Review on Deeply Supervised Convolutional Neural Network for Pavement Crack Detection

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ABSTRACT

Pavement crack detection is an important problem in road maintenance. There are many processing methods, including traditional and modern methods, solving this issue. Traditional methods use edge detection or some other digital image processing for crack detection, but these approaches are sensitive to many types of noise and unwanted objects on the road. For the purpose of increasing accuracy, image pre-processing methods are required for many of these techniques. Recently, some techniques that utilize deep learning to detect cracks in images have achieved high accuracy, without pre-processing. However, some of them are very complicated, some make use of manually collected data and some methods still need some form of pre-processing. In this paper we are going to get insight on some of the methods used in the process of pavement crack detection.

Keywords: - *Convolutional Neural Network, Fault analysis, Encoder-decoder, Deep supervision, multiscale feature fusion.*

1. INTRODUCTION

A typical Deep Learning neural network design in computer vision is the convolutional neural network (CNN). A computer can comprehend and analyse visual data or images thanks to the discipline of artificial intelligence known as computer vision. Artificial neural networks do incredibly well in machine learning. In many datasets, including those with pictures, audio, and text, neural networks are employed. Different forms of neural networks are employed for various tasks. For example, to predict the order of words, recurrent neural networks—more specifically, an LSTM—are used. Similarly, to classify images, convolution neural networks are employed.

There are three different sorts of layers in a typical neural network:
Input Layer: It is the layer where we enter data into our model. The entire number of features in our data (or the number of pixels in the case of a picture) is equal to the number of neurons in this layer.
Hidden Layer: The hidden layer receives the input from the input layer. Depending on our model and the volume of the data, there may be numerous hidden levels. The number of neurons in each hidden layer might vary, although they are often more than the number of features. Each layer's output is calculated by multiplying the output of the layer below it by its learnable weights, adding learnable biases, and then computing the activation function, which makes the network nonlinear.
Output Layer: After being passed through a logistic function like sigmoid or softmax, the output from the hidden layer is transformed into the probability score for each class. Road maintenance must be done effectively and economically, which requires automatic fracture detection. Recent crack detection technology has benefited from the rapid growth of convolutional neural networks (CNNs). approaches mostly rely on CNNs.

We present a unique multiscale convolutional feature fusion module-based highly supervised convolutional neural network for crack identification. The high-level features are directly incorporated into the low-level features at various convolutional layers inside this multiscale feature fusion module. Additionally, deep supervision offers integrated direct supervision for convolutional feature fusion, enhancing model convergency and crack detection performance at the end. Cracks, whose geometric patterns are complex and scarcely captured by single-scale features, are convincingly represented by fusing together multiscale convolutional features learnt at several convolutional stages. We assess the proposed network using three public crack data sets in order to show its superiority and generalizability. Our method surpasses existing cutting-edge fracture identification, edge detection, and picture segmentation techniques in terms of F1-score and mean IU, according to sufficient experimental findings.

2. LITETRATURE REVIEW

The [1] describes a revolutionary deep learning-based method for identifying and analysing pavement cracks. The authors suggest an automated system that is capable of precisely recognising and classifying pavement cracks in order to solve the issue that manual inspection methods are time-consuming and prone to mistakes. The suggested approach uses deep learning to extract high-level representations from pavement photos, more especially deep multiscale convolutional features. These in-depth features enable more accurate fracture detection by capturing both local and global data.

The deep convolutional neural network (CNN) architecture created by the authors efficiently mixes multiscale features taken from different network layers. A sizable collection of pavement photos with identified crack locations is utilised to train the algorithm. The dataset was meticulously crafted to include a range of fracture kinds, lighting effects, and pavement surface textures. The CNN is trained using backpropagation and stochastic gradient descent by the authors employing a supervised learning strategy in order to optimise the model's parameters. The suggested method is evaluated experimentally and contrasted with existing cutting-edge fracture detecting methods. The outcomes show that, in terms of accuracy and resilience, the deep multiscale convolutional feature-based technique is preferable. The model exhibits excellent recall and accuracy rates, demonstrating its efficacy in precisely recognising pavement fractures. The authors also investigate how variables like picture quality, network depth, and training dataset size affect crack detection performance.

They give practical suggestions for improving the system's performance and shed light on the model's sensitivity to these variables. The automatic crack detection technology described in this research will have a big impact on managing and maintaining pavement. It provides a more effective and reliable tool for locating and evaluating crack damage in road surfaces by minimising the need on manual inspection techniques. This development may enable prompt repairs and provide safer driving conditions while also potentially saving time and costs.

In [2] a novel encoder-decoder architecture based on convolutional neural networks (CNNs) is proposed for automatic crack identification on road pavements. In order to increase the effectiveness and precision of crack detection procedures, the authors discuss the difficulties with manual fracture detection techniques. The suggested approach makes use of an encoder-decoder CNN architecture, which is intended to efficiently extract local and global contextual information from pavement photos.

In order to extract abstract features that convey pertinent information about the cracks, the network's encoder portion learns hierarchical representations of the input pictures. Accurate crack identification is made possible by the decoder component, which reconstructs the crack locations using the learnt representations. A sizable collection of photographs of road pavement with identified fracture locations is utilised to train the algorithm. The dataset was carefully selected by the authors to contain a range of fracture kinds, lighting effects, and road surface textures.

They use a methodology called supervised learning, where the model is trained using backpropagation and optimisation methods like stochastic gradient descent. The suggested strategy is contrasted with various cutting-edge fracture detection techniques in the experimental assessment. The outcomes show that the encoder-decoder design performs better in terms of crack detection precision. The model displays great accuracy and recall rates while accurately identifying and defining fractures.

The authors also examine how several elements, including input picture resolution, network depth, and training dataset size, affect crack detection performance. They give useful advice for enhancing the system's performance in actual-world circumstances and shed light on the model's sensitivity to these variables. The planned automated crack detection technology will have a substantial impact on managing and maintaining roads. Pavement cracks may be identified more quickly and effectively by automating the crack detection process, which lowers the reliance on manual inspection techniques. This development may lead to prompt maintenance and repairs, improving road safety and extending the useful life of road infrastructure in the process.

In [3] In a novel method for picture segmentation utilising deep learning methods is presented. The design of encoder-decoder models has been optimised by the authors in order to increase the precision and effectiveness of crack segmentation algorithms. The suggested technique makes use of a convolutional neural network (CNN)-based encoder-decoder architecture developed particularly for crack segmentation.

The network's encoder section collects hierarchical representations of the input pictures and extracts pertinent features that encode data about cracks. In order to precisely identify and delineate fractures, the decoder portion reconstructs the crack segmentation maps using the learnt representations. The authors suggest a number of improvements to the encoder-decoder design to boost the model's performance. They examine how various elements, including network depth, skip connections, and activation functions, affect the model's precision. They determine the most efficient setups that result in better crack segmentation outcomes through methodical trial and analysis. The problem of unbalanced crack datasets, where the bulk of the picture pixels indicate non-crack areas, is also addressed by the authors.

They suggest a unique weighted loss function that gives crack pixels more weights, allowing the algorithm to concentrate on precisely capturing fracture borders. The evaluated deep encoder-decoder models are contrasted with various cutting-edge crack segmentation techniques. The outcomes show considerable increases in accuracy and robustness. The suggested models successfully segment cracks with high accuracy and recall rates while reducing false positives. The optimised deep encoder-decoder algorithms for crack segmentation have significant practical consequences. Planning maintenance efforts and evaluating the state of the pavement depend on accurate and effective crack segmentation. These techniques save time and effort by automating the fracture segmentation process while offering an accurate and impartial evaluation of crack severity. This enables prompt repairs, effective resource allocation, and improved administration of the road infrastructure.

In paper [4] a unique method for detecting pavement cracks using a random structured forest algorithm. By adding different criteria to accommodate fracture changes and boost segmentation outcomes, the scientists hope to increase the accuracy and effectiveness of crack detection algorithms. The suggested approach makes use of a random structured forest algorithm, a random forest version that combines the advantages of decision trees with random sampling methods. The discriminative model for fracture identification in pavement photos is learned using this approach.

The algorithm can recognise the features of various crack kinds since it was trained using a sizable collection of annotated pavement photos. The authors present a triple-threshold approach to deal with the problem of fracture variations. With this approach, three alternative thresholds—a global threshold, a local threshold, and an adaptive threshold—are applied to the crack detection findings. The adaptive threshold deals with fractures of varied widths, while the local threshold deals with cracks with erratic patterns. The global threshold tackles fissures with constant features. The suggested method is contrasted with various fracture detecting strategies in the experimental assessment.

The outcomes show how the triple-threshold approach can increase the accuracy of fracture detection. The technique successfully detects cracks with high recall and accuracy rates while minimising false positives and false negatives. The triple-threshold pavement crack detection system has important practical implications for managing and maintaining pavements. The technique offers a reliable and flexible strategy for crack identification by utilising the random structured forest algorithm and adding numerous criteria. This makes it possible to quickly identify cracks of various forms and variations, permitting prompt maintenance and proactive repairs to maintain safe road conditions and extend pavement lifespan.

In paper [5] Deep convolutional neural networks (CNNs) are used in an ensemble technique in this research. to detect and quantify pavement cracks automatically. By merging the predictions of various CNN models, the scientists hope to increase the precision and reliability of fracture detection systems. The suggested approach comprises of a group of CNNs, each of which has been trained individually using a sizable dataset of photos of cracked pavement. The CNNs are made to pick out distinguishing elements and record the intricate patterns linked to pavement cracks. The ensemble technique tries to capture a variety of fracture features and enhance performance by training numerous models.

Each CNN in the ensemble individually analyses the input pavement picture during the fracture detection phase to produce crack probability maps. These maps show the probability that each pixel is part of a fracture. The final fracture detection result is produced by fusing the individual probability maps together. The authors also suggest a crack measuring technique that makes use of the ensemble methodology. Accurately determining the length and breadth of discovered cracks is required for the crack measuring. The variability of predictions from many models is taken into account by the ensemble models to produce more precise crack measurements. The suggested ensemble method is contrasted with individual CNN models and other cutting-edge fracture detection techniques in the experimental assessment.

The outcomes show the ensemble approach's improved performance, with high accuracy in crack identification and accurate measurements of crack diameters. The ensemble of deep CNNs has important practical implications for autonomous pavement crack identification and measuring. The technique enables increased crack detection accuracy and robustness by using the variety and collective intelligence of many CNN models. Accurate crack measurements enable efficient pavement management and maintenance, enabling prompt fixes and preventative measures to guarantee safer driving conditions and increase the lifespan of road infrastructure.

3. CONSOLIDATED TABLE

S.L. No	AUTHOR	YEAR	DESCRIPTION	LIMITATION
1	W. Song, G. Jia, H. Zhu, D. Jia, and L. Gao	**2020**	• The proposed method utilizes multiscale features extracted from different layers of a pre-trained CNN model, which enables the detection of cracks at various scales and levels of detail. • The performance of the proposed method is evaluated on a benchmark dataset, and various metrics such as accuracy, precision, recall, and F1 score are reported to assess its effectiveness in crack detection.	• Limited diversity in the training dataset • Lack of comparison with non-deep learning methods • Limited discussion on model interpretability
2	Z. Fan et al.	**2020**	• It employs a deep learning approach based on an encoder-decoder architecture, specifically a U-Net model, to automatically detect and segment pavement cracks from images. The U-Net architecture is known for its effectiveness in image segmentation tasks. • It is capable of accurately detecting and segmenting pavement cracks. The proposed method offers a promising approach for automating crack detection tasks in road maintenance, which can improve efficiency	• Sensitivity to hyperparameters • Evaluation metrics

3	J. König, M. D. Jenkins, M. Mannion, P. Barrie, and G. Morison	**2020**	• It uses deep encoder-decoder framework to improve crack segmentation accuracy. These include the utilization of skip connections, which allow information from lower-level feature maps to be directly passed to the decoder, aiding in precise localization of cracks. • The authors also introduce novel loss functions and training strategies to enhance the model's performance.	• Performance trade-offs • Dataset limitations
4	C. Peng et al.	**2020**	• The key technique utilized in this study is the random structured forest, which is a machine learning algorithm based on decision trees. The RSF algorithm combines the advantages of random forest and structured forest to achieve robust and accurate classification. • It utilizes a large number of decision trees and their ensemble to perform crack detection on pavement images.	• Scalability • Resource utilization • Not optimal long term solution
5	Z. Fan et al.	**2020**	• The CNNs are designed to identify distinctive features and document the complex patterns connected to pavement cracks. By training several models, the ensemble approach aims to capture a range of fracture properties and improve performance. • During the fracture detection phase, each CNN in the ensemble separately evaluates the input pavement picture to create crack probability maps. These maps display the likelihood that every pixel is a component of a fracture. The individual probability maps are combined to give the final fracture detection result.	• Computational requirements • Training time • Limited Scope

4. CONCLUSIONS

In conclusion, the development of automated detection techniques has resulted in substantial breakthroughs in the field of pavement crack identification. Road pavement cracks can be found using time-consuming, inaccurate traditional manual inspection methods. Convolutional neural networks (CNNs) and other deep learning approaches have revolutionised the process of automated crack identification, nevertheless. According to studies, automatic crack detection techniques based on deep learning models are more accurate and effective than conventional methods. These models make use of the strength of the deep features that can be derived from pavement photos to collect both local and global data. These models can accurately identify and locate fractures in road surfaces by utilising cutting-edge designs like encoder-decoder networks.

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