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Asphalt Pavement Bleeding Evaluation using Deep Learning and Wavelet Transform

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ABSTRACT: Pavement inspection is an important part of pavement management systems because this part provides input and raw material information to the system. If the pavement situation has not been assessed or incorrectly assessed, it will not be possible to carry out optimum maintenance and repair operations. It can also cause higher maintenance costs and the risk of accidents. Pavement distress information is crucial data that should be collected and evaluated in the pavement inspection process. Accordingly, wide research has been conducted to develop more efficient systems for the evaluation of pavement distresses using new technologies. Bleeding is one of the asphalt pavement distresses, which directly affects the skid resistance and vehicle maneuverability. Based on the literature, pavement bleeding received the attention from the research community less than other pavement distress such as cracks, rutting, raveling, and potholes. This research attempts to develop an efficient system for the automatic evaluation of asphalt pavement bleeding. For this aim, the transfer learning method was applied to train a pre-trained convolutional neural network for bleeding detection. Also, various image processing techniques (wavelet transform analysis as the main technique) were used to segment bleeding regions in pavement images. Results indicated that the proposed system has good performance in bleeding detection and segmentation with 98% and 87%, respectively. Accordingly, this system can be applied as an efficient system for pavement bleeding evaluation.

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1- Introduction

In most countries, pavement management systems (PMS) are developed to monitor the pavement condition and planning to improve the safety and serviceability of roads. An efficient PMS leads to work planning for pavement maintenance by a proper maintenance method at the optimum time, and with optimized cost [1]. Pavement inspection is an important step in PMS because most of the input information for evaluating pavement condition is obtained during the pavement inspection procedure and this information has a significant impact on PMS efficiency [2, 3]. Pavement distresses information is the most important information that should be collected in the pavement inspection procedure.

Pavement bleeding is a type of damage to asphalt pavements. This pavement distress leads to create a thin layer of binder on the pavement surface and is usually caused by traffic loads in hot weather [4, 5]. Bleeding directly affects pavement surface characteristics in terms of microtexture and macrotexture which are important factors in pavement skid resistance. Roads safety and vehicle maneuverability are significantly associated with pavement skid resistance [6]. Accordingly, bleeding causes reducing road safety. This impact can intensify with the hydroplaning effect in wet and rainy regions [7].

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Pavement inspection is conducted traditionally (visual inspection) the past. This approach has some defects, including high labor costs, time-consuming, unreliable results, and unsafe working conditions for staff. Accordingly, the majority of transportation agencies try to apply new technologies for more efficient pavement inspection. According to the literature, 2D image-based, 3D measurement-based, radar-based, optic-based, acceleration-based, sonic-based technologies, and hybrid methods are some of the more prevalent technologies for pavement distress evaluation [3].

In recent years, wide researches have been conducted to develop an automatic system for analyzing skid resistance and detecting various pavement defects such as cracking, rutting, raveling, pothole, etc. However, there is no research with the aim of the automatic inspection of asphalt pavement bleeding as much as other pavement distress such as cracking, rutting, pothole [8].

This research proposes an image-based system for automatic detection and segmentation of asphalt pavement bleeding using deep learning and image processing techniques. In this study, deep convolutional neural networks (CNN) were applied using transfer learning for bleeding detection and applied image processing techniques for segmenting bleeding areas, including histogram

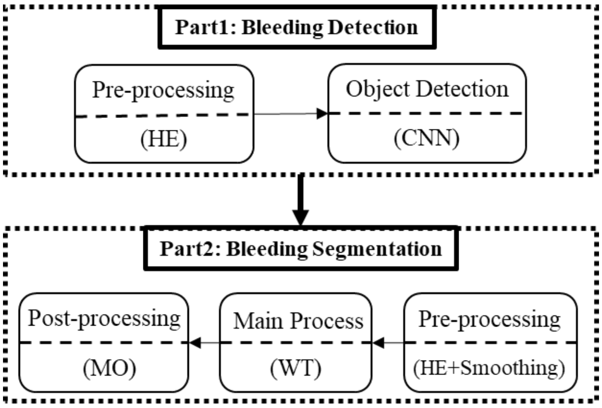

Fig. 1. Research methodology.

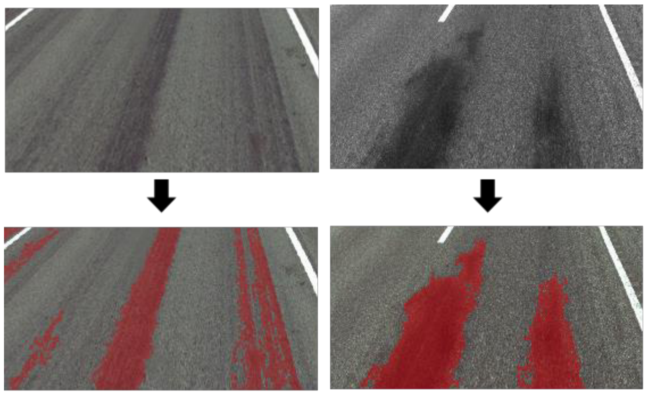

Fig. 2. Examples of system outputs.

Table 1. Details of datasets.

Class	Dataset		
	Train	Validation	Test
B (Bleeding)	400	100	270
N (Non-Bleeding)	400	100	270
Total	1000		540

equalization (HE), image smoothing, wavelet transform (WT), thresholding, and morphological operations (MO).

2- Methodology

As can be seen in Fig. 1, the research process consists of two main parts, including bleeding detection and segmentation.

For bleeding detection, at first, HE has been used to make the more obvious image as a pre-processing. Then, a CNN model has been used to detect pavement images that there is bleeding distress in them. In this part of the research, a data set of pavement images has been collected for training and testing a pre-trained CNN model (AlexNet) using the transfer learning technique. Details of collected datasets are shown in Table1.

In the second part of the research (bleeding segmentation), a pre-processing including HE and smoothing was done to prepare pavement images for the main process. Then, a WT module was developed to separate the bleeding areas in pavement images as the main process. Finally, global thresholding and MO were applied as post-processing to improve the quality of output images.

It should be noted that all computations were performed using a personal computer with a 64-bit operating system, 8.0 GB memory, and Intel(R) Core i7-4710HQ @ 2.50 GHz processor running a GeForce GTX 850M graphics processing unit (GPU).

3- Results and Discussion

After implementing the proposed system, the pavement image with bleeding distress can be detected and bleeding areas can be segmented as presented in Fig. 2

The efficiency of the proposed system has been evaluated based on the processing speed and various performance indices. The time taken for bleeding detection is 0.44 and 0.042 seconds per image in pre-processing and object detection process, respectively. Also, the time taken for bleeding segmentation is 1.55 seconds per image.

To evaluate the efficiency of the models in bleeding detection, the confusion matrix was calculated to achieve performance metrics such as accuracy, sensitivity, precision, and F-score. The average of the performance metrics is almost 98 percent. This result showed that the created CNN model using transfer learning has a good performance in bleeding detection.

The performance of the proposed system for segmenting the bleeding areas was evaluated by comparing the outputs with pixel-level ground-truth labels based on the Dice and recall metrics. The results showed that the proposed system can segment the bleeding areas with 89.94 and 87.47 percent based on the Dice and recall metrics, respectively.

4- Conclusion

Bleeding is important pavement distress that has a direct effect on the pavement skid resistance and reduces road safety. This research tried to apply machine learning and image processing techniques for automatic detection and segmentation of bleeding in asphalt pavements.

For bleeding detection, a pre-trained CNN model (AlexNet) was retrained based on the collected dataset using the transfer learning method. Results of applying the model on the test dataset indicated that retraining the pre-trained CNN is an efficient method for bleeding detection with almost 98% based on the various metrics.

For segmenting the bleeding areas, an image processing-based method was developed using WT as the main process and some other techniques such as HE, smoothing, thresholding, and MO. Comparing the similarity of outputs with ground-truth images showed that the developed method is efficient with 89.94% based on the Dice similarity coefficient.

According to the results, this system can improve PMS performance in various countries by efficiently detecting and segmenting the asphalt pavement bleeding.

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