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Review and Analysis of Crack Detection and Classification Techniques based on Crack Types

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ABSTRACT

Cracks are highly widespread in buildings, bridges, roads, pavement, railway tracks, automobiles, tunnels, and planes in the real world. Because the presence of a crack reduces the value of civil infrastructure, it is vital to determine the severity of the fracture. Crack detection and classification techniques combined with quantitative analysis are essential for determining the severity of a crack. The length, width, and area are the different quantitative measures. The quantity of photos acquired for analysis is rapidly increasing as a result of rapid technological advancements. As a result, systems for automatically detecting and classifying cracks in civil infrastructure are critical. The following three goals are the subject of this paper: I A comparison of different crack detection and classification techniques based on crack kinds. (ii) Implementation of Otsu's based crack detection thresholding method (iii) Design of proposed system.

Keywords : Crack types, crack detection, crack classification, image processing, and machine learning.

I. INTRODUCTION

A crack is the result of the breaking or fracturing of concrete into two or more portions, which might be complete or partial. Buildings, bridges, roads, pavements, railway tracks, autos, tunnels, and aircraft are just a few examples of surfaces where cracks might appear. Active and dormant cracks are the two types of cracks that can be found. In active cracks, the direction, width, or depth of the crack changes with time, but in dormant cracks, the direction, width, or depth remains constant. Both active and dormant fractures give access for moisture entry, which can lead to future harm if left unaddressed. Longitudinal cracks, transverse cracks, various fractures, crocodile cracks, and reflection cracks are some of the active cracks. In nature, dormant cracks are exceedingly fine, and they mend on their own over time. Micro cracks, thin cracks, sealed cracks, mixed cracks, line-like cracks, minor cracks, tiny cracks, medium cracks, huge cracks, and complicated cracks are some of the different types of cracks based on their structure. The research challenges and advancements in the field of fracture detection and classification approaches are discussed in this paper.

Different crack detection approaches have been examined and studied by Arun Mohan and Sumathi Poobal, 2016. The analysis in that work is based on the objectives, image processing techniques, error level, accuracy level, and datasets, however crack classification approaches and their concerns are not discussed. That issue has been addressed in our work through study and partial implementation. Crack detection and crack classification strategies based on crack kinds, implementation of an existing system, and design of a suggested system are the three aspects of the article. In addition, the shortcomings of the current system are explored, as well as potential alternatives.

A. Crack detection

Crack detection is a technique for automatically detecting a crack in an image using image processing techniques. Segmentation, morphological operation, sobel edge detection method, cannel edge detection method, Otsu's method, gradient method, clustering method, least square method, histogram equalisation method, particle filter, maximum entropy method, wiener filter, and wavelet transform are some of the image processing techniques available. In this section, we'll go over the different image processing approaches for crack detection.

The crack is detected using morphological operation, binarization, histogram equalisation, and de-noising in railway track crack detection [Rizvi Aliza Raza et al., 2017]. Video cameras are installed in separate sections of the track to acquire images, and the crack is detected using morphological operation, binarization, histogram equalisation, and de-noising. Furthermore, the Gabor Filters Invariant to Rotation technique [Roberto medina et al., 2017] is utilised to show alternative orientations for a single crack over its length. This approach is not affected by light. In general, plastic surfaces have line-like cracks, which are detected using a series of approaches [Haiming Liu et al., 2016]. The methods are: noise reduction, image gradient for crack image reconstruction, shape based optical model for crack identification, and circularity to locate the shape. The proposed methods outperform Otsu's method and the clustering method. [Aliza et al., 2017] stated that tiny cracks in vehicle or aeroplane applications cannot be detected from a single image, necessitating the use of a longer time period. A single case's image was acquired three times: 7 metres above centre, 7 metres to the right, and 7 metres to the left. Thresholding, morphological operation, and canny edge detection are then applied for fracture detection. Preprocessing mitigates the negative influence of non-uniform backdrop and pavement markings, followed by morphological operation that strengthens the posterior features to detect sealed cracks in the pavement, according to [Mojtaba et al., 2016].

Romulo et al., 2016, employed a colour feature extraction method to distinguish undesirable features from outside photos (sky, grass). This method uses quantitative analysis to classify the segmented window based on colour, particle filtering for particle selection, clustering for crack identification, and the least square approach for crack type classification based on direction. Using wavelet transform and KD-tree, Chen et al., 2016, found cracks in low-resolution photos and image discontinuities. For crack identification, [Rabihamhaz et al., 2016] employed the Minimal Path Selection (MPS) approach, while for assessment they employed Pseudo Ground Truth (PGT) and the DSC (DICE Similarity Coefficient) rate. [Yuansen et al., 2016] examined thin cracks in Reinforced Concrete (RC) bridges, which necessitates a lot of pen marking and so is challenging to implement in real-time applications. The stereo triangulation technique, the least square method, and optical flow analysis methods are used to locate cracks.

The damages that develop around the surface roughness and patterns in masonry, edges from windows, doors, and the ends of the structure that produce problems with edge identification of surface cracks were discussed in masonry wall [Ellenberg et al., 2014]. Irrelevant objects are distinguished from crack objects in subway tunnel fracture detection [Wenyu et al., 2014]. Dark cracks in concrete walls are notably darker than the background, while unclear cracks are considerably brighter than conventional cracks [Tomoyuki et al.,2008]. The improved percolation value (Alteration of threshold value) approach finds the unclear fracture in the same way as dark cracks are detected. However, image processing techniques such as thresholding, segmentation, and morphological operations are widely used.

B. Crack classification

Crack classification is a method of applying machine learning algorithms to identify a certain crack type. Crack detection is the process of detecting or recognising the presence of a crack, whereas crack classification is the process of classifying the fracture based on the feature retrieved from the crack region. Machine learning is an artificial intelligence (AI) subfield that can be used to conduct classification, prediction, and grouping of datasets, depending on the application. supervised learning algorithms are used for classification and prediction, while unsupervised learning techniques are used for clustering. Support Vector Machine (SVM), K Nearest Neighbors algorithm (KNN), Extreme Learning Machine (ELM), adaboost, and random forest are examples of supervised learning algorithms that have been used for crack categorization.

It can be difficult to discover and categorise cracks in an underwater dam [Pengfeishi et al., 2017]. As a result, using the tensor voting approach, solar pictures are used to detect and classify cracks as small, medium, or large. According to [Salari and Ouyang, 2016], photographs contain not only a road section, but also additional sophisticated background components. SVM, fractal thresholding, and the radon transform are used to detect and classify cracks in the pavement photos with complicated background components such as trees, homes, and so on. For effective results, several of the photos require preprocessing techniques. It comes with a wiener filter to remove blurriness and a noise reduction technology. [Chen et al., 2016] Chen et al. are a group of researchers who came up with a

SVM is used to classify the bridge crack into vertical, longitudinal, reflexive, and crocodile fractures. When the input regions cannot be described clearly and precisely, the fuzzy clustering method [Nouha Ben et al., 2017] comes in handy. For pavement cracks, a combination of the fuzzy clustering approach, k-means thresholding, segmentation, de-nosing, morphological operation, and skeletonization yields an accuracy of 82 percent.

II. RELATED WORK

A detailed review based on crack type has been done for crack detection and classification. The first level crack types (minor, moderate and severe) and its appropriate subtypes are shown in Fig.1.

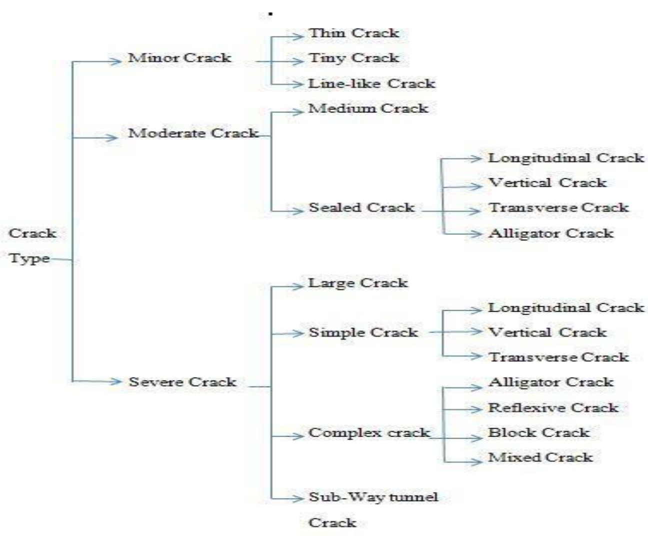

Figure 1. Crack type Classification

A. Minor cracks

Minor cracks are very small or thin fractures that can be divided into three categories: thin, tiny, and line-like fractures. RC bridges, underwater dams, polymers, autos, and aeroplanes are all susceptible to this break. Thin fractures are prevalent in RC bridges and can be discovered using the stereo triangulation approach, the least square approach, and the optical flow analysis approach [Yuansen et al., 2015]. These techniques can catch concrete surface fractures with a width of 0.2 pixels utilising a Region of Interest (ROI) and a control point, however for a better result, the photos should be acquired with a single camera that does not affect the lighting impact. Because it is difficult to detect and classify cracks into microscopic, medium, and large fractures in an underwater dam [Pengfeishi et al., 2017], solar images are used. Adaptive tensor voting, minimal spanning tree, and K-means clustering are some of the techniques used in that paper. Line-like cracks are widespread in plastic surfaces, and they may be detected using a series of approaches [Haimingliu et al., 2016]. The methods are: noise reduction, image gradient for crack image reconstruction, shape based optical model for crack identification, and circularity to locate the shape. The proposed methods outperform Otsu's and clustering methods, however discontinuities and quantitative analysis are not addressed. Minor cracks require more time to identify and classify, according to the results of the investigation. Because cracks are microscopic and discontinuities exist, accuracy ranges from 80 to 86 percent.

B. Moderate cracks

Because moderate cracks are not as serious as severe cracks, corrective actions are required. This sort of crack is commonly found in underwater dams and concrete roads, and comes in three different types: mild, sealed, and severe. According to Pengfeishi et al., 2017, it is difficult to detect and classify cracks into microscopic, medium, and large cracks, thus solar images are employed. Adaptive tensor voting, minimal spanning tree, and K-means clustering are some of the techniques used in that paper. Sealed cracks, such as longitudinal, vertical, transverse, and alligator cracks, are widespread in concrete roads [Mojtaba et al., 2016;]. With a high level of precision and consistency, it may be recognised using the thresholding approach, segmentation, and morphological operation. Recall, precision, and accuracy metric values were found to be 87 percent, 98 percent, and 93 percent, respectively. According to the analysis, moderate crack sizes are greater than minor crack sizes, implying that discontinuities can be easily handled. The categorization accuracy of mild cracks ranges from 93 percent to 93.3 percent.

C. Severe cracks

Severe cracks are extremely large and dangerous, need prompt remedial action. This type of fissure is commonly found in underwater dams, subway tunnels, bridges, pavements, concrete roads, and civil structures. Large, simple, and intricate cracks all fall into the category of severe cracks.

Large cracks can be easily spotted [Pengfeishi et al., 2017], however underwater dam cracks are difficult to identify and identify, hence the solar picture is employed. Adaptive tensor voting, minimal spanning tree, and K-means clustering are some of the techniques used in this paper. This method is more efficient than the wasp colony algorithm, with a 93.3 percent accuracy for large cracks. morphological operation, thresholding operation, ELM, radial basis function neural network (RBF), SVM, and KNN are used by [Wenyu Zhang et al., 2013] to detect and classify sub-way tunnel cracks. The rate of accuracy is 90% in this case.

According to the findings, serious cracks can be diagnosed even in the presence of complex backgrounds such as trees, homes, and other structures, with a 90% accuracy rate. For serious cracks, the accuracy level hovers around 95%. For easier reading, a summary of significant cracks is provided in Table 1.

Table 1: Severe Crack

Crack type	Crack surface	Crack detection techniques	Crack Classification techniques
Large crack	Underwater dam	Particle filter method	K-means clustering, adaptive tensor voting and minimum spanning tree
Sub-way tunnel crack	Sub-way tunnel	Morphological operation, thresholding operation	RBF, SVM, and KNN

Simple cracks

Simple cracks are less complex and it includes longitudinal, vertical and transverse crack. Longitudinal crack are common in bridges, pavements, concrete road and civil structure.

Table 2: Simple Cracks

Crack type	Surface	Crack detection techniques	Crack Classification techniques
Longitudinalcrack	Bridges, pavements ,concrete road and civil structure	Wavelet transform, morphological operation, KD-tree,EMD method, binarization, regiongrowing method and fractal thresholding	SVM, randomforest and adaboost
Vertical crack	Bridges, concrete road and civil structure	Particle filtering, sobel edge detection method, least square method, wavelet transform, morphological operation, KD-tree	SVM, randomforest and adaboost
Diagonal crack	Concrete road, concrete pavement and civil structure	Thresholding method, segmentation, morphological operation, color feature extraction method, particle filtering, sobel edge detection method, least square method, fractal thresholding, radontransform	SVM, randomforest and adaboost

Wavelet transform, morphological operation, KD-tree, EMD method, binarization, region expanding method, and fractal thresholding have all been used to detect it, and SVM, random forest, and adaboost have all been used to classify it [Romulo et al., 2016; Chen et al., 2016; Weili et al., 2017]. Particle filtering, sobel edge detection method, least square method, wavelet transform, morphological operation, KD-tree, and SVM, random forest, and adaboost can all be used to detect vertical cracks in bridges, concrete roads, and civil structures [Mojtaba et al., 2016; Romulo et al., 2016; Chen et al., 2016]. Transverse cracks are common in concrete roads, concrete pavements, and civil structures, and they can be detected using thresholding, segmentation, morphological operations, colour feature extraction, particle filtering, sobel edge detection, least square method, fractal thresholding, and radon transform, and classified using SVM, random forest, and adaboost [Mojtaba et al., 2016; Salari and Ou, 2016]. Wavelet transform and KD – tree can also be used to detect simple cracks in low-resolution photos as well as image discontinuities. Table 2 provides an overview of basic cracks for easier reading.

Complex cracks

Because the shape and orientation of complicated cracks are so different, more information is needed to classify them. Bridges, pavements, concrete roads, and civil structures are all susceptible to complex cracking. Alligator, reflexive, block, and mixed cracks are all examples of complex cracks. Alligator cracks are common in bridges and concrete pavements, and they can be detected using thresholding, segmentation, morphological operations, EMD method, binarization, radon transform, region growing method, least square method, and classified using SVM, random forest, and adaboost [Mojtaba et al., 2016; Salari and Ouyang, 2016; Chen et al., 2016; Weili et al., 2017]. Wavelet transform, morphological operation, KD-tree, and SVM can all be used to detect reflexive cracks in bridges [Chen et al., 2016]. Block cracks in concrete pavement are widespread and can be detected using fractal thresholding, radon transform categorised using SVM, and random forest adaboost [Salari and Ouyang, 2016]. In asphalt pavement, mixed cracks are widespread and can be detected using the Gabor filter approach [Salman et al., 2013]. Table 3 summarises the many types of complicated cracks.

Some inferences can be drawn from the analysis. I For underwater crack identification, the particle filter technique is the best choice (ii). Random forest algorithm and adaboost both performed better in classification than K-nearest neighbour, while Otsu's approach is extensively used for crack detection. The Otsu-based thresholding methodology was used to determine the constraints of the present system for a variety of picture capture scenarios.

Table 3: Complex Cracks

Crack type	**Surface**	**Crack detection techniques**	**Crack Classification techniques**
Alligator crack	Bridges, concrete pavement	Thresholding method, segmentation, morphological operation, EMD method, binarisation, radon transform, regiongrowing method, Least square method	SVM, random forest andadaboost
Reflexive crack	Bridges	wavelet transform, morphological operation, KD- tree	SVM
Block crack	Concrete pavement	Fractal thresholding,radon transform	SVM, random forest andadaboost
Mixed crack	Asphalt pavement	Gabor filter method	

III. IMPLEMENTAYTION OF EXISTING WORK

Most of the existing system uses Otsu's thresholding based method because of its global automatic thresholding principle. Otsu's method is used to detect the crack because it is based on class-invariance principle i.e.; within class variance is minimum and between class variance is maximum.

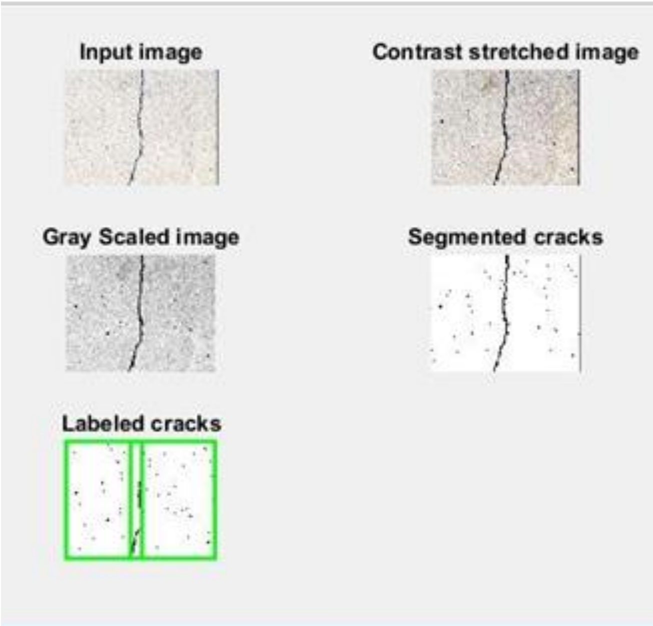

Figure 2.a) Preprocessing module **b)** Resize the image **c)** Normalizing the intensity value **d)** Segmentation by thresholding **e)** Extracting crack region (labeledcracks are highlighted in green color)

In Fig.2, stage I represents input image. In stage II, the contrast stretched image is obtained through normalization of the intensity value. In stage III, contrast stretched image is converted into gray scaled image. In stage IV, by optimum threshold crack region are segmented from non-crack region. In stage V, crack region is shown in green color. More sample set of output are shown in Fig.3 and Fig.4.

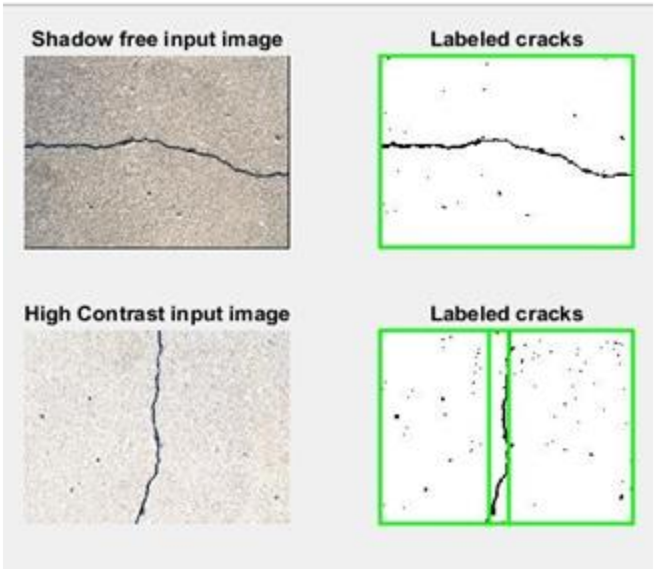

Figure 3. a) Shadow free image **b)** Result of shadow free image **c)** High contrast image **d)** Result of high contrast image

From the visualization of Fig.4, the detected crack region is not accurate for shadow and low contrast images. It also labels some of the non-crack region as crack region. Discontinuities in crack region are also not resolved.

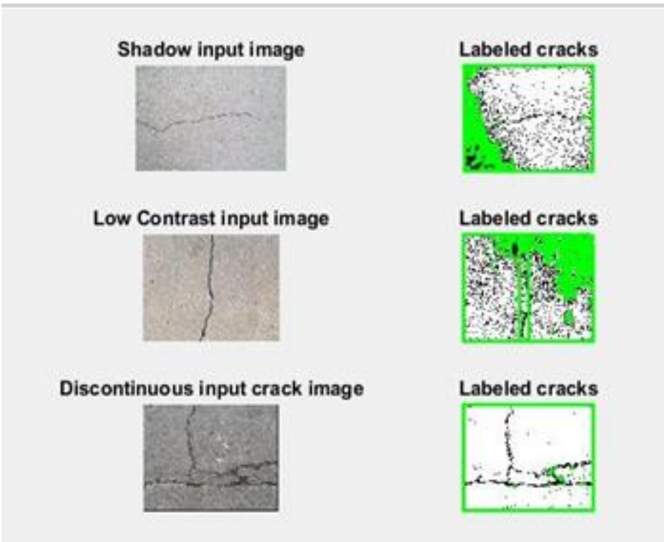

Figure.4.a) Shadow image **b)** Result of shadow image **c)** Low contrast image **d)** Result of low contrast image

e) Discontinuities crack image **f)** Result of discontinuitiescrack image

IV. Conclusion

The survey of alternative fracture detection and classification strategies is presented in this study, followed by the implementation of an existing Otsu-based crack detection approach. The limits are deduced from this implementation, and a new design is presented to solve the constraints, such as erroneous crack identification for shadow or low contrast images, and crack region discontinuities. We intend to address these concerns in the future by using wavelet transform and SVD with a random forest method for crack classification. Finally, image processing and machine learning techniques are used to carry out the analysis. The data must be examined using appropriate fracture detection and classification quantitative criteria.

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