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Crack Detection Via Spatially Tuned Multiple Feature Classifier

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Abstract*: Cracks are an important indicator of the safety status of the civil structures. Detection of cracks on civil structures is a vital task for maintaining the structural health and reliability of structures. A single camera installed in a truck or even in a robot can be used to capture the sequence of images. Then those images are processed and crack is detected. We can use it for online analysis too. The proposed system is an automated crack detection method using spatially tuned multiple feature classifier. By using machine learning classifier, we can eliminate the need of manually tuning threshold parameters. This method uses a mean filter in preprocessing stage to smoothing the image. Then use a line fitting method to localize crack regions even in the presence of noise. Spatially tuned multiple visual features are computed for those line detected regions. Intensity and gradient based features are computed here. The classification results are obtained with the structural surface image with crack and no crack. A crack density map for the structural surface provides the view of the spatial patterns of the cracked regions.
***Keywords*: Image analysis, machine vision, spatially tuned multiple feature, crack density map, image gradient.**

I. INTRODUCTION

Crack is an important indicator reflecting the safety status of the civil structures. Unfortunately, throughout the history there has been many building collapses across the world due to poor maintenance. However, due to effects, such as Permeability of concrete, thermal movement, creep, human damage and topographic change, civil structures suffer from breaks in their surfaces and internal structures. So these are principal causes of cracks in buildings .As deterioration process in concrete begins with penetration of various aggressive agents, low permeability is the key to its durability. Thermal movement is most potent causes of crack in buildings. Timely and accurate monitoring about cracks in structures is necessary for the maintenance of concrete buildings and prevention of accidents. Accidents have highlights the tragical results of structural failure and the importance of periodic maintenance.

Image based reconstruction in automatic crack detection increases in past few years, this can be applicable in many areas such as laboratory testing, field inspection, quality assurance and construction quality control. Crack detection in experimental testing need specimen, whereas the researchers can take the photograph of the specimen from a distance and have the reconstructed model in digital crack detection. This is an added feature in crack detection. The use of spatially tuned multiple feature classifier gives an improved result as compared with previous methods. This can be implemented in onsite analysis too.

In past years, inspection of crack has been done manually by careful and experienced inspectors or by using some microscopic instruments. Besides, the poor lighting condition and the height of the structure make it hard for inspecting the cracks from a distance. So that preferring machine vision inspection, in which cracks are identified and classifying based on the image analysis. In machine vision inspection, camera is placed in robot or somewhere else.

This paper presents an automatic crack detection methodology for civil structure safety monitoring. This approach uses spatially tuned multiple feature classifier for the automatic detection of crack. The intensity and gradient based features are used for classification. A crack density map is also introduced for analyzing the spatial patterns of the crack in the surface.

To test the methods proposed in this paper, several test were conducted on controlled environment as well as on real concrete structures to validate the method. This paper describes the related work in Section II. Proposed architecture and the different methods in the proposed method are described in Section III. The experimental results and analysis are in Section IV. Finally, the conclusion is in Section V.

II. RELATED WORKS

In the past few years cameras based crack inspection systems are the main method used in civil structure monitoring. Many techniques are there to detect and measure the cracks. Image processing technique for automatic crack detection and identification are the focus of most methods. To detect a crack on surface, the edge and corner information are enough. Some simple filtering procedures are also able to detect the crack on a concrete surface [1]. Most of the crack detection method use simple edge detection and thresholding, but these methods are non-robust to noise and required some manual parameter adjustments. When the cracks are high contrast regions against a near uniform background, as shown in Fig. 1(a) and 1(b), the simple methods may perform well. If the crack is not evident one, as shown in Fig 1(c) and 1(d), in such cases simple methods may not work.

(a) (b) (c) (d)

Fig.1. (a), (b) images that are with high contrast. Simple methods like edge detection and thresholding can be applicable to these images for crack detection.
(c), (d) Images from structural surface shows significantly more distractors and pose a more challenging crack detection problem.

A local binary pattern based operator is used to detect the crack on pavements [2]. In which classify the whole image into smooth and rough area. Further segmentation is performing only on rough areas [3]. This is a texture classification method. Similarly wavelets and neural networks are used for the crack detection [4].

The eddy current test (ECT) is probably one of the most widely used electromagnetic techniques for the inspection of thin defects (cracks) in conductive material [5]. This is relatively low cost and simple hardware setup. Laplacian and Sobel operator is also used to detect the edges in the image [6] [7].

Particle filter based crack detection is a novel method in automatic crack detection field. The system is composed of a camera to take images from the environment, a processing device is there to detect the crack and measure the crack geometries in real time, a remote station to receive the data from the processing device through a channel, and a database is created based on the measurement history. The database is a part of the architecture of proposed system, but it will not be used for comparison purpose. It is used as the history of the state of the cracks for the maintenance process.

Studies have been conducted on radio frequency identification (RFID) tag, it is a promising device for the management of products at low cost. Install large number of low cost RFID sensors on structure, even after the disaster of the structure we can access this sensors wirelessly and very easily [8]. A printed sheet is a part of the structure and a copper wire is connected with the structure and the RFID tag. When crack occur in the structure, the printed sheet is broken resulting increase in resistance. Similarly the crack width can be calculated by the ability of an RFID transmitter to communicate with the tag. Very small steel crack can be identifying by using this method. A robust automatic crack detection method from concrete surfaces with noise is proposed in [9], however the "noise" in this method is image shadows.

Several studies are conducted on nondestructive technique to characterize the surface opening crack depth in concrete. This may be of two types, one is time-of flight based approach and other one is wave transmission based approach [10]. In the time-of flight based method, the depth is measured by using the time required for a longitudinal wave generated by an event on a side of a surface opening crack to diffract at the top of the crack and be captured by a surface mounted receiver placed on the opposite side of the crack. Wave transmission method is performed under laboratory conditions. Among different wave transmission approaches cutoff frequency method is the most commonly used one.

III. METHOD

Cameras are using as a main sensor, which has many advantages over traditional methods [11]. Even though, a correct setup of components in system is important to ensure the accuracy.

The proposed method consists of mainly two sections, crack detection and crack density map construction. In the crack detection stage, A mean filter is used at the preprocessing stage, it is simply replace each pixel value in the image with the mean value, so it smoothing the images. It is often used to reduce the noise. The next stage in crack detection is a spatially tuned multiple feature classifier is used for the crack detection. It consist of three steps, i) a line segment detector ii) spatially tuned multiple feature computation iii) a machine learning classifier. In the next section, crack density map construction image gradient is used and in the

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last section of the construction of 3D structure is based on texture based volume rendering. The overall block diagram of the proposed system is shown in Fig. 2.

A. Line Segment Detector

Line detection is a form of image segmentation, something that can be done using either similarity or discontinuity. Thresholding, region growing, region spitting and merging are all examples of similarity methods and are called region-based segmentation. Line segments are fixed below a fixed percentage of average intensity with its neighboring pixels. Such a neighborhood is called blocks [12]. If the size of the block is small then it will help to localize curved regions [13]. This approximation is equivalent to a Taylor series approximation where curved cracks can be represented locally with line segments. Line fit can be approximate with higher order curve fit, but lower order fits are more reliable in neighborhood. Line segment is obtained from each block and machine learning classifier is classifying it into crack region or no crack region. Training samples are provided with manual label.

B. Spatially Tuned Multiple Feature Computation

After the detection the line segment on the image, features are extracting from that region. The multiple feature vectors are a combination of intensity and gradient [14]-[15] based futures. These multiple features are combining into a crack appearance vector. Spatially tuned multiple features provide a quantitative description of the line segment detected regions [16]. The mean of the pixel intensity can detect crack on the line segment, because cracks are generally have lower intensity. But the problem with the mean value is that, it is not enough for high accuracy classification. For thin cracks, the darkness of the pixel intensities is not reliable. Also, a few dark pixels along the line segment in a non-crack region are a reason for low mean intensity. Multiple features are combined in the proposed system method. Specifically, we use the following set of intensity and gradient based features that are computed with pixels along the robustly detected line segment:

1) Mean of intensity histogram
2) Standard deviation of intensity
3) Mean of gradient magnitudes
4) Standard deviation of gradient magnitudes

The standard deviation of intensity in the image indicates that the crack segments have as approximate uniform intensity compared to non-crack segments. The component gradient magnitude is used because the gradient magnitudes will have larger value in the crack regions, and standard deviation of gradient magnitude indicates that the gradient magnitude along a crack is expected to be more uniform than for line segments in no crack regions.

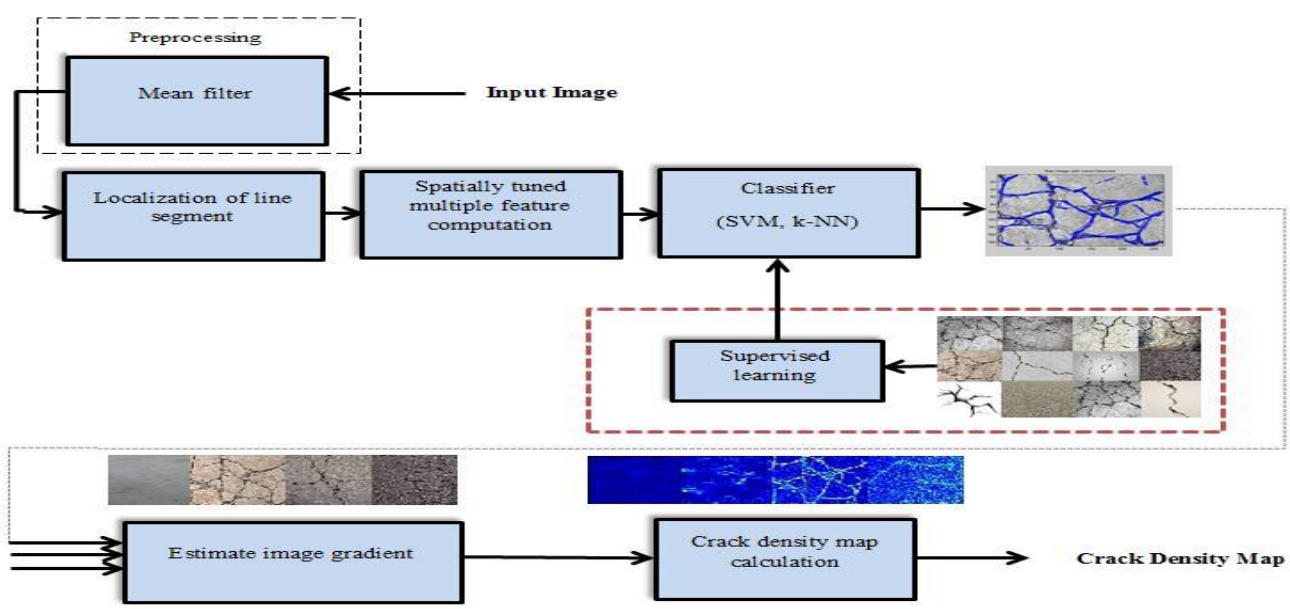

Fig. 1. Overall block diagram of the proposed system.

C. Classifier Training and Testing

The crack appearance vector (obtained by combining spatially tuned multiple feature vector) is used as input to machine learning classification. For statistical inference, classifiers are chosen based on empirical performance and investigate the following classifiers: support vector machines (SVM) [17], k- nearest neighbors (k-NN) [18]. Here four Features are used to evaluate the performance of each of the three classifiers to yield the highest possible accuracy. Furthermore, a classification test that is geographically mutually exclusive is provided where the training data is and the test set is obtained from different structures. If the surface is classified as a cracked surface, then drawing the line segment along the detected line segments. In such a way provides identification for the crack on the surface.

D. Crack Density Map

Crack location and its characteristics are important to detect, evaluate and archive. Additionally, presentation of the crack detection results may be constructed to a human inspector. There is a challenge of communicating spatial patterns of cracks over the surface. The density map is constructed using image gradient [13]. An image gradient is a directional change in the color or intensity in an image. An image gradient is used to extract information from images.

This is done by computing the image derivative in the x and the y directions, and then combining these into one vector. The second point is that the direction of this vector is the direction in which the image is changing most rapidly, and the vector magnitude is the rapidity with which the image is changing in this direction.

IV. EXPERIMENTAL INVESTIGATION AND RESULTS

The experimental results use an image database collected by robotic scans of different civil structures consisting of 100 images. For the experimental results, combinations of features (intensity-based and gradient-based) are used. The validations and training set are chosen from 100 samples per different structures in the labeled database with equal number crack and non-crack samples. Using these 100 samples quantify the classifier performance.

This section describes the experiment to access the feasibility of the proposed method. In Section IV-A describes about the outline of the experimental setup provided. In Section IV-B the classifier performance is mentioned. In Section IV-C explains the application of the crack detection method and also showing some practical results obtained. Section IV-D describes the applications of crack density map construction.

A. Outline of the Experimental Setup

The experimental setup is composed of a robot with a camera travelling on the wall. To test the reliability of the system, collect number of images from various structures. The implementation of the proposed system was carried out and the results were recorded.

B. Performance of the Classifier

The classifier performance is evaluated using geographically distinct test data, i.e. from different civil structure datasets. For this purpose, we constructed training and test sets of images collected from different structures. 100 different samples were labeled with equal positive and negative instances. The classifiers were evaluated with the multi-feature vector .The classifier performance when trained on the sample images are shown in Table I.

Using the spatially tuned intensity-based features along the local line segments, as described in Section II-A, the blocks is classified. The combined feature vector using Mean of intensity histogram, standard deviation of the intensity, mean of the gradient magnitude and standard deviation of the gradient magnitudes performs best. The proposed method uses the 4⇥1 feature vector and evaluates the classifier performance on the samples. The combined intensity-based feature vector led to an increase in accuracy and precision of the classifiers. K-NN classifier has the highest correct rate and sensitivity, and both the classifiers showing the same specificity.

TABLE I

CLASSIFIER PERFORMANCE WITH 100 IMAGE SAMPLE DATASET

Classifier	Correct Rate	Sensitivity	Specificity
SVM	95.92	95.83	96
k-NN	97.96	100	96

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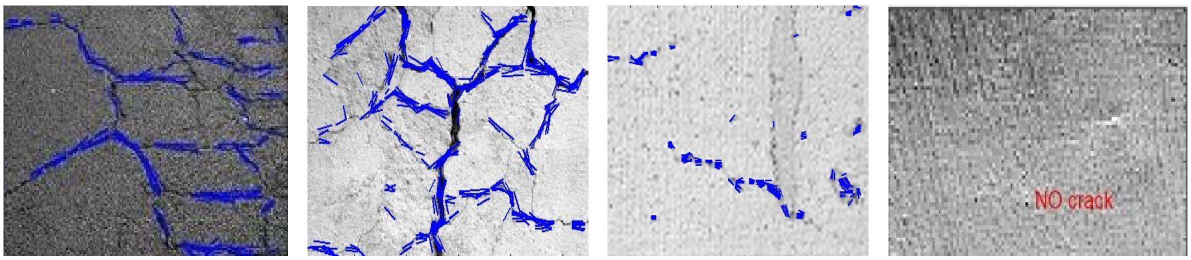
C. Application of the Crack Detection Method

Crack detection approach is based on a line segment detection and in which the lines are drawn on the images where line segment is detected (this process is done only in such images, those are classifier classifies surface as crack area). Number of runs with different materials was performed, the samples are taken from the real concrete structures. The experiment with real concrete structures influences the light, light was allowed to vary. Then all the samples were processed in order to detect the crack only by using image.

Inputting the images that have been taken from the real concrete structures, each sample is processed and the crack detection section is outputting an image with blue coloured lines, showing the crack. Fig. 3(a), 3(b) and 3(c) showing an image with recognized crack and Fig 3(d) showing the output in a non-crack area.

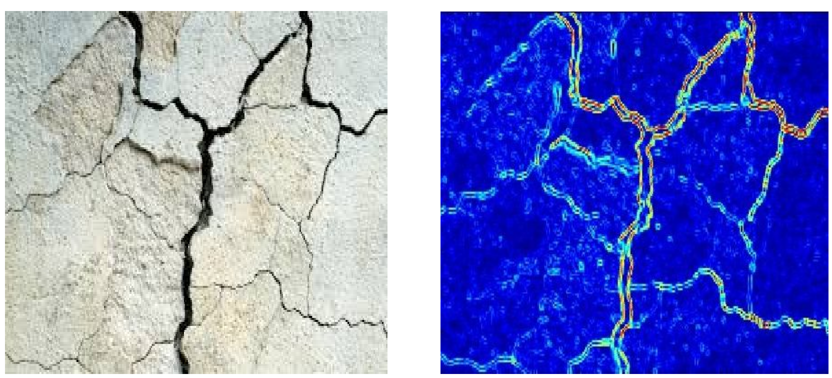


(a) (b) (c) (d)

Fig. 3. (a), (b) and (c) recognized crack on different structural surfaces, (d) is the output get from a no crack surface.

D. Applications of Crack Density Map Construction

This color-map shows various levels of degradations indicated by the different colors where dark blue corresponds to region of low crack density and different crack densities are indicated by using different intensities. A crack surface is shown in Fig. 4(a) and its corresponding density map is shown in Fig. 4(b). If we require a global view of the surface of the structure, take a video of the structure then find the density map of the each frame in the video. Then stitch these frames together for the global analysis by using image stitching procedure [19].



(a) (b)

Fig. 4. (a) a surface with a crack and (b) is the crack density map of the image

V. CONCLUSIONS

In this paper, proposed a method using spatially tuned multiple feature classifier for crack detection on civil structures provides a method of inspection. The proposed methodology allows for automatic crack measurement in civil structures. According to the methodology, a sequence of images is processed by the crack detection algorithm in order to detect the cracks. The algorithm receives images as inputs and outputs a new image with detected crack. Experiments are done using 100 images on dataset. Test and train these 100 images using two classifiers, SVM and k-NN. Both the classifiers performs almost same. The proposed method is capable of detecting even thin cracks in the structure as compared to some previous methods. The result shown suggests that the k-NN classifier provides a useful method for generalizing the trained model to surfaces of different civil structures.

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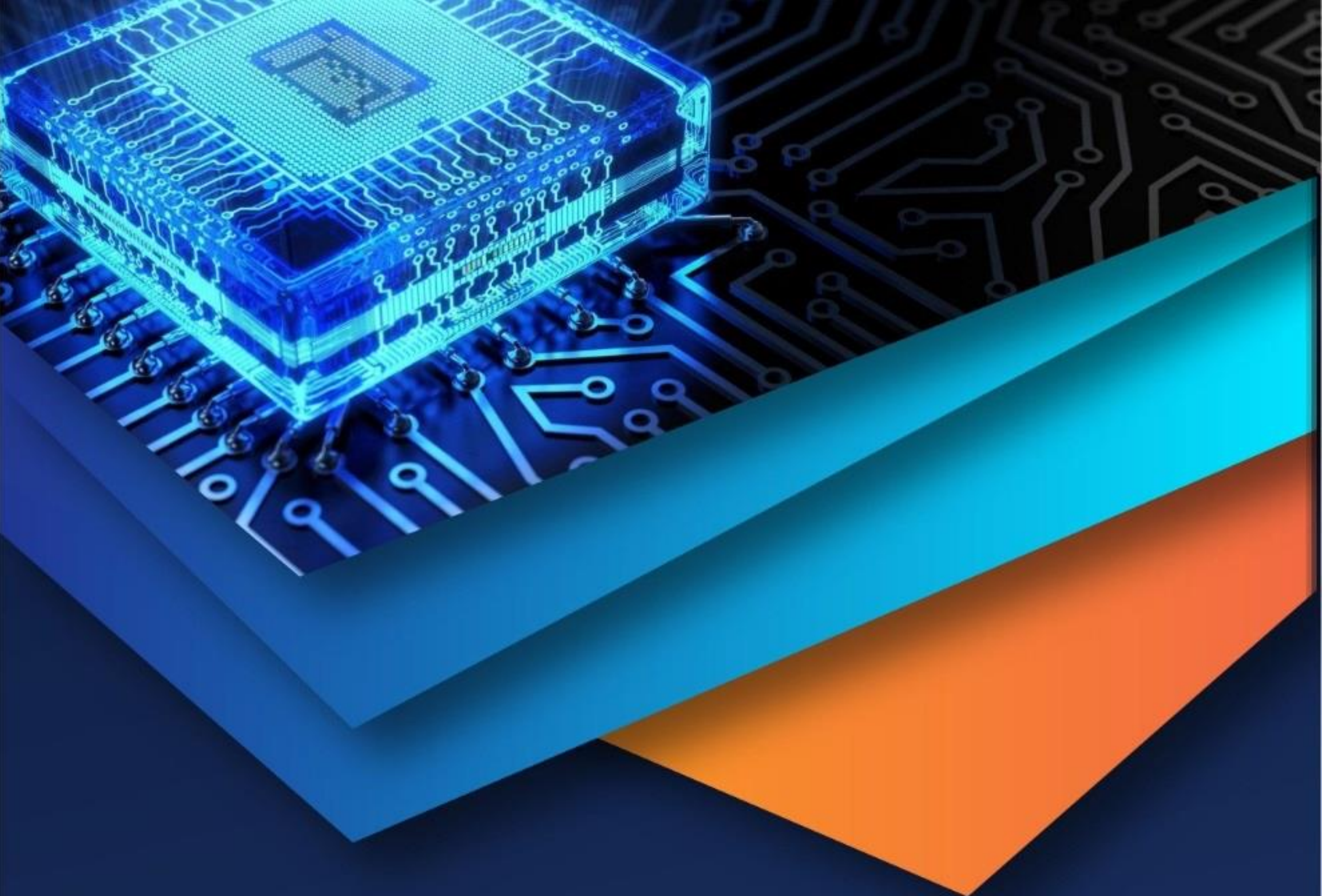

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