Texas Department of Transportation

CENTER FOR TRANSPORTATION RESEARCH

PROJECT SUMMARY REPORT

0-7031-01: Develop Efficient Prediction Model of Highway Friction on an Annual Basis on Texas Network

Background

Measuring network skid resistance annually is essential for the safety of the road users and the public. However, current skid resistance measurement equipment is inefficient due to the large volumes of water required, limiting TxDOT to assessing at most one-third of the state-maintained network on an annual basis. While past efforts to estimate skid numbers based on texture had varied success, recent advancements at the University of Texas at Austin have shown that it is feasible to measure texture accurately in the field at highway speeds and to use those measurements to estimate pavement friction with an accuracy around 0.05 in terms of Skid Number (SN). This research project developed a system to measure texture at highway speeds and created a methodology to predict SN for the entire Texas network. The new system allows efficient, high-speed field measurements, enhancing TxDOT' operations and safety. This approach improves the accuracy of skid number predictions and enables comprehensive annual assessments, significantly advancing friction management and highway safety.

What the Researchers Did

The researchers collected extensive field data over 400 miles of pavement using a specialized data collection prototype across various pavement types and climate conditions. This dataset comprised approximately 300 miles of flexible pavements and 100 miles of rigid pavements. Leveraging this comprehensive database alongside advanced machine learning algorithms, the researchers addressed the limitations of traditional regression methods in predicting pavement friction, such as underfitting and the need for frequent recalibration due to surface deterioration.

The researchers began conducting a cluster analysis, grouping pavement sections with similar characteristics. These clusters were used to specify the regression models for predicting pavement friction and served as labels to train a classification algorithm. The goal was to test multiple algorithms and pick the one that achieved the highest accuracy when classifying these pavement clusters. Next, an ensemble linear regression model was implemented to capture the complex relationships between texture indices, surface information (cluster predictions), and pavement friction.

The researchers integrated these algorithms and developed a standalone Windows application, referred to as the Texan Texture Friction Forecaster (TexTex FricFore), which can process raw data, compute texture indices, and implement the developed models for accurate pavement friction prediction.

What They Found

Through cluster analysis, it was found that eight distinct clusters for flexible pavements and five for rigid pavements could be identified. For flexible pavements, clusters ranged from polished open-graded mixes to high friction surfaces with uniform gradation. For rigid pavements, clusters included new generation diamond grinding, conventional diamond grinding, and various tining techniques. This grouping of pavement surfaces facilitated the understanding of different textural

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and frictional properties across pavement types. The classification analysis employed twelve machine learning algorithms to categorize these clusters. The random forest model achieved the highest performance with an F1 score of 0.903, indicating superior accuracy in identifying and classifying pavement clusters. In contrast, the extreme gradient boosting model recorded the lowest performance with an F1 score of 0.080.

An advanced ensemble multiple regression model was developed for predicting pavement friction in terms of Skid Number. This model achieved an R2adj of 0.767, a mean absolute error (MAE) of 0.050, and a root mean square error (RMSE) of 0.071. In comparison, a deep neural network (DNN) regression model had an R2adj of 0.669, an MAE of 0.066, and an RMSE of 0.085. The ensemble model demonstrated higher goodness-of-fit and lower error rates, making it more desirable for practical applications.

What This Means

These findings indicate that the proposed model can predict pavement friction with high goodness of fit using texture indices and surface information, underscoring the importance of integrating advanced machine learning techniques to enhance pavement safety management and resource allocation. The ability to reliably predict friction at a network level holds significant safety benefits for TxDOT. This capability enables decision-makers to immediately identify low-friction pavement sections, allowing for proactive maintenance whenever friction levels fall below the intervention threshold. Consequently, this ensures a safer road network for all Texans by minimizing the risk and cost of wet-weather accidents and potentially saving lives. Additionally, the application developed through this research can supplement existing pavement management systems by providing estimates of friction for all highways in the network, including those whose friction was not directly measured. This comprehensive approach saves TxDOT time, money, and resources by minimizing the need for surveys with the locked wheel testers. When the findings of this project are implemented, estimates of Skid Number will be available for the entire network on an annual basis.

For More Information

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