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Quality Management of Cracking Distress Survey in Flexible Pavements Using LTRC Digital Highway Data Vehicle

INTRODUCTION

The Louisiana Department of Transportation and Development (DOTD) currently uses a 3D automatic data collection system for collecting pavement condition data in DOTD's Pavement Management System (LA-PMS). While the collected pavement condition data is commonly used to model pavement performance in making consistent and cost-effective decisions of pavement maintenance and rehabilitation, more agencies are now also consider to use the collected pavement condition data in project-level pavement applications, such as the local-calibration of the distress models in the Mechanistic-Empirical pavement design guide. Therefore, the ability to evaluate and determine the quality and accuracy of pavement condition data is an essential need. Since the pavement cracking measurement data in LA-PMS is automatically collected through pavement image analysis by a computer software (not by a human survey), the accuracy and precision of the automated cracking data is warranted to be further evaluated. In addition, there is a need for reporting pavement surface crack measurements from high-resolution pavement images collected by a 2D automatic system currently owned by the Louisiana Transportation Research Center (LTRC).

OBJECTIVE

The objectives of this study included: (1) to evaluate and assess the accuracy and precision of the 3D automated cracking data of flexible pavements in LA-PMS through comparison with manual measurements on high-resolution pavement images; (2) to develop a prototype image analysis application in pavement cracking identification on high-resolution 2D pavement images collected by the high-speed data vehicle at LTRC.

SCOPE

To achieve the objectives, manual cracking surveys were performed on selected pavement projects in LA-PMS, including 23 flexible pavement sections and nine DOTD-used pavement calibration sites. Manual measurements were reported for every 50-ft. and 0.1-mile subsections for a project- and network-level assessment, respectively. The automated cracking data for every 0.1 mile was collected from the 2017 LA-PMS database and 50-ft. cracking data were collected from the contracted vendor's proprietary software. Statistical analyses were conducted to evaluate and assess the difference between the manual and automated measurements, including the comparative analysis, the accuracy and precision analysis, t-test, Monte-Carlo simulation, and linear regression. To utilize the LTRC vehicle's high-resolution pavement images, a crack detection algorithm was modified and used in developing an image analysis software application.

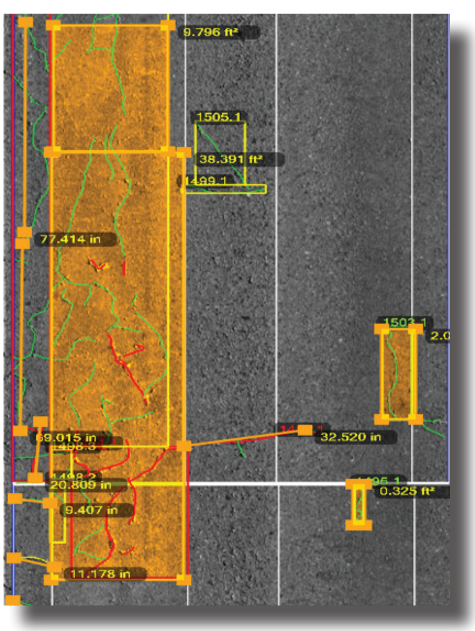

Figure 1. Example of manual cracking data collection

METHODOLOGY

A comprehensive manual cracking survey was conducted on selected pavement sections using on the high-resolution pavement images collected during the 2017 LA-PMS's pavement condition data collection cycle. Due to time and budget constraints, the manual survey was performed carefully by one rater and verified through multiple double-checks and repetitions on the surveyed pavement images. In a manual survey, the rater first marks all individual pavement cracks on a computer

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workstation using a vendor-provided image processing software named Vision. Then, the rater identifies and determines each cracking type with a severity level (low, medium, and high) according to DOTD's cracking distress protocol and input the identified cracking information into the processing software. Finally, the process software produces a detail manual cracking report for a selected pavement section according to the marked pavement cracks and a chosen subsection length. Figure 1 shows an example of the manual cracking identification and classification used.

Statistical comparison was performed to determine the difference between the manual and automated cracking measurements in terms of the false-positives, missed cracks, and accuracy and precision of the data. The obtained cracking measurements on 0.1-mile subsections were then used to determine if the automated and the manual cracking indices would provide the same or different treatment selections based on the current DOTD's treatment trigger values. In addition, a feed-forward ANN model was proposed to correlate the automated and manual cracking measurements evaluated in this study.

A cracking imaging analysis application using MATLAB was developed to generate automated cracking reports for 2D pavement images collected at LTRC. Figure 2 presents a framework used in the development of the imaging analysis application.

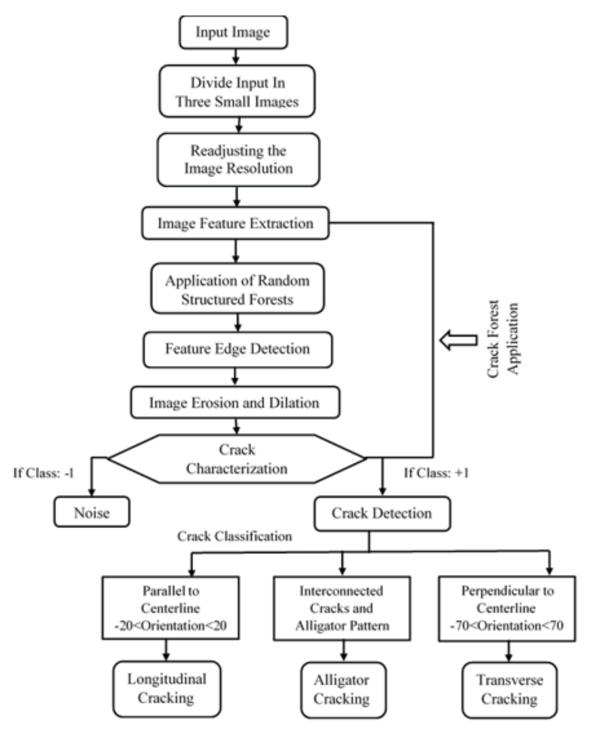

Figure 2. Framework used in developing automated crack survey application

CONCLUSIONS AND RECOMMENDATIONS

- From the cracking measurements on the nine calibration sites, the 3D automated system was found more accurate than the 2D automated system in terms of both crack identification and crack detection when compared to the manual survey results.
- Based on 50-ft. subsections using the 2017 LA-PMS cracking measurements, false positive errors produced by the 3D automated system were to be 8.5%, 9.8%, and 8.8% for alligator, longitudinal, and transverse cracking, respectively, and the corresponding missed crack errors were 5.0%, 7.9%, and 1.4%, respectively.
- By directly comparing the manual results to the 2017 LA-PMS cracking measurements, the automated system was found to over-estimate the medium severity level for all flexible pavement crack types (alligator, longitudinal, and transverse). To qualitatively estimate the accuracy and precision, a t-test on measurement errors and a Fligner-Kileen variation test were performed. The results indicated that, at the project-level (on 50-ft. subsections), the automated system could produce significantly accurate results for high severity transverse cracking and significantly precise results for low severity alligator cracking. At the network level (on 0.1-mile subsections), the automated system produced significantly accurate estimation at low severity alligator cracking and high severity transverse cracking. The automated system also produced significantly precise cracking measurements at low severity level for all crack types.
- The developed ANN application showed satisfactory results in predicting cracking indices using the automated cracking measurements. Therefore, it is recommended to be used in adjusting the 2017's LA-PMS flexible pavement cracking data when the cracking indices are the control parameters in a treatment selection. Due to the complexity and variations in pavement cracks, the applicability of the developed ANN model can be improved through collecting more manual and automated measurements.
- The discrepancy between the automated and manual cracking measurements may be partially attributed to different image files involved. That is, the LCMSRange images were used in the automated system and the LCMS3D images were associated with the manual survey. Due to different imaging properties (e.g., intensity), some pavement cracks shown on LCMSRange cannot be detected in the corresponding high-resolution LCMS3D image. It is recommended to conduct further study to clarify: (1) whether or not some of those unseen cracks in LCMS3D images are real pavement cracks through the field investigations; (2) if LCMSRange images were found to over-predict pavement cracks, then determine how to improve the accuracy in the future DOTD's cracking data collection.
- It was observed that the developed cracking imaging analysis application for the collected 2D high-resolution pavement images can produce summary cracking results for a continuous 0.1-mile pavement section in seven minutes. However, the developed prototype application sometimes failed to remove deep tire marks and shoulder markings. Further algorithm improvements in crack detection and noise removal are still warranted.