Texas Department of Transportation

CENTER FOR TRANSPORTATION RESEARCH

PROJECT SUMMARY REPORT

0-7139: Determination of Pavement Surface Type

Background

Accurate knowledge of pavement surface type is crucial for effective pavement management, tracking performance, predicting skid numbers, and forecasting noise levels. Although surface type is included as a data element in Pavement Analyst, it currently lacks the precision needed for informed decision-making. Previous attempts by other agencies to populate this field by integrating various data sources, such as DCIS and PMIS, were not implemented due to insufficient accuracy.

Advancements in laser, video, and 3D technologies now enable the scanning of extensive networks at highway speed with full coverage on an annual basis. By leveraging artificial intelligence and these technologies, surface type prediction can achieve accuracy rates exceeding 90 percent. This research project employed the latest technologies to develop equipment and methodologies for accurately determining pavement surface types using pavement profile indices and pictures of the pavement surface.

What the Researchers Did

The researchers developed a system to accurately classify pavement surfaces using machine learning techniques. They designed a prototype integrating laser scanners, high-speed cameras, and lighting systems to capture high-resolution pavement profiles at highway speeds. This system improved upon previous methods, allowing for precise data collection across various pavement types and conditions.

Extensive field data collection was conducted across 427 miles of Texas pavements, including 317 miles of flexible and 110 miles of rigid pavements. The researchers compiled over 800,000 high-resolution images and all the 2D surface profiles into a comprehensive database. This database served as the foundation for developing and validating machine learning models for this project and future projects.

The researchers employed a hierarchical classification framework, organized by levels of specificity, to enhance the precision of their predictions. A cluster analysis grouped pavements with similar surface profile characteristics as a first step. Subsequently, numerous supervised classification methods were implemented to classify the pavements based on images and 2D profile indices.

The developed models underwent rigorous evaluation using multiple test sets to ensure accuracy and reliability. The final product was a standalone application that compiled all the knowledge accrued during the project. The application processes raw data, computes profile indices, and implements the models to accurately predict pavement surface types. This tool represents a significant advancement in pavement management, enabling more precise project identification and network segmentation.

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What They Found

The researchers found that high-resolution profiles effectively differentiate and classify various pavement surfaces through unsupervised machine learning analysis. The Partition Around Medoids (PAM) method was identified as the most robust clustering method. For flexible pavements, five distinct clusters were identified, ranging from high macrotexture surfaces to coarse well-graded surfaces. For rigid pavements, seven clusters were identified, including conventional and new generation diamond grinding, exposed aggregates, dragged surfaces, and various tining techniques. Classification algorithms were developed to classify the pavements according to levels of specificity, with pixel-based classification (PBC) models achieving an accuracy of 0.995 at Level 1 in distinguishing flexible from rigid pavements, outperforming index- based models (IBM), which achieved 0.935. For Levels 2 through 4, IBMs demonstrated superior performance, with the Shallow Neural Network (SNN) achieving an F1 score of 0.980 at Level 2, the Support Vector Machine (SVM) achieving 0.962 at Level 3, and the K-Nearest Neighbor (KNN) model leading at Level 4 with an F1 score of 0.887. PBC models excelled at Level 5, determining the orientation of tining with an exceptional F1 score of 0.999.

The classification results indicated that a joint classifier using PBC for Levels 1 and 5, and IBMs for Levels 2 through 4, provided the best performance. Rigorous validation across six diverse test sets confirmed the models' robustness and effectiveness. These findings highlight the benefits of integrating pixel-based and index-based classifiers for precise pavement surface classification, enhancing pavement management systems by improving road safety, optimizing resource allocation, and supporting future research and practical applications in the field.

What This Means

The indings from this research indicate that the proposed machine learning models can significantly enhance the accuracy and reliability of pavement surface classification for pavement management applications. The integration of pixel-based models for broad and fine-grained classifications, alongside index-based classifiers for intermediate specificity levels, offers a comprehensive approach that ensures consistent performance across various conditions. This improvement in classification accuracy is crucial for pavement management systems, enabling more precise and efficient identification and segmentation of the network for planning appropriate maintenance strategies. By leveraging these artificial intelligence techniques, the developed models can aid in the determination of pavement surface information to track a specific type of pavement mix over time, or to aid in the empirical estimation of pavement/tire interactions, such as skid resistance, noise or rolling resistance. The rigorous validation across diverse test sets further confirms the models' robustness and applicability in real-world scenarios, supporting future research and practical applications in the field.

For More Information

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