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ARTIFICIAL INTELLIGENCE SYSTEM FOR DETECTION AND CLASSIFICATION OF FLEXIBLE PAVEMENT CRACK'S SEVERITY

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ABSTRACT

Effective road maintenance system is vital to safeguard traffic safety, serviceability, and prolong the life span of the road. Traditional practices based on manual visual observation in the inspection of distressed pavements is no longer effective in vast networking of our existing road infrastructures. Manual method of inspection is laborious, time consuming and poses safety hazard to the maintenance workers. This project focuses in utilizing an Artificial Intelligence (AI) method to automatically classify pavement crack severity. Field data verification was performed to validate 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 and the good agreement between field measurement data and DCNN prediction of crack's severity validated the reliability of the system up to 93.30%. In conclusion, the automation system is capable to classify the crack's severity based on the JKR guideline of visual assessment.

Keywords: Pavement distressed, deep convolution neural network, road maintenance, crack's severity

1. INTRODUCTION

Sizeable part of existing road infrastructure is looming the end of its service life, which is placing more pressure on the budgets in the coming years [1]. Traditional 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]. Thus, an innovation in the automation of pavement distressed survey utilizing an AI is a practical solution in fourth industrial revolution (IR 4.0). 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 maintenance workers working on busy roads, which is dangerous, costly, time-consuming, and inefficient [5]. This study uses MATLAB software to develop a system to analyses 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 analyses 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. The 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 accuracy and reliability of the automation system is then verified using field datasets.

2. METHODOLOGY

The methodology implemented in this project includes four main 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 validated with the field measurement data to confirm its accuracy and reliability of the AI system.

2.1 Data collection of pavement crack and its severity

A total of 520 images of asphalt pavement crack were acquired from various location in Penang and Terengganu. Data collection focuses on pavement cracks with various level of severity. Photos were taken with its optical perpendicular to the road surface. The device 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, manual measurement of the crack's width is performed using vernier calliper for field data collection.

2.2 Image labelling, resizing, and enhancing

Pavement crack images were labelled based on the measurement of the average width of the pavement's crack. Images will be classified into low, medium, and high severity of crack based on [7] 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. For this study, the total number of images for low, medium, and high severity of crack are 320, 100 and 100 respectively.

Figure 1. Classification of crack's severity from low, moderate to high (left to right) [7]

Resizing images is required because it will slow down the training process in DCCN operation. For this research, 64x64 is found to be the optimal image size. For resizing images, using photoshop is preferred and easier method. 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.

2.3 DCNN training and validation for crack severity classification

The network prepares two sets for training and testing dataset purposes: types of crack's severity classification consist of low, moderate, and high [8]. To achieve the objective, DCNN must be trained first. The dataset was divided into 70% for training and 30% for validation. After accomplishing with the training of the coding in MATLAB, the next stage is validation of pavement crack images. The system will ask to select the input images we want to test and after completed the testing DCNN system will state the severity of pavement cracks of the images. The propose DCNN structure is illustrated in Figure 2. The DCNN has 2 convolution and 2 max-pooling layers. The fully connected layer (FC) has 3 outputs which belong to low, medium, and high severity of crack

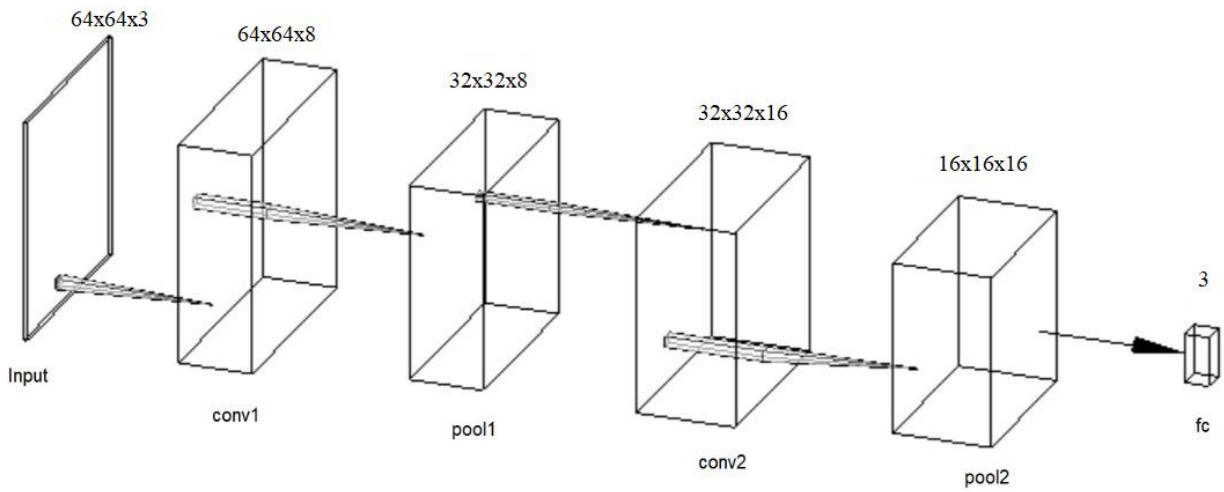


Figure 2. The architecture of DCNN for crack's severity classification

2.4 Performance evaluation

The performance of the DCNN was tested based on testing patches that have not been used in the training process. The common statistical measure, accuracy is used to benchmark the agreement between DCNN prediction and actual labels, and further summarized in form of matrix analysis which is called confusion matrix. For this research, confusion matrix shows the accuracy for each classified data which are low, moderate, and high data.

3. RESULTS AND DISCUSSION

A graphical user interface (GUI) was developed using MATLAB to ease of training and validation process of DCNN. Figure 3 shows the GUI developed for this study. Dataset division allows user to partition the dataset into training and validation. For this study, the dataset was divided into 70% for training and 30% for validation. The 'Train DCNN' button is used to train the DCNN after setting the dataset division by user. During the training process, the DCNN training progress and performance can be accessed from the graph of accuracy and loss against iteration, as shown in Figure 4.

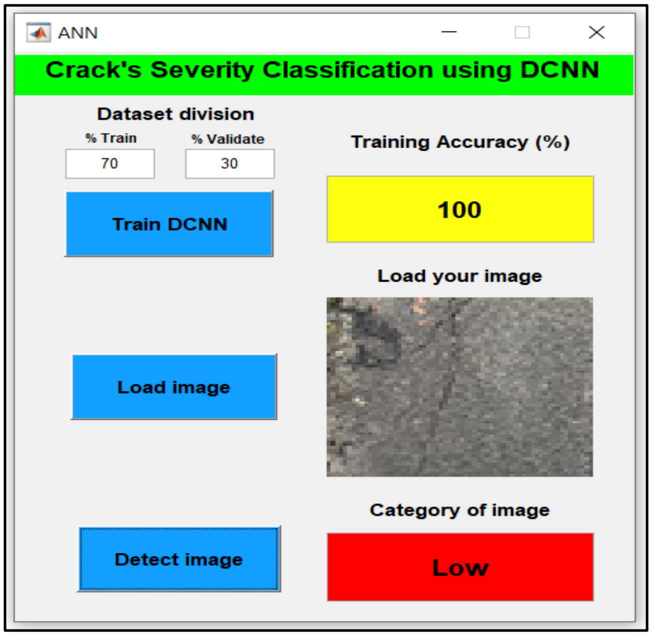


Figure 3. The GUI developed for DCNN training and validation process

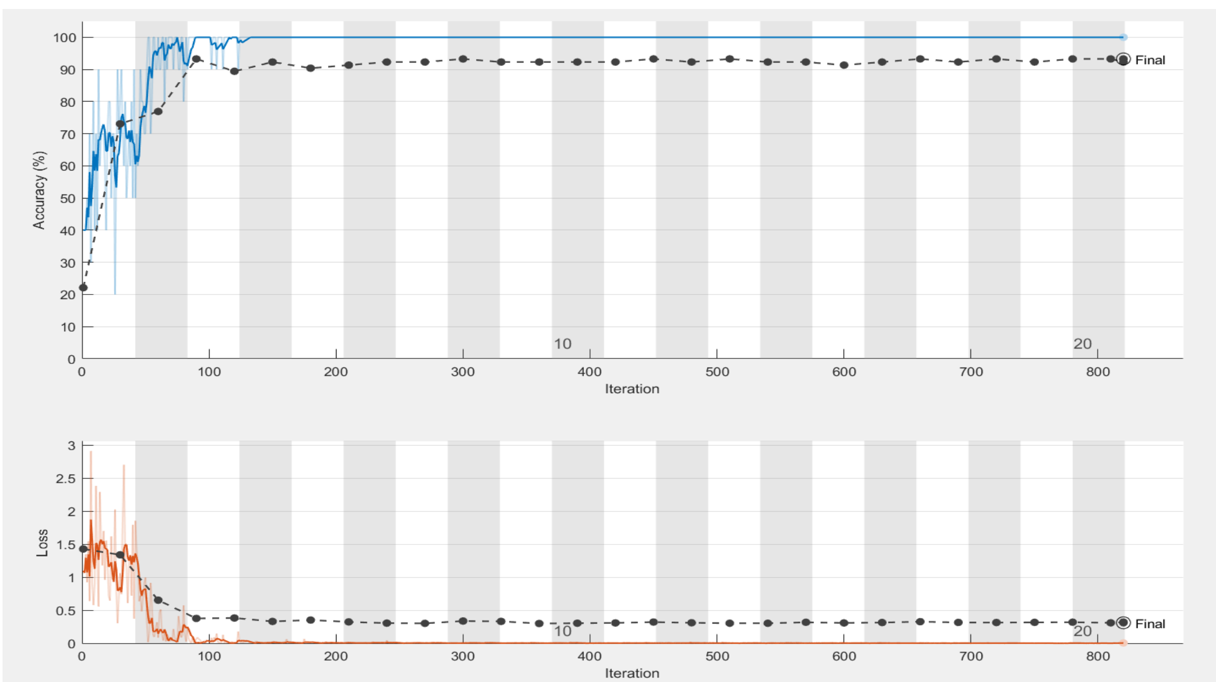
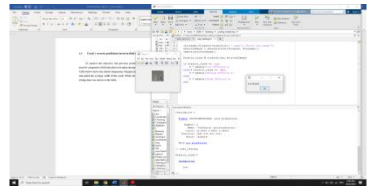
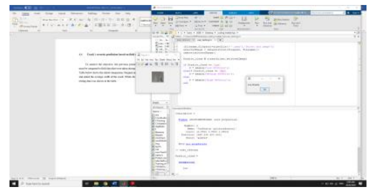
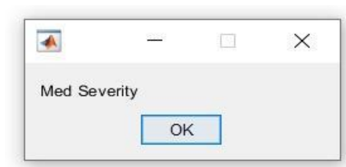
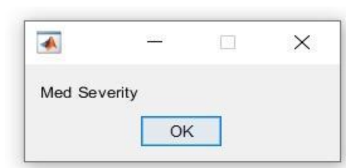
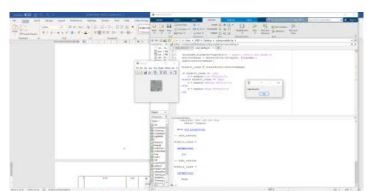
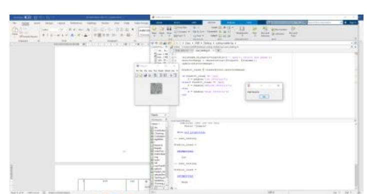


Figure 4. Accuracy and loss of DCNN against iteration during the training process

Table 1 shows example of predicted crack's severity by the DCNN. Two images of each of crack's severity level were randomly selected from the validation dataset and presented to the DCNN for prediction. The result of DCNN shows all the crack images were correctly classify according to their severity by the DCNN.

Table 1. Comparison between prediction using AI and field data

Image	Crack's severity (Field)	Crack's severity (DCNN)
	*4.21* *(Low)*	 *Low severity*
	*5.40* *(Low)*	 Low severity
	*7.37* *(Medium)*	 Medium severity
	*8.14* *(Medium)*	 Medium severity
	*47.76* *(High)*	 *High severity*
	*53.40* *(High)*	 *High severity*

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Kelulusan daripada pihak YBhg. Profesor dalam perkara ini amat dihargai.

Sekian, terima kasih.

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