

UNIVERSITI TEKNOLOGI MARA

**A HIERARCHICAL DEEP
CONVOLUTIONAL NEURAL
NETWORK FOR ASPHALT
PAVEMENT CRACK DETECTION
AND CLASSIFICATION**

NOR AIZAM MUHAMED YUSOF

PhD

August 2021

AUTHOR'S DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Teknologi MARA. It is original and is the results of my own work, unless otherwise indicated or acknowledged as referenced work. This thesis has not been submitted to any other academic institution or non-academic institution for any degree or qualification.

I, hereby, acknowledge that I have been supplied with the Academic Rules and Regulations for Post Graduate, Universiti Teknologi MARA, regulating the conduct of my study and research.


Name of Student : Nor Aizam Binti Muhamed Yusof

Student I.D. No. : 2017693682

Programme : Doctor of Philosophy (Electrical Engineering) -
EE950

Faculty : College of Engineering

Thesis Title : A Hierarchical Deep Convolutional Neural Network
For Asphalt Pavement Crack Detection And
Classification

Signature of Student : 

Date : August 2021

ABSTRACT

Asphalt pavement cracks are one of the major road damage problems in the civil field as they may potentially threaten road and highway safety. Crack detection and classification are challenging tasks due to the complicated pavement conditions such as the presence of shadows, oil stains, and water spots. These conditions will eventually result in poor visual and low contrast between cracks and the surrounding pavement. Therefore, in tackling these issues, this study proposes a fully automated pavement crack detection and classification using a new Deep Convolutional Neural Network architecture (DCNN) called hierarchical DCNN (Hi-DCNN). The image of pavement cracks is manually prepared in RGB format with a dimension of 1024×768 pixels. This image is captured using NIKON digital camera and segmented into patches (32×32 pixels) as a training dataset from the original pavement cracks. To ease these processes, this study introduces a new app, CrackLabel, that can automatically label patches in the crack images into two groups, crack and non-crack. The CrackLabel utilises a special design image thresholding algorithm known as Global and Lower Quartile Average Intensity (GLQAI). In the first part, a DCNN structure, DCNN-1, is proposed to perform crack detection based on the labelled patches as its input. This is necessary to build training and testing datasets for the network. As a result, the network managed to achieve better performance in crack detection with 98.50%, 98.85%, 98.68%, and 98.67% for recall, precision, accuracy, and F-score respectively. As for the second part involving the crack classification process, DCNN-2 is proposed to classify the detected crack images, obtained from the previous step. This stage is performed to classify images into three groups which are transverse, longitudinal, and alligator cracks. The Hi-DCNN structure achieved promising accuracy of 96.80%, 97.41%, and 95.58% for transverse, longitudinal and alligator respectively. The last part is the integration of the optimized performance networks from the Hi-DCNN, which proposes a new app system that can automatically detect and classify pavement cracks. This app can facilitate and assist civil surveyors in determining pavement distress through a simple and user-friendly interface. For future work, this study suggests a real-time automated app that allows the integration between crack images and a manual operated digital camera to facilitate the automated process. In addition, the conversion of the RGB images into HSV colour space and further evaluation on the crack depth analysis help to obtain fine-detailed information for handling network robustness.

ACKNOWLEDGEMENT

Alhamdulillah

In the name of Allah S.W.T, Most Gracious, Most Merciful. Being grateful for His blessing that allowing me to embark on my PhD and for completing this long and challenging journey successfully. My gratitude and thanks go to my main supervisor Dr. Muhammad Khusairi Osman, and co-supervisors, Dr. Mohd Halim Mohd Noor, and Prof. Dr. Nooritawati Md. Tahir. Thank you for the support, patience and ideas in assisting me with this project. I also would like to express my gratitude to Dr Anas bin Ibrahim Faculty of Civil Engineering (FKA), UiTM Pulau Pinang and Dr Norbazlan Md Yusof of the PLUS Persada for providing the knowledge and assistance.

My appreciation goes to all supportive staff from the Advanced Control System and Computing research group (ACSCRG) Faculty of Electrical Engineering (FKE), UiTM Pulau Pinang who were both directly and indirectly involved. Without their cooperation and help, I would not have been able to complete this project.

Thanks to my loving kids Muhammad Amirul Ashraf, Nur Farhana Izzati, Nur Alya Nabilah and Muhammad Afiq Izzuddin who have been the sources of encouragement and inspiration to me throughout my life. Thanks to Mr Nazrulnizam Zainal Abidin who was willing to engage and support my daily struggles.

Finally, this thesis is dedicated to my family members and friends for their support and encouragement in the completion of this project. They were always together with me when I faced problems in this project.

Thank you for your support, encouragement, ideas and comments for the success of this project. This victory is dedicated to all of you.

TABLE OF CONTENTS

	Page
CONFIRMATION BY PANEL OF EXAMINERS	ii
AUTHOR'S DECLARATION	iii
ABSTRACT	iv
ACKNOWLEDGEMENT	v
TABLE OF CONTENTS	vi
LIST OF TABLES	x
LIST OF FIGURES	xiii
LIST OF SYMBOLS	xvi
LIST OF ABBREVIATIONS	xviii
CHAPTER ONE: INTRODUCTION	1
1.1 Introduction	1
1.2 Problem Statement	3
1.3 Research Objectives	6
1.4 Research Scope	6
1.5 Thesis Outline	8
CHAPTER TWO: LITERATURE REVIEW	10
2.1 Introduction	10
2.2 Pavement Distress	11
2.2.1 Causes of Pavement Distress	12
2.2.2 Types of Pavement Distress	14
2.2.3 Manual Visual Inspection Method For Pavement Distress Analysis	18
2.3 Automatic Inspection Method For Pavement Distress Analysis	19
2.3.1 Commercially Available Systems For Automated Pavement Distress Inspection and Analysis	19
2.3.2 Common Thresholding Methods	21
2.3.3 Pavement Crack Detection using Image Processing Methods	24
2.3.4 Critical Review Using Image Processing Methods	28