Flexible Pavement Crack's Severity Identification and Classification using Deep Convolution Neural Network

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ABSTRACT

Effective road maintenance program is vital to ensure traffic safety, serviceability, and prolong the life span of the road. Maintenance will be carried out on pavements when signs of degradation begin to appear and delays may also lead to increased maintenance costs in the future, when more severe changes may be required. In Malaysia, manual visual observation is practiced in the inspection of distressed pavements. Nonetheless, this method of inspection is ineffective as it is more laborious, time consuming and poses safety hazard. This study focuses in utilizing an Artificial Intelligence (AI) method to automatically classify pavement crack severity. Field data collection was conducted to allow meaningful verification of accuracy and reliability of the crack's severity prediction based on AI. Several important phases are required in research methodology processes including data collection, image labelling, image resizing, image enhancement, deep convolution neural network (DCNN) training and performance evaluation. Throughout the analysis of image processing results, the image output was successfully classified using MATLAB software. The good agreement between field measurement data and DCNN prediction of crack's severity proved the

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reliability of the system. In conclusion, the established method can classify the crack's severity based on the JKR guideline of visual assessment.

Keywords: *Road maintenance; DCNN; Crack severity; Flexible pavement*

Introduction

Road networks are crucial infrastructures that provide transport services, and a catalyst for the economic development of a nation. A large part of the current road infrastructure is approaching the end of its service life, which is placing even more pressure on the budgets in the coming years [1]. Road maintenance involves monitoring road performance and repairing defects such as potholes, pavement cracks and rutting. Some examples of pavement defect treatments are pothole patching, crack sealing, mill and pave and road reconstruction [2]. Manual pavement distress survey is inefficient and lead to low productivity in road maintenance. For example, one pavement inspector can only inspect less than 10 km per day [3]. The goal of this study is to improve pavement maintenance survey using an AI by measuring the level of severity of distressed pavement. AI is an area of computer science that accentuates the development of smart machines that function and respond like humans. AI performs frequent, high-volume, computerized tasks reliably and without fatigue rather than automating manual tasks. This work introduces a customized image processing algorithm for high-speed, real-time inspection of pavement cracking [4]. Traditionally, it requires engineers working on busy roads, which is dangerous, costly, time-consuming, and inefficient [5]-[7].

Several attempts have been made in the past to automate the pavement distress survey using image processing techniques. Among them are based on image segmentation [8], seed growing [9], local optimal thresholding [10] and matched filtering algorithm [11]. However, these methods suffer from problem of intensity variation in pavement images due to shadow, oily, complex, and rough pavement surfaces. To overcome these problems, recent researches have integrated artificial intelligence such as random decision forest [12], support vector machine (SVM) [13]-[14], artificial neural network [14]-[15] and fuzzy inference system [16]. This study utilises MATLAB software to develop an AI system based on deep convolutional neural network to analyse pavement distress images automatically. The AI system will automate the classification of crack severity of flexible asphalt pavement. To further advance the system, the automated crack detection was moved to the next stage of computer vision where utilizing machine learning approach that can be found in many studies. Machine learning is a subset of AI, where it uses algorithms to analyse and learn from a sample dataset, and then decide or make new predictions about other datasets. This is compatible with the objective of machine learning which is to allow the system to learn automatically without human intervention. Consequently, the main aim of this project is to develop an intelligent system based on DCNN to detect and classify pavement cracks of asphalt pavement. To achieve that, this project focuses on developing an AI system for flexible pavement crack's severity classification. The system is then tested using field datasets to verify its accuracy and reliability.

Research Methodology

The methodology adopted in this project involves four major steps starting with the data collection, image processing and labelling, Deep Convolution Neural Network (DCNN) training and evaluation of the system's performance. The prediction data of pavement crack's severity will be compared with the field measurement data to ensure its accuracy and reliability of the AI system.

Data collection of pavement crack and its severity

The images of asphalt pavement crack were acquired from various location in Penang and Terengganu. Generally, there are three main types of pavement cracks which are longitudinal, alligator and transverse cracks. For this study, the focus is on pavement cracks with various level of severity. Photos were taken using a mobile phone camera with its optical perpendicular to the road surface. The data collection can be carried out with any device that can take pictures downwards [17]. The camera is mounted on a phone holder with a consistent height of 100 cm from the pavement surface to achieve accurate, reliable, and efficient image collection. For every captured image, Vernier calliper is used to directly measure the width of the crack for field data collection

Image labelling, resizing, and enhancing

Pavement crack images obtained from field were labelled based on the measurement of the average width of the pavement's crack. Images will be classified into low, moderate, and high severity of crack based on [18] guideline of visual assessment of flexible pavement surface condition as shown in Figure 1. Low severity of asphalt pavement crack's width is below than 6 mm, moderate severity's width is between 6 mm to 19 mm, and high severity's width is 19 mm and above.

Resizing images is compulsory because if the size is too big, it will slow down the process in training process in Deep Convolutional Neural Network operation. For this research, 64 x 64 is found to be the optimal image size. For resizing images, using photoshop is preferred and easier method.

Figure 1: Classification of crack's severity from low, moderate to high (left to right).

Image enhancing is performed to increase the number of images. To achieve this, images were edited into 90° anti-clockwise, 90° clockwise, perpendicular, and vertical rotation form. Higher number in images from data collection will allow better accuracy in the training process of DCNN system.

DCNN data training and testing

The network prepares two sets of training and testing dataset: types of crack classification consists of transverse, longitudinal and alligator [19]. To achieve the objective, Deep Convolutional Neural Network (DCNN) must be train first. Divide the data into datasets for the testing and validation. Using 70% of the photos for processing, and 30% for validation. After succeeding with the when training the coding in MATLAB, run the other codes to test the pavement crack images. When running the codes, it will ask to input the images we want to test. After selecting the image, MATLAB will state the severity of pavement cracks in the images.

Performance evaluation

The performance of the DCNN was tested based on testing patches that have not been used in the training process. The value of prediction and actual labels in this study uses of matrix analysis which is called confusion matrix. Figure 2 shows that the confusion matrix represents all the parameters that have been mention before. The predicted labels are relayed on the horizontal axis while for the actual labels is relayed on the vertical axis. Usually, training data has higher accuracy than the validation data. For this research, confusion matrix shows the accuracy for each classified data which are low, moderate, and high data.

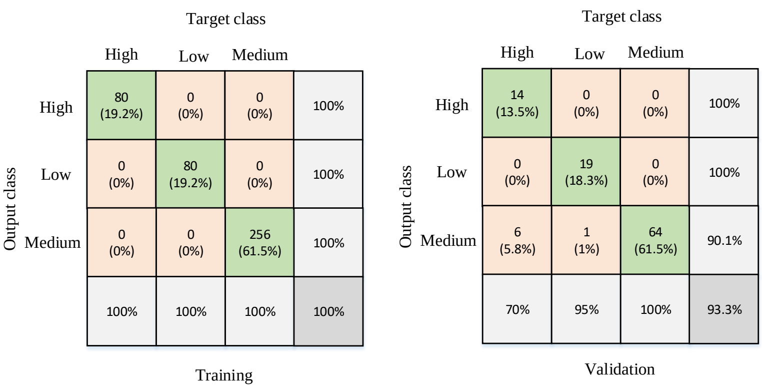


Figure 2: Training confusion matrix (left) and validation confusion matrix (right).

Result and Discussion

The results of prediction from DCNN and validation based on field data collection were discussed to ensure the main objective of this study is achieved. This project aims to have an AI that will enable auto classification of crack's severity of flexible pavement.

Flexible pavement crack's severity using artificial intelligence system result

Figure 3 shows the training process for DCNN. Deep learning models of the neural network learn to map inputs to outputs given an example collection of training data. The training method includes finding in the network a set of weights that proves to be sufficient or sufficient to solve the problem. A validation set is used to evaluate the model during the training [20]. The developed system managed to achieve 93.27 % accuracy for all data.

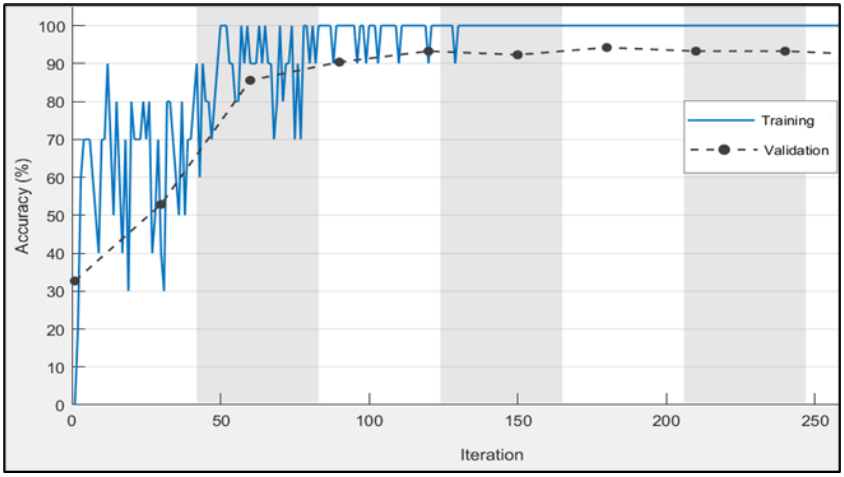


Figure 3: Training confusion matrix (left) and validation confusion matrix.

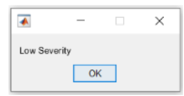
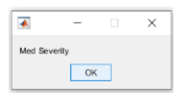
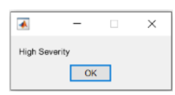
Crack's severity prediction based on field data comparison

Prediction results using AI must be validated with the field data that were acquired from field works on selected roads. Table 1 presents the comparison of predicted and measured data of crack's severity level. Original images show cracks at various severity and measurement was taken to obtain average width of the crack. The prediction results using AI are tabulated on the right column to show the comparison between prediction and field results.

To evaluate this proposed DCNN model, three (3) different datasets were used which are low, medium, and high severity of pavement crack. The selection of dataset is based on the JKR guideline in the visual assessment of flexible pavement functional surface. Another reason for using three (3) different datasets is to study whether the size of the patch used to train and test if the model will affect the model or vice versa. Low, medium, and high datasets contain identical size of patches which is 64 x 64 pixels. After determining the most ideal characteristics for the proposed DCNN model, it is tested on real data which are images that have been developed during this study and the structure of the pavement image represents the general pavement condition in Malaysia.

The evaluation result obtained is quite good with an accuracy of 93.27% and very low loss of only 20 epochs. The complete training and test process took about 1 minute and 29 seconds which is relatively short. This is due to the small dataset used, with a total of 520 input data and 64 x 64 patch size. The output of DCNN prediction of crack severity shows promising results, allowing fast evaluation of flexible pavement crack severity, and eliminating the hazard of conducting visual road assessment manually on the field. Improving field images acquisition in future works will allow higher quality and better consistency of pavement distress images analysis. Thus, the need to develop a system and hardware that can control the environment conditions will enhance the efficiency and reliability of images analysis using the AI system.

Table 1: Comparison between prediction using AI and field data

No	Image	Crack's severity of field data					Crack's severity prediction using AI
		Width			Average	Severity	
1		2.66	2.43	2.96	2.68	Low	
2		5.06	6.02	8.04	6.37	Medium	
3		58.42	40.92	43.94	47.76	High	

Conclusion

In conclusion, the prediction of crack severity using DCNN could be effectively conducted without relying on operator judgement on the field assessment. Throughout the analysis of processing images, the objectives were successfully achieved using MATLAB software with excellent accuracy of output data. The predicted results using the developed system indicated a good agreement with the field data, which proved the reliability of the system.

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