Asphalt pavement bleeding evaluation using deep learning and wavelet transform

Sajad ranjbar[1], Fereidoon Moghadas Nejad[2*], Hamzeh Zakeri[3]

[1] PhD student, Department of Civil & Environmental Engineering, Amirkabir University of Technology, Tehran, Iran
[2] Professor, Department of Civil & Environmental Engineering, Amirkabir University of Technology, Tehran, Iran
[3] PhD, Department of Civil & Environmental Engineering, Amirkabir University of Technology, Tehran, Iran

ACCEPTED MANUSCRIPT

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 of the research community less than other pavement distress such as cracks, rutting, raveling, and potholes. This research attempts to develop an efficient system for automatic evaluation of asphalt pavement bleeding. For this aim, the transfer learning method has been applied to train a pre-trained convolutional neural network for bleeding detection. Also, various image processing techniques (wavelet transform analysis as the main technique) have been used to segment bleeding regions in pavement images. Results indicate 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.

KEYWORDS

Pavement management system, distress evaluation, bleeding, deep learning, wavelet transform

* Corresponding Author: Fereidoon Moghadas Nejad, Email: moghadas@aut.ac.ir

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 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 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 factor in pavement skid resistance. Roads safety and vehicle maneuverability are significantly associated with pavement skid resistance[6]. Accordingly, Bleeding causes to reduce road safety. This impact can intensify with the hydroplaning effect in wet and rainy regions[7].

Pavement inspection is conducted traditionally (visual inspection) in the past. This approach has some defects, including high labor costs, time-consuming, unreliable results, and unsafe working conditions for staffs. 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 and etc. However, there is not 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, we applied deep convolutional neural networks (CNN) using transfer learning for bleeding detection and applied image processing techniques for segmenting bleeding areas, including histogram equalization (HE), image smoothing, wavelet transform (WT), theresholding, and morphological operations (MO).

2. Methodology

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

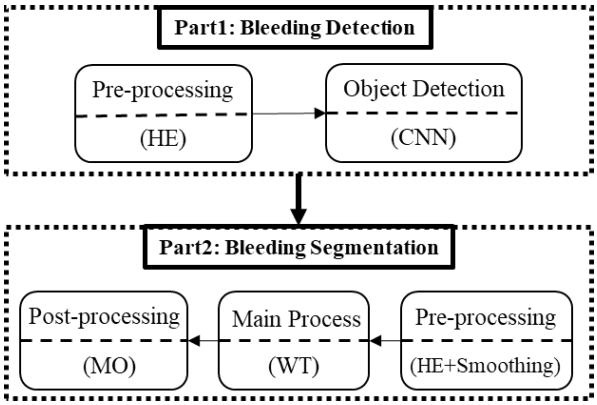

Figure 1. Research methodology

For bleeding detection, at first HE has been used to make 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 research, a data set of pavement image 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.

Table 1. Details of datasets

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

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

ACCEPTED MANUSCRIPT

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. Discussion and Results

After implementing the proposed system, the pavement image with bleeding distress can be detected and bleeding areas can be segmented as presented in Figure2.

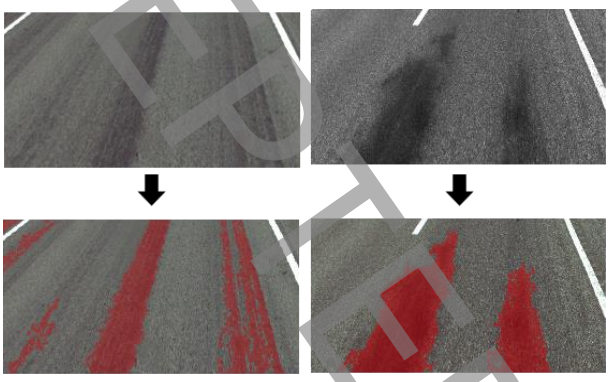

Figure 2. Examples of system outputs

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

Bleeding is an important pavement distress that has a direct effect on the pavement skid resistance and reduce the road safety. This research tries 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 transfer learning method. Results of applying the model on test dataset indicate 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 shows 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.

5. References

[1] F.M. Nejad, H. Zakeri, The Hybrid Method and its Application to Smart Pavement Management, in: X.-S. Yang, A.H. Gandomi, S. Talatahari, A.H. Alavi (Eds.) Metaheuristics in Water, Geotechnical and Transport Engineering, Elsevier, Oxford, 2013, pp. 439-484.

[2] M.Y. Shahin, Pavement management for airports, roads, and parking lots, 1994.

[3] H. Zakeri, F.M. Nejad, A. Fahimifar, Image Based Techniques for Crack Detection, Classification and Quantification in Asphalt Pavement: A Review, Archives of Computational Methods in Engineering, 24(4) (2017) 935-977.

[4] J.S. Miller, W.Y. Bellinger, Distress identification manual for the long-term pavement performance program, United States. Federal Highway Administration. Office of Infrastructure Research and Development, 2014.

[5] A. Designation, D6433 Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys, (2007).

[6] B. Mataei, H. Zakeri, M. Zahedi, F.M. Nejad, Pavement friction and skid resistance measurement methods: a literature review, Open J. Civ. Eng., 6(04) (2016) 537.

[7] W. Lawson, S. Senadheera, Chip seal maintenance: solutions for bleeding and flushed pavement surfaces, Transportation Research Record: Journal of the Transportation Research Board, (2108) (2009) 61-68.

[8] T.B. Coenen, A. Golroo, A review on automated pavement distress detection methods, Cogent Engineering, 4(1) (2017) 1374822.

ACCEPTED MANUSCRIPT