. Analyzing and manipulating the image;
iii. Output in which result can be transformed image.

Automatic crack detection is the effective method for Non-destructive testing. The assessment of deterioration is difficult by manual inspection. The automated crack detection can be done using some of the Non-destructive testing techniques such as

i. Infrared and thermal testing,
ii. Ultrasonic testing,
iii. Laser testing, and
iv. Radiographic testing

There is a heightened interest in image-based crack detection for non-destructive inspection. Due to the random shape and irregular size of cracks and various noises such as irregularly illuminated conditions, shading, blemishes, and concrete spall in the images there arises some difficulties in the image-based detection. Many of the image processing detection techniques are proposed due to its simplicity in processing. These methods comprise of four categories, namely morphological approach, integrated algorithm, percolation-based method, and practical technique. The major advantage of the image-based analysis of the crack detection is that it provides accurate result by using the image processing technique compared to the conventional manual methods. The difficulty in processing while crack detection depends on size of image. The resolution of recent digital cameras is beyond 10 megapixels. The acquisition of detailed images of any surfaces is due to the increase in resolution. A wide range of any surface can be developed in a single shot by using the modern cameras of commercial purpose. For less economical applications, an extensive range image can be used for the practical crack detection. Fig. 1 shows general architecture to detect the crack based on the image processing techniques.

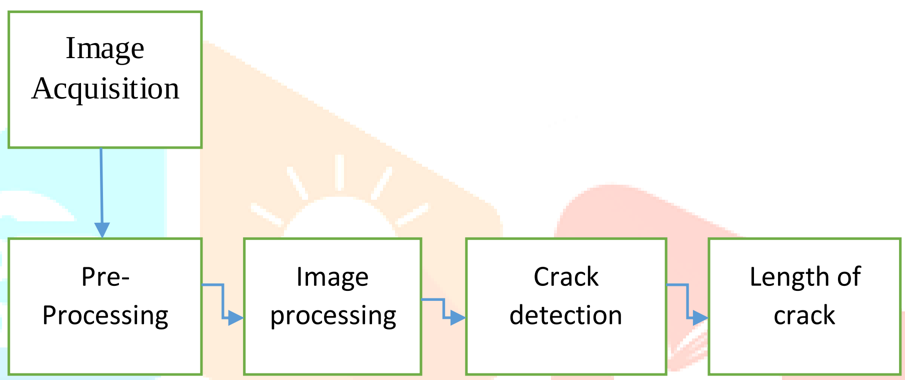

Fig 1. The architecture of image processing for crack detection

The steps involved in image processing technique are:

i. Using the camera or any sources at first collect the image of the structure which will be subjected to the crack detection process.
ii. After completing image acquisition, the images which were collected undergo pre-processing technique within which the methodologies like segmentation are done there by making it an efficient one for the image processing procedure.
iii. In the image processing, to process the deducted image sample some of the techniques are used.
iv. Using the result of the processed image the crack detection will be noticed here on the surface.

In this paper, a detailed survey is conducted to determine the research challenges and achievements till data in the field of crack detection using various methodology in explained in next section. The basic architecture for the crack detection using bottom – hat algorithm is discussed in section 3. Result analysis of cracked images is discussed in section 4. Followingly, Concluded by the experimental evidence of the proposed algorithm.

2. LITERATURE SURVEY

Yiyang et al. [1] have proposed a crack detection algorithm by pre- processing, image segmentation and feature extraction, they have obtained the information about the crack image. In, Threshold method of segmentation was used after the smoothening of the accepted input image. To judge their image, they have calculated the area and perimeter of the roundness index. Then by the comparison, they have evaluated the presence of the crack in the image. Even though many of the commercial camera-based image processing techniques dictate only upon the pre-processing, some techniques concentrate on the integration algorithm where the feature extraction would be made.

Adhikari et al. [2] developed a model that numerically represents the defects. Their integration model consists of crack quantification & detection, neural network, and 3-D visualization model respectively.

An image stitching algorithm developed by Brown and Lowe [3] has been adopted which works on feature-based registration. They have used a skeletonization algorithm for the retrieval of the crack segments. The detection of the crack based upon the width and the length was completely based on the crack quantification model evaluation. Also, the integrated model as proposed by them has crack length and change detection supported by neural networks to predict crack depth and 3Dvisualization of crack patterns.

Alam et al. [4] have proposed a detection technique by the combination of the digital image correlation and acoustic emission. The former method gives a very precise measurement of surface displacements, thus crack openings and crack spacing were determined. In order to complement that method and to investigate damage mechanisms, acoustic emissions resulting from internal damage were also analyzed. A manual grouping method (similar to K-means method) was used to identify different classes of AE energy released from the Beams of three different sizes. In their methodology, they have used three different beam proportionalities for the effectiveness of the output.

Iyer et al. [5] have designed a three-step method for the crack detection from the high contrast images. The proposed method detects the crack like pattern in the noisy environment using curvature evaluation and mathematical morphology technique. It was based on mathematical morphology and curvature evaluation that detects crack-like patterns in a noisy environment. In their study, segmentation is done defining the crack like pattern with respect to a precise geometric model. Linear filtering was performed after cross curvature evaluation to distinguish them from analogous background patterns. They have identified the irregularity sequentially by the Geometry-based recognition crack features.

The Filtering techniques adopted in the image processing scheme also alter the overall efficiency of the process. Salman et al. [6] proposed an approach to automatically distinguish cracks in digital images based on the Gabor filtering. Multi- directional crack detection can be achieved by a high potential Gabor filter. The Gabor filter is a highly potential technique for multidirectional crack detection. The image analysis of the Gabor filter function was directly related to the manual visual perception. Once filtering is completed, the cracks aligned to different directions are detected. They have a detection precision of 95% for their proposed methodology.

Shan et al. [7] have presented stereovision-based crack width detection. In their approach, two cameras were used unlike other proposals reviewed here. They have recovered coordinates of the crack edge by using those stereo vision cameras. They have used the Canny-Zernike algorithm to obtain the image coordinates of a crack edge on the recovered coordinate of the stereo vision cameras. Then the crack width was assessed using the minimal crack edge detection technique. The proposed experimental results have accuracy as that of the measurement taken from the vernier caliper.

Sinha et al. [8] have investigated the cracks by using the two-step approach. They have developed a statistical filter design for crack detection. After the filtering, they have got to the two-step approach at which the crack feature extraction was done locally at the first step of the pre-processing and then they have fused the images. The second step is to define the crack among the image segment by the process of cleaning and linking. They have overcome their previous work disadvantage where the morphological approach was used.

Talab et al. [9] have presented a new approach in image processing for detecting cracks in images of concrete structures. Here the methodology involves three steps: First; change the image to a gray image using the edge of the image and then use Sobel's method to develop an image using Sobel's filter for detecting cracks. Then by using a suitable threshold binary image of the pixel they are categorized into the foreground and the background image. Once the images are categorized, Sobel's filtering was used for the elimination of residual noise. After the vast filtering procedure of the image, cracks were detected using the Otsu's method. They have replaced the sober filter with the multiple median filtering in certain cases.

Yamaguchi et al. [10] have developed a percolation-based crack detection technique. They have obtained their less computation time by the adaptation of the termination and skip add procedures. They have a high-speed percolation algorithm which will make use of the neighboring pixels based upon the circularity of the pixel needs. The template matching technique was the key to their proposal of percolation because matching in the percolation images was easy to analyze.

Yang et al. [11] have proposed an image analysis method to capture thin cracks and minimize the requirement for pen marking in reinforced concrete structural tests. They have used studies like crack depth prediction, change in detection without image registration, crack pattern recognition based on artificial neural networks, applications to micro-cracks of rocks, and efficient subpixel width measurement. Stereo triangulation method was the adopted technique based on cylinder formula approximation and image rectification. Once they have the rectified output, the surface of the observed regions can be unfolded and presented in a plane image for following displacement and deformation analysis. From which the crack detection was analyzed.

Zou et al. [12] have developed a fully automatic method to detect crack in pavement images. They used a geodesic shadow removal algorithm to remove the pavement shadows by pre- serving the crack. After shadow removal, using the tensor voting methods, a crack probability map was built. Then by mapping crack probability maps were represented by a graph model. Once the model was represented, Minimum Spanning Trees were derived from which the crack extraction data can be taken off by conducting recursive tree-hedge pruning.

Oliveira et al. [13] have designed a system for automatic crack detection. Here the crack detection was based on the sample paradigm. In the sample paradigm, a subset of the available image database was automatically selected and used for unsupervised training of the system images. They have characterized operations based on the classification of the non-overlapping image blocks. Then based on the crack block-based detection, the width of the crack was estimated.

Nguyen et al. [14] have proposed a method based on the edge detection of concrete cracks from noisy 2D images of concrete surfaces. They have observed the cracks as tree-like topology. Then based on the PS CEF non-crack objects were removed. After the separation, thresholding filter, and morphological thinning algorithm have been used to binarize the image for the crack center line estimation. Then the center line was fitted by cubic splines. They have linked the edge points to form the desired continuous crack edge. From the crack edge, the surface of the crack was attained.

Lins et al. [15] have developed a system-based machine vision concepts with the goal to automate the crack measurement process. In their method, they have used only a single camera for the processing of the sequence of the images for the crack dimension estimation. The crack model algorithm HSB and RSV were used by which the sequences of the images are subjected to a crack detection algorithm in order to detect the crack. The proposed algorithm receives images as inputs and outputs a new image with red particles along the detected crack. The pixel positions of the particles were stored in a vector and passed along to the crack measurement algorithm. With the pixel positions, the algorithm estimates the number of pixels in a cross section and outputs the crack dimension.

Li et al. [16] have incorporated a new approach for detecting the crack in the defects with the dark color and the low contrast using the fast discrete curvelet waveform and texture analysis. They have initially decomposed and reconstructed the original image using the FDCT algorithm. Then the thresholds of the decomposition coefficients were calculated by the texture feature measurements, from which the surface textures in the images were eliminated. Finally, by extracting the contours from the reconstructed images, the expected image without texture but with crack defect contours was obtained.

Lee et al. [17] have designed a system for particle crack detection. They used the nearest neighbor and two-point correlation methods for the estimation of the second order microstructural descriptors. Based on the probability function of their corresponding location the crack features were found out. The edge effect was eliminated by the nearest neighbor estimate from the high-resolution montages.

Wang et al. [18] have proposed a system for the image-based crack detection and to characterize the crack based upon their effectiveness. They have categorized the present image-based crack detection into four categories. They are an integrated algorithm, morphological approach, percolation approach and practical technique. A shading correction was done using an integrated algorithm. The unclear crack prediction was detected using a percolation method. The crack detection was done using morphological approach for the micro crack detection with the practical method providing high- performance feature extraction.

Jahanshahi et al. [19] have proposed a method as an alternative to current monitoring method. They have proposed a less time-consuming method. They used an autonomous robotic system with vision-based crack detection methodology for the processing of the 2D images. The depth parameters were adjusted automatically by the autonomous system. Then by using the 3D reconstruction technique, depth perception was obtained. The depth perception was obtained using 3D scene reconstruction. Their system was appropriate because they extract the whole crack from its background.

Hamrat et al. [20] have proposed an experimental work on the flexural behavior of three types of concrete: normal strength concrete (NSC), high strength concrete (HSC) and high strength fiber concrete (HSFC) in terms of crack detection, crack development, crack width measurements and strain components, using the Digital Image Correlation (DIC) technique. They have used the classical measurement techniques (strain gauges, LVDT sensors) and the DIC technique for the analysis of strain components. The mutual understanding between the two measurement methods indicates DIC as an efficient measuring tool for obtaining displacement. Measurements of strains and displacements at or close to failure are usually not possible with the classical methods due to the risk involved in terms of safety to the personnel and damage to the equipment. They reduce both the crack spacing and the crack width by as much as 35–70% in mm as considered as an error.

Gunkel et al. [21] have developed a detection algorithm for the accuracy over the variability of the crack numbers and crack lengths over the similar image. The micro crack was detected using the shortest path algorithm in a situation where the cracks are surrounded by deformations. They have initially detected the crack clusters with a threshold value. Then Dijkstra's algorithm was used to determine the crack paths. The linear paths of the linked path were determined by their algorithm.

Fujita et al. [22] have proposed a system for automatic crack detection on the noisy concrete surface mages. Their system includes two pre-processing steps and two detection steps. Only the original image was used for the pre-processing. They have removed the shadings using the median filtering. A multi- scale line filter with the Hessian matrix was used to emphasize the cracks.

Glud et al. [23] have proposed an automated method for counting propagating matrix tunneling cracks for use in mechanical testing of GFRP laminates under different loading conditions. In, white light images were captured from specimens during the loading. The transmitted light was used to detect the cracks in the images, which were then processed to count the cracks as they develop and grow through the duration of the test. The reproducibility and accuracy of the image processing were demonstrated using simulated transverse crack densities and patterns.

3. RELATED WORK

The total procedure of crack detection and classification consists of five steps is shown

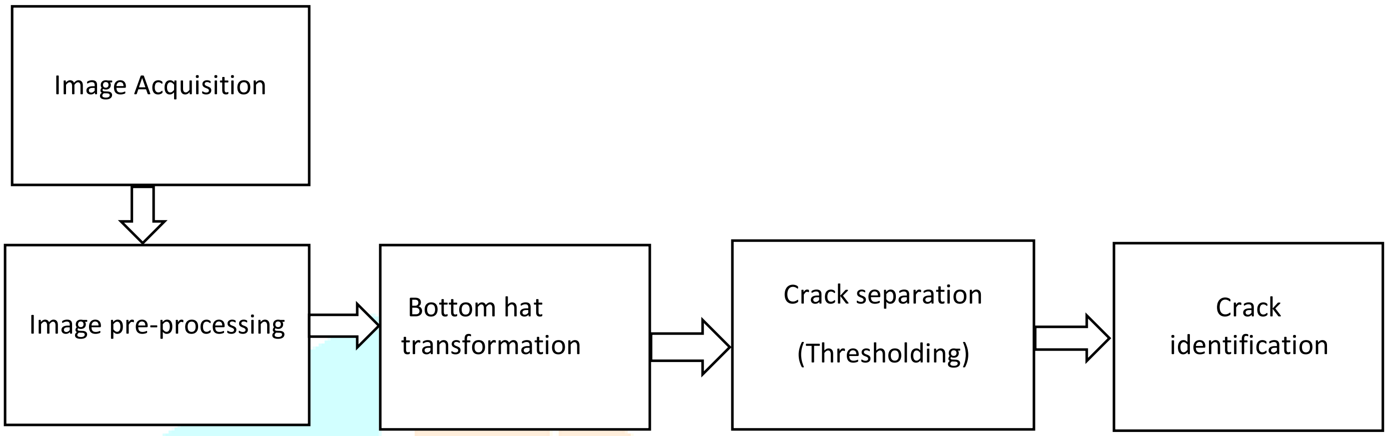

Fig 2. Flowchart of proposed method

A. Image Acquisition:

By using CMOS line scan digital cameras, images of concrete structure can be acquired. For image acquisition purpose a machine that can roll on with built in cameras can be used such that when machine moves on the concrete surface it captures images for detection purpose. In case of huge concrete structure or historical buildings of concrete, picture taken from satellite can also be used.

In the process of image collection for our work we only considered the images that do not have any other object other than concrete structure because if images contain other objects then that object can be considered as crack. Also cracks has to be at least visible by human eye though there may be huge number of noises else no crack will be detected by this method.

B. Image Pre-Processing:

Using some basic image processing useless details can be removed from the original image that we consider here as image preprocessing. There are various steps in image preprocessing which are given below:

i. Contrast stretching:

All the images are resized to the width of 512 pixels and the height was adjusted such that original image aspect ratio maintained to maintain uniformity of the system such that all images have same criteria for crack detection procedure.

ii. RGB to Grayscale Image Conversion:

For image preprocessing, first the RGB image is converted to grayscale image which makes the process much easier, because here we need not to maintain three matrixes for three color components red(R), green(G), blue(B). Each pixel is represented by a single value in grayscale image which is between 0 to 255.this single value is known as luminance or intensity of that pixel. For calculating the effective luminance of a pixel there is a standard NTSC conversion formula:

Intensity = 0.2989*red + 0.5870*green + 0.1140*blue

iii. Median filtering:

Median filter is a nonlinear filtering, because it does not need the image in the process of actual operation of statistical properties, so more convenient. Median filter was first used in one-dimensional signal processing technology, then was quoted by two-dimensional image signal processing technique. Under certain conditions, can overcome the image detail fuzzy linear filter, and image scanning to filter out pulse interference and noise is the most effective.

The so-called "median" is refers to data in a data sequence from big to small order (or opposite), if the length of the sequence for odd number, ranked in the middle of the number is in this sequence of values; If the length of the data sequence is an even number, put in the middle two Numbers for the average value. The simplest way of median filtering is to use a sliding window contains an odd number of points in the processing of image point by point on the slide, gray value of the middle point in window is instead by points in window median value.

$$\hat{f}(x,y) = \underset{(s,t)\in S_{xy}}{\text{median}}\, g(s,t)$$

Although we cannot remove useless details that is why we need to classify detected local dim region as either crack or not by using fuzzy logic. We use a 5*5 moving average filter to replace each pixel by the average of pixel value in a 5*5 square, or windows entered on that pixel. The result to reduce noise in the image, but also to blur the objects in the image.

C. Bottom-hat transformation

Bottom-hat transformation is the morphological image processing which is used to extract image components such as shape of the cracks. The bottom-hat transformation is based on closing operation of image which is another morphological operation. The bottom-hat transform, is defined as the residual of a closed comparative original image that is

$$B\_hat\,(f) = (f \bullet b) - f$$

Where f•b is the morphological closing operation and b is the structuring element.

The closing operation is given as

$$f \bullet b = (f \oplus b) \ominus b$$

Where erosion and dilation operations are done respectively.

The bottom-hat transform returns an image, containing the objects or elements that are smaller than or equal to the structuring element, and are darker than their surroundings. To obtain the crack from the image the structing element plays a vital role. The selection of structuring element is based on two parameters, namely:

1. type of structuring element that is diamond, disk, line, rectangle, square etc.

2. Size of the structuring element that is specifying the width of square type element.

The size of structural element should be chosen such that the widest crack in the image must be covered.

The high intensity values of the bottom-hat transform image is considered as crack pixels. The cracks with same brightness as the background of image is hard to detect the image.

D. Thresholding

To separate crack from the image the thresholding operation on bottom-hat gray image must be done. The thresholding operation on the image is done based on the global threshold value.

Threshold segmentation is a kind of typical image segmentation method which divides image mainly according to the background region and target areas that occupy different grayscale range, and the key to this method is to find a suitable.

Global threshold method is a method that chooses a threshold to divide the whole image into two areas, and the choice of segmentation threshold is based on the histogram of the image. These two areas are color-coded, and the typical color is black and white, color images can also be divided into red, green or any other color that has quite different hue. If the contrast of the entire image is relatively modest, the contrast of the background is close to the target, and the gray value of background image remains stable, then, using global threshold will generally achieve a good segmentation result. The formula can be presented as follow:

$$g(x,y) = \begin{cases} 1, & f(x,y) > T \\ 0, & otherwise \end{cases}$$

where, T is a gray threshold set in advance, f represents the input image, and g is the output image.

E. Thinning

The thinning of a set by a structuring element denoted can be defined in terms of the hit-or-miss transform:

$$A \otimes \mathrm{B} = \mathrm{A} - (A * B)$$

A more useful expression for thinning symmetrically is based on a sequence of structuring elements:

$$\{\mathrm{B}\} = \{\mathrm{B}^1, \mathrm{B}^2, \dots \dots \dots \mathrm{B}^n\}$$

we now define thinning by a sequence of structuring elements as

$$\mathrm{A} \otimes \{B\} = \left(\left(\dots \dots . \left(\left(A \otimes B^1\right) \otimes B^2\right) \dots \dots\right) \otimes B^n\right)$$

ALGORITHM:

1) Read the image.
2) Convert the color image into gray image. If the image is already in gray image this step can be ignored.
3) Resize the image for uniformity through contrast stretching.
4) Perform image filtering using median filtering. Remove the noise present in image. The noise may be salt and pepper noise.

$$\hat{f}(x,y) = \underset{(s,t)\in S_{xy}}{\mathrm{median}}\, g(s,t) \qquad p(z) = \begin{cases} P_a & z = a \\ P_b & z = b \\ 0 & otherwise \end{cases}$$

5) The structural element should be specified based on element size and type. Here we used disk shaped structural element for crack detection.

$$\hat{B} \equiv \{w | w = -b \quad \forall\, b \in B\}$$

6) Perform the bottom hat transformation using structural element in step 5.
   a. $B\_hat\,(f) = (f \bullet b) - f$
7) Compute the global threshold value of gray image. The threshold is normalized to the range [0,1].
   1. $g(x,y) = \begin{cases} 1, & f(x,y) > T \\ 0, & otherwise \end{cases}$
8) Convert the bottom hat transformed image into binary image using the threshold value from step 7.

9) Remove the small objects in the image. If the small objects are not present in the image this step can be ignored.
10) Perform thinning operation on the noise free image.
    i. $A \otimes \{B\} = \left(\left(\ldots \ldots \left(\left(A \otimes B^1\right) \otimes B^2\right) \ldots \ldots\right) \otimes B^n\right)$
11) Display the crack in image.
12) Calculate the length of the crack.

4. RESULT ANALYSIS:

The work is simulated using MATLAB 2018b. Fig 3 shows the original image. The conversion of RGB to gray image is represented in Fig 4.

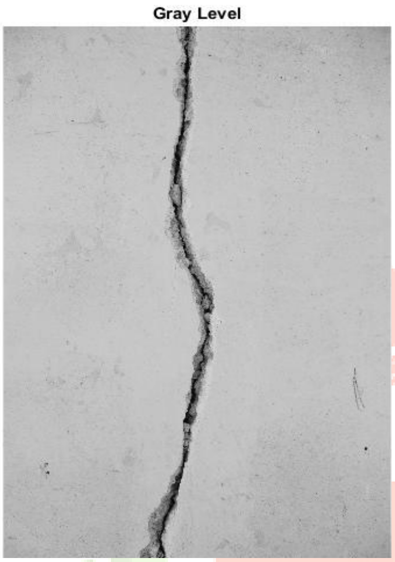

Fig 3: original image Fig 4: Gray image

Contrast stretched image is shown in the Fig 5. Using median filtering, image filtering is performed, and it is shown in Fig 6. Histogram is the graphical representation of an image.
In Fig 7, it represents the gray image of a histogram. Fig 8 represents the histogram specification of gray image.

Fig 5: contrast stretched image Fig 6: median filtered image.

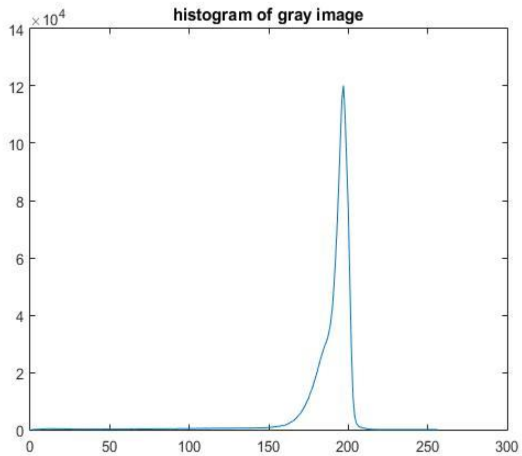

Fig 7: histogram of gray image

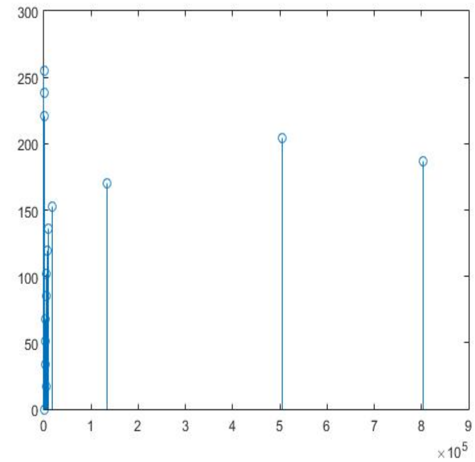

Fig 8: histogram specification

Using structural element bottom-hat transformation is obtained which is shown in Fig 9. Convert the bottom-hat transform image to binary image as shown in Fig 10. Fig 11 represents the removal of small objects in image. The thinned image is shown in Fig 12. The final image of crack is detected in the Fig 13. The graphical representation of crack detected image is shown in Fig 14.

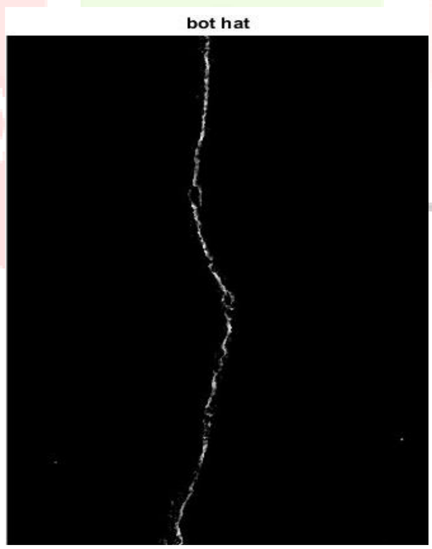

Fig 9: Bottom hat transformed image.

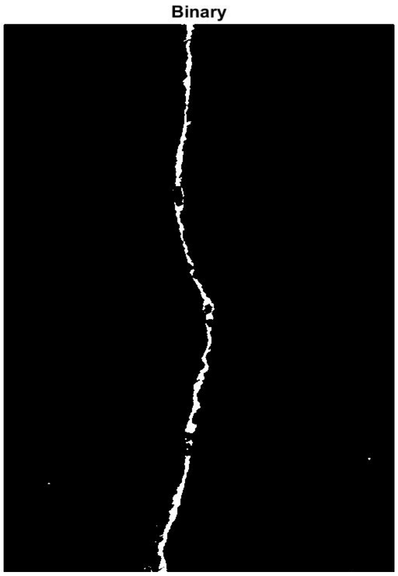

Fig 10: Binary image

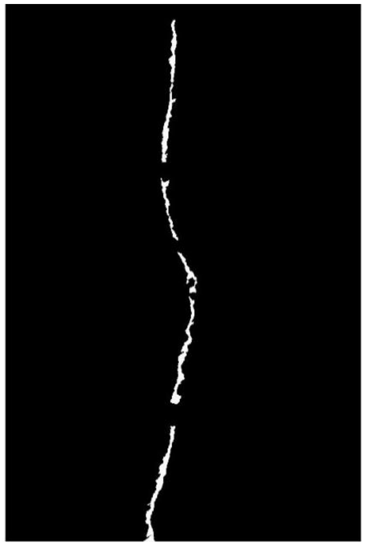

Fig 11: Removal of small objects in the image

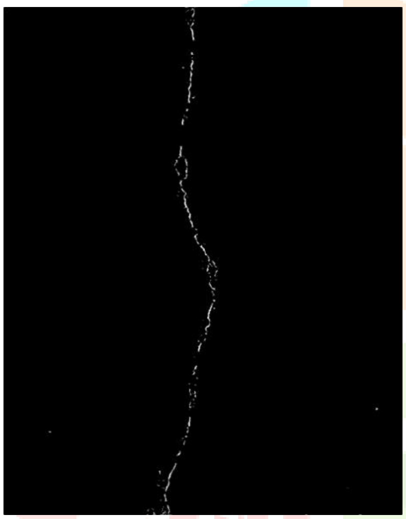

Fig 12: Thinned image

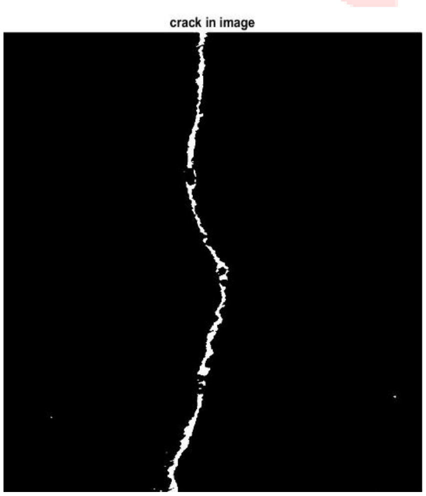

Fig 13: crack detected image

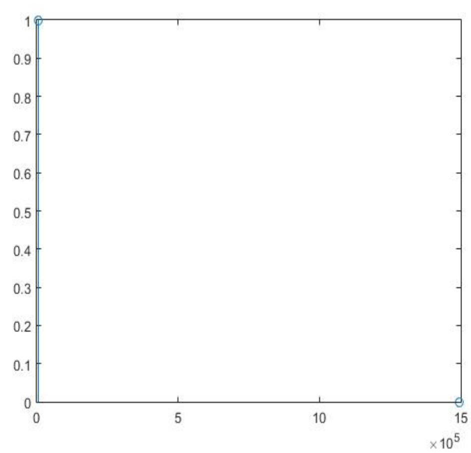

Fig 14: histogram specification of crack detected image

5. CONCLUSION

The proposed work constructed an image processing model for detecting crack defects on the surface of any structure which may be buildings structures, railway tracks, pipelines. Since the digital images taken for crack analysis feature various difficulties like low contrast, uneven illumination, and noise pollution for the image analyzing process, the bottom hat transformation provided satisfactory outcomes. Images are analyzed by applying several image processing techniques and finally crack is detected using bottom hat transformation. This method of crack detection is applied on different situations where the images contain noise. In this method we identify the cracks in image more accurately after the removal of noise in image. The newly constructed model is proficient of detecting crack objects and evaluating their characteristic like length. The experimental results confirm that the cracks in testing images have been precisely identified. The bottom-hat transformation followed by the global thresholding method described in the current work can be easily integrated into many crack detections and categorization models developed in the future. The primary reason is that the proposed approach is relatively direct. The secondary reason is that the method, as demonstrated in the experimental results, can deliver exact crack detection property namely length of crack.

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