Texas Department of Transportation

TEXAS STATE UNIVERSITY

PROJECT SUMMARY REPORT

0-7150: Artificial Intelligence for Pavement Condition Assessment from 2D/3D Surface Images

Background

There are approximately 4.20 million miles of public roads in the United States. Texas has a total of 0.68 million miles, according to the Federal Highway Administration (FHWA). Automated pavement condition survey systems including two-dimensional or three-dimensional (2D/3D) laser line scan cameras mounted on the vehicles have been used to scan about 100,000 state-maintained lane miles each year since 2017 for pavement condition evaluation in Texas. The collected 2D/3D images are processed by computer vision algorithms to deliver information to rate pavement surface condition and provide support for maintenance decision-making. But it is challenging for agencies like the Texas Department of Transportation (TxDOT) to manage pavement data collection when different vendors are using different automated survey systems and producing vast amounts of visual data in different formats. An initiative was launched to develop standard data format for 2D/3D pavement surface images from the FHWA to remove this technical barrier. This project aimed to create a library of standard format 2D/3D pavement surface images to comply with this requirement. Also, another need for TxDOT is to check data quality on automated pavement condition assessment with more independence from the data collection vendors. In addition, it is desirable to develop Artificial Intelligence (AI) and machine learning (ML) methods to replace the existing image processing algorithms to improve the accuracy and speed performance of the automated pavement surface condition evaluation system.

What the Researchers Did

The project started with reviewing the literature of available datasets, established AI models and practices in the U.S. and other countries. The research team investigated the acquisition of high-resolution images with American Association of Highway and Transportation Officials (AASHTO) standard MP47 and created a tool for viewing the vendor's data and labeling different distresses on three pavement types (Asphalt Concrete Pavement (ACP), Jointed Concrete Pavement (JCP), and Continuously Reinforced Concrete Pavement (CRCP), respectively). 2D/3D images were selected carefully to include diverse pavement defects to be annotated. For each type, the selected images were labeled with bounding boxes to manually locate and mark the pavement surface distresses. Segmentation masks were provided for a small portion of images for potential applications. A comprehensive image library was established in the AASHTO standard data format, capturing diverse pavement conditions and surface types in Texas. The dataset includes 5,892 2D/3D image pairs and associated labels for ACP, 7,750 for JCP, and 5,776 for CRCP, respectively. These corresponded to 10,885, 16,943, and 13,779 individual distress instances in the three pavement types, respectively, as defined by the TxDOT Pavement Management Information System (PMIS), for a total of 19,418 images. Neural network models such as YOLO (You Only Look Once) series were trained on the established library datasets for generalization and robustness of pavement distress measurements. These models were integrated into practical tools for calculating PMIS distress scores and delivered via a dedicated software application for TxDOT. A pilot study was carried out to validate the developed AI/ML models and pavement condition evaluation methods using the image data newly collected in 2024.

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What They Found

The research yielded several key findings regarding the use of Artificial Intelligence for pavement condition assessment with 2D/3D surface images in the AASHTO standard format. The pilot study showed very promising accuracy performance in effectively detecting pavement distresses for the three different pavement types. All the developed AI/ML models gained higher than 0.70 Mean Average Precision (mAP50) scores for the three pavement types. While the proposed models achieved robust performance on validation datasets, with mAP50 scores exceeding 0.80 for ACP, 0.70 for JCP, and 0.75 for CRCP for most distresses, their accuracy declined significantly for infrequent distress types, particularly those with fewer than 50 instances in the whole data library. These findings were further validated in the pilot study on the 2024 collection of pavement data in Brazoria County, Texas, which exhibited similar performance trends. In fact, during the development of the image library, the team encountered challenges in sourcing sufficient examples of rare pavement distresses from the data provided by TxDOT. This data scarcity hindered the optimization of the AI/ML models.

To overcome current limitations and facilitate a statewide implementation of these research products, the following strategic actions are recommended: 1) to continuously expand the 2D/3D image library by specifically sourcing and labeling high-priority, underrepresented pavement distresses to improve model generalization, 2) to enhance annotation granularity of the data library by providing both bounding boxes and pixel-level segmentation of pavement distresses to achieve higher precision in both identification and severity measurement , and 3) to continuously commit to state-of-the-art AI/ML model development and pavement condition assessment practices with an enhanced data library.

What This Means

In the project, a library of 2D/3D pavement surface images in AASHTO standard was created and AI/ML models were trained using the established dataset. There is a need to continue the research effort to improve from the project's current Technology Readiness Level (TRL) at 5 or 6 to the required TRL 8 for implementation. An extension to the project is needed to close the gap compounded by the lack of sufficient data for several pavement distress types and to meet the agency's requirement of distress segmentation, which is very time consuming and expensive to achieve. The extension could allow the time to revise and optimize the AI/ML models to make needed improvements to achieve the implementation goal.

For More Information

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