MIDWEST TRANSPORTATION CENTER

Development of a Computational Framework for Big Data-Driven Prediction of Long-Term Bridge Performance and Traffic Flow

tech transfer summary

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MTC RESEARCH PROJECT TITLE
Development of a Computational Framework for Big Data-Driven Prediction of Long-Term Bridge Performance and Traffic Flow

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The Midwest Transportation Center (MTC) is a regional University Transportation Center (UTC). Iowa State University, through its Institute for Transportation (InTrans), is the MTC lead institution.

MTC's research focus area is State of Good Repair, a key program under the 2012 federal transportation bill, the Moving Ahead for Progress in the 21st Century Act (MAP-21). MTC research focuses on data-driven performance measures of transportation infrastructure, traffic safety, and project construction.

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New sources of data offer opportunities to predict long-term behavior of bridges and traffic flow that will lead to improved decision-making abilities for safer and more economic bridges.

Objective

The objective of this project was to develop and validate foundational computational tools to facilitate data collection, data squashing, data merging, data curing, and data prediction that will allow practitioners and researchers to learn from past data, predict various information regarding long-term bridge performance, and conduct data-driven efficient planning of bridge management and improvement.

Problem Statement

While the bridge structural health monitoring field has shown remarkable advancements to effectively manage over 600,000 bridges nationwide, engineers still substantially lack reliable data analysis and processing tools with a statistical rigor due in part to big data-related challenges.

Background

Advances in data-driven research, particularly the recent ability to combine advanced machine learning methods with existing engineering databases, have become essential in the engineering field, but the access to big data has come with challenges. Those include the immense size and volume of bridge and traffic data, too many explanatory variables that are interwoven, heterogeneous types of bridges, time-varying environmental and traffic datasets, and critically, missing data. Addressing those challenges with newly developed data tools can offer a more substantial benefit to assess bridge performance measures and improve predictability.

Research Methodology

This project sought to transform the way to manage and analyze big data of bridge performance, thereby proposing new data-driven remedies to long-term infrastructure management and rehabilitation directions.

The research team developed four tools that can be applied to future bridge big data and traffic data:

- A data-squashing tool that can shrink years-long bridge strain sensor data to manageable datasets
- A data-merging tool that can synchronize bridge strain sensor data and traffic sensor data

- A data-curing framework that can fill in arbitrarily missing data with statistically reliable values
- A data-prediction tool that can accurately predict bridge and traffic data

The research team also investigated the new dense data source of using surface sensors.

For all programs, the team developed and shared detailed manuals and examples, and also provided resultant hybrid bridge data.

Key Findings

By utilizing all the developed programs, this project revealed several practically meaningful findings:

- Not all variables are necessarily helpful for improving predictive power.
- For the best predictive power, a direct search of the optimal combination of variables is necessary.
- A simple correlation-based selection of significant variables may lead to relatively low predictive power.
- Curing missing data in the original datasets helps improve the predictive power.
- Merging traffic data into bridge big data improves the predictive power.
- Bridge big data can be predicted by using traffic data, and in turn, traffic data can be predicted by using bridge big data.

Implementation Readiness and Benefits

The research team created and shared a suite of computational tools that can perform multiple functions for data-driven bridge data prediction that will allow future researchers to easily leverage bridge big data and traffic big data for prudent decision-making, strategic maintenance planning, and efficient rehabilitation planning. Along with that, the team offered practical recommendations and guidelines to effectively use the project's deliverables in the field.

This project's outcomes will promote a shift toward a data-driven research paradigm in bridge engineering, and also in transportation. Further understanding the new refined data source of surface sensors will be important for general extension of the developed framework.