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A Survey on Crack Detection Using Image Processing Techniques and Deep Learning Algorithms

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***Abstract*—Due to seasonal changes and poor quality of construction materials, cracks may develop in the walls of the building. One of the initial signs of the degradation of a concrete surface is cracks. Manual inspection has got many drawbacks like invisibility of cracks, time consuming and requirement of expert's knowledge. So it can be done automatically by using image processing. Deep learning algorithms have been investigated for solving many challenging problems in image classification. Literature presents many techniques to automatically identify the cracks using image processing methods and deep learning algorithm. In this literature survey some of the recent papers on crack detection have been reviewed and the analysis of the review is being done on image processing techniques. Literature also states that deep learning algorithms applied for crack detection results in better accuracy**.

Keywords: Crack Detection, Image Processing, Deep learning Algorithms.

I. INTRODUCTION

Crack detection is the process of detecting cracks in building walls and also concrete surfaces. Crack detection can be done in two ways. One is destructive testing and another one is non-destructive testing. Crack detection should be done accurately by measuring the dimensions of the cracks for reliability. Human inspection is time consuming and slower hence automatic crack detection methods is being adopted as it's processing speed is better than that of human inspection. Image based crack detection has been increased rapidly. Accuracy of results is the major reason behind adoption of image processing methods for crack detection .In this paper a survey is being conducted on crack detection using image processing methods and the neural networks algorithms that can be applied on images captured with camera. The major advantage of using image processing techniques in crack detection is the accurate results when compared to manual methods. There are many difficulties in image based detection due to cracks, irregularities and noises. In crack detection the difficulty in processing depends upon the size of the image. Deep learning algorithms are those algorithms in which they are evolved from artificial intelligence. The ability of humans to classify objects can be applied to computers also and that is the logic behind applying deep learning algorithms. Deep learning algorithms can be divided in to two categories they are deep neural networks and restricted Boltzmann machine. Deep learning algorithms could be used for solving many challenging problems in areas of image processing, speech recognition, signal processing etc.

II. LITERATURE REVIEW

A. Image Processing Techniques for crack Detection

The main steps included in the detection of cracks are mentioned in "Fig A.".They are pre-processing, detection and

classification. From the literature it is clear that during the preprocessing phase the smoothing and filtering methods were used and detection phase have been carried out by many methods like otsu method ,statistical approach, threshold method and classification can be done using deep learning algorithms like convolutional neural network ,fuzzy logic controlled etc.

Fig. A. Steps for Crack Detection

Shivprakash et al. (2005) has introduced a method to detect cracks in the noisy environment using mathematical morphology technique and curvature evaluation. Their objective was to find the surface of the crack. In their study filtering and segmentation was performed. The sequential irregularities were identified in this paper using geometry based features of cracks. They have used real dataset and the accuracy was less than 70 percent. The major drawback of their research was the poor implementation of the algorithm which in turn resulted in less accuracy.

Ahmed et al. (2016) has adopted a three steps methodology. Their objective was to find the surface of the crack. First step was the conversion of the image to gray scale image and then they have used sobel's filter for the detection of cracks. The next step was to categorize the images in to foreground and background images. After categorizing the noise removal was done by using sobel's filtering. After that Otsu method has been used for the detection of cracks. They have used real dataset and accuracy was above 85percent.

A method was introduced by Baohua et al. (2016) for the detection of width of the cracks. Their objective was to find the surface of the crack. They have used stereo vision cameras to recover the co-ordinates of the edges of the crack. In order to obtain the image coordinates they have used the Canny-Zernike algorithm. The width of the crack was assessed using a technique called minimal crack edge detection. They have used real dataset and the accuracy was 90-95 percent. The limitation of their work was regarding the effect of lighting conditions that has to be deeply investigated.

A picture analysis methodology was planned by Yuan-Sen et al. (2016) in order to capture the cracks. They have minimized the requirement for pen marking in reinforced concrete structural tests. Their objective was to find the surface of the crack. They have used the studies like crack depth prediction, crack pattern recognition based on artificial neural networks, applications to micro-cracks of rocks and efficient sub-pixel width measurement .They adopted stereo triangulation method based on cylinder formula approximation and image rectification. Their observation was that once the rectified output was obtained, surface of the observed regions could be unfolded and presented in a plane image for displacement and through deformation analysis, the crack were analyzed. They have used real dataset and the accuracy was less than90 percent. The limitation of their work was that the adopted methods were not applicable for thin cracks, which do not present clear dark lines in images.

A novel method based on sparse representation was developed by Xiaoming et al. (2012) that could detect pavement cracks and reconstruct the main pavement profile. Their objective was to find the surface of the crack. The key for cracks separation from main profile was based on the features of the mixed over-complete dictionary, which consisted of two kinds of atoms, one for crack representation and another for main profile representation. In their study, atoms of trapezoidal membership function were adopted to represent crack, and exponential function for main pavement profile. They have stated that the novel method would match with the steps of the crack very well when compared with wavelet and median filter without damaging the information of the main profile signal. Experiments were conducted by them proved that that the method was able to detect the position of pavement crack efficiently as well as reconstruct the main profile.

They had also stated that in future they will be able to achieve improved computational efficiency by using computer grid technology. The datasets used was locally available images. The accuracy achieved by them was more than 90 percent. The limitation of their work was that the main profile was very time consuming.

A new method for accurately detecting crack edges on a concrete surface was proposed by Hoang-Nam et al. (2014). Their objective was to find the surface of the crack. In their method, a novel phase symmetry-based crack enhancement filter was developed for detecting crack edges. Geometric properties of cracks including line-like and local symmetry across the centre-lines were considered carefully to detect the true crack-edges from 2D image. Specially, edges of cracks were specified from analyzing the cross-section of cracks. It was stated that, the time taken to identify crack edge was very less. The results of application of the method to images of concrete surfaces showed that their method can accurately detect weak crack edges and considerably reduce the noise caused by unintended objects. Furthermore, their proposed techniques could be extended to compute crack width from the edge points in the cross-section profiles. Their proposed image processing technique was expected to make the crack inspection process more efficient and cost effective. They have

used locally available images and the accuracy was 80-85 percent. The limitation was that crack width alone was computed.

J. Zakrzewski et al. (2010) used nonlinear imaging of a crack. Their objective was to find the surface of the crack. Acoustic signals at two different fundamental frequencies were launched in their sample, one photo acoustically through heating by the intensity-modulated scanning laser and another by a piezo electrical transducer. The acoustic signal at mixed frequencies generated due to system nonlinearity has been detected by an accelerometer. The contrast of the images obtained at a mixed frequency was compared with the obtained linear photo acoustic images. They have used CNRS dataset and the accuracy was 85 -90 percent. The limitation of their work was that only physical mechanisms of the nonlinearity contributing to the contrast in linear and nonlinear photo acoustic imaging of the crack were discussed

Sunil et al. (2006) has investigated the cracks by using the two-step approach. Their objective was to find the surface of the crack. They have developed a statistical filter design for the crack detection. After filtering, the two-step approach at which the crack feature extraction was carried out at the first step of the pre-processing and then they have fused the images. The second step was to define the crack among the image segment by the process of cleaning and linking. They have used real dataset and the accuracy was less than 90 percent. The limitation was that although joints and laterals have a predictable appearance, the presence of randomness and irregularity of cracks made modeling a difficult task.

Yusuke et al. (2016) has proposed a system for automatic crack detection on the noisy concrete surface mages. Their objective was to find the length of the crack. Their system includes two pre-processing steps and two detection steps. The original image was used for the pre-processing. They have removed the shadings using the median filtering. A multi scale linear filter with the Hessian matrix was used to emphasize the cracks. After pre-processing, they have detected the crack coarsely without noise by a probabilistic method. They detected the crack more finely using an adaptive threshold algorithm. They have used real dataset. The accuracy was 90-95 percent.Limitation was that they have evaluated robustness and accuracy of their proposed method quantitatively by using 60 actual noisy concrete surface images.

Leo et al. (2017) has proved that as the number of layers are increased the accuracy and recall of the network increases. This is mainly because as the networks get deeper it learns more and more discriminative features from the images that helps the networks to differentiate the pavement cracks from non-crack images. The network trained on images taken from a particular location does not perform well when tested on images taken from another location. Therefore, location variance is a very important hurdle that has to be tackled for implementing a universal automatic crack detection system using computer vision techniques. They have used real dataset and accuracy was more. The major limitation was the training with limited data.

B. Deep learning algorithms that can be used for Crack Classification

- Back-Propagation Algorithm

The main objective of Back Propagation method is adapting synaptic weights in order to minimize an error function. The approach most commonly used for the minimization of the error function is based on the gradient method. Leo et al. (2017) has recommended that fine tuning is a strategy that is commonly found in deep learning. It can be used to greatly improve the performance of stacked auto-encoders. From a high level perspective, fine tuning treats all layers of as a single model, so in that one iteration, it is improved upon all the weights. As the back propagation algorithm which is based on descent gradient technique can be extended to apply for an arbitrary number of layers, back propagation algorithm can be used on stacked auto- encoders of arbitrary depth. In their work, to adopt the connections weights were adopted in order to obtain minimal difference between the network output and the desired output.

BackPropogation algorithm is quite simple; output of neural network is evaluated against desired output. If results are not satisfactory, connection between layers are modified and the process is repeated again until error is small enough.

- Fuzzy Logic Controlled Deep Neural Network

Leoet al. (2017) has proposed a fuzzy logic management technique which may be helpful in representing human information in a very specific domain of application and in reasoning there with information to create helpful inferences or actions. A symbolic logic system consists of 4 parts. A fuzzifier converts knowledge into fuzzy knowledge or Membership Functions (MFs). The fuzzy rule base contains the relations between the input and output. The fuzzy illation method

combines MFs with the management rules to derive the fuzzy output, and therefore the deffuzifier converts the fuzzy numbers back to a crisp worth. There are two reasons that symbolic logic systems are preferred: fuzzy systems are appropriate for unsure or approximate reasoning and that they permit higher cognitive process with calculable values underneath incomplete or unsure data. By using a fuzzy system to adaptively change the training parameters of the neural network in keeping with the MSE error, it is possible to cut back the chance of overshooting throughout the training method and facilitate the network to get out of an area minimum. There are four parameters accustomed to produce the principles for the symbolic logic management system; the relative error (RE), amendment in relative error (CRE), sign amendment in error (SC) and accumulative total of sign amendment in error (CSC).

- Fuzzy Deep Neural Network Training

L.zhang et al. (2016) has given that deep multi-layer neural networks have several levels of non- dimensionality permitting them to succinctly represent extremely non- linear and extremely variable functions. The coaching section of deep neural network contains two major steps of parameter data format and fine standardization. The data format step is vital in deep learning. A stronger robust data format strategy might facilitate the neural network to converge to a good local minimum more efficiently. The fine standardization step permits to exactly adjust the parameters within the neural network in a much supervised way to enhance the discriminate ability of the ultimate feature.

- Convolutional neural network for crack classification (CNN)

L. Zhang et al. (2016) has proved that Crack detection is an important application of neural networks .Steps for detection and classification of cracks suggested by L. zhang et al. (2016) were,

a) Data preparation

This first step to be done for crack detection is data preparation.

b) Design and train the convolutional neural network

A deep learning architecture could be designed to have pooling, convolutional and fully connected layers. The CNNs were trained using the stochastic gradient descent method. The dropout method was used between two fully connected layers and the rectified linear units as the activation function.

c) Evaluate the performance of the convolutional neural network

The convolutional neural network could be compared with the support vector machine and the Boosting methods. CNN's use relatively little preprocessing when compared to other image classification algorithms like support vector machine. The CNN's requires less training and it has got the ability to detect complex non linear relationships between dependent and independent variables. The features for training the Support vector machine and the Boosting method are based on the texture and color of each patch which are associated with a binary label indicating the presence or absence of cracked surface.

III. CONCLUSION

In this paper, a survey on various crack detection techniques based on image processing techniques and deep learning algorithms were evaluated. The digital image processing techniques are very helpful for analyzing the defects of assorted surfaces by applying various methods like otsu method, statistical approach, median filtering, threshold method in image processing. Each method has its own merits and demerits. From this review it can be understood that some methods are fast, but lack proper accuracy, where as some other methods have high accuracy but restricted by complex computations, which leads to low speed. For real time processing, high speed and high accuracy are essential at the same time. This review shows that each method is suitable for detection of some specific defects. So it can be concluded that there is no general technique that has yet been proposed for detecting all different types of surface defects. From the survey it is understood that an increase in the depth of the deep networks will lead to better performances in terms of accuracy and recall. The deeper the networks are, the more it learns about detecting cracks although a threshold has not yet been defined.

REFERENCES

[1] Baohua Shan, ShijieZheng, JinpingOu, "A stereovision-based crack width detection approach for concrete surface assessment", KSCE J. Civ. Eng. 20 (2) (2016) 803–812. Springer.

[2] ShivprakashIyer, Sunil K. Sinha, A robust approach for automatic detection and segmentation of cracks in underground pipeline images, Image Vis. Comput. 23 (10) (2005) 931–933

[3] Yuan-Sen Yang, Chung-Ming Yang, Chang-Wei Huang, Thin crack observation in a reinforced concrete bridge pier test using image processing and analysis, Adv. Eng. Softw. 83 (2015) 99– 108

[4] Sunil K. Sinha, Paul W. Fieguth, Automated detection of cracks in buried concrete pipe images, Autom. Constr. 15 (1) (2006) 58– 72.

[5] Ahmed Mahgoub Ahmed Talab, Zhangcan Huang, Fan Xi, Liu Hai Ming, Detection crack in image using Otsu method and multiple filtering in image processing techniques, Optik – Int. J. Light Electron Opt. 127 (3) (2016) 1030–1033.

[6] G. E. Hinton, S. Osindero, and Y.-W.Teh, "A fast learning algorithm for deep belief nets," *Neural Computation*, vol. 18, no. 7, pp. 1527–1554, 2006

[7] A. Ahmed, K. Yu,W. Xu, Y. Gong, and E. Xing, "Training hierarchical feed-forward visual recognition models using transfer learning from pseudo-tasks," in *Proceedings of the in EuropeanConference on Computer Vision*, pp. 69–82, Springer, Marseille, France, October 2008

[8] Laurent, John, Jean François Hébert, and Mario Talbot. "Automated detection of sealed cracks using 2d and 3d road surface data."

[9] U.F. Eze, I. Emmanuel and E. Stephen, "Fuzzy Logic Model for Traffic Congestion," Journal of Mobile Computing and Application, 2014, pp.15-20.

[10] Y.LeCunand Y. Bengio, "Convolutional networks for images, speech, and time series," *The Handbook of Brain Theory andNeuralNetworks*,vol.3361,no.10,p.1995,1995

[11] L. Zhang, F. Yang, Y. Daniel Zhang, and Y. J. Zhu, "Road crack detection using deep convolutional neural network," in *Proceedingsof the IEEE International Conference on Image Processing(ICIP '16)*, pp. 3708–3712, Phoenix, Ariz, USA, September 2016.

[12] Leo Pauly, Harriet Peel, Shan Luo, David Hogg and Raul Fuentes,Applied Computational Intelligence and Soft Computing, Volume 2017

[13] Xiaoming Sun, Jianping Huang, Wanyu Liu, MantaoXu,Pavement crack characteristic detection based on sparserepresentation, EURASIP J. Adv. Signal Process. (2012).

[14] Hoang-Nam Nguyen, Tai-Yan Kam, Pi-Ying Cheng, Anautomatic approach for accurate edge detection of concrete crack utilizing 2D geometric features of crack, J. Signal Process.Syst. 77 (3) (2014) 221–240.

[15] J. Zakrzewski, N. Chigarev, V. Tournat, V. Gusev, Combinedphotoacoustic–acoustic technique for crack imaging, Int. J. Thermophys. 31 (1) (2010) 199–2.