Study Title

i-BM: An Intelligent Bridge Management Tool for Bridge and Culvert Deterioration Forecasting and Anomaly Detection based on Physics-Guided Deep Learning

Brief Type

Interim

Date

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Study Timeline

January 2023 – December 2025

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i-BM: Bridge Management Tool

Study Objectives

1. Develop i-BM (short for intelligent Bridge Management), a user-friendly software tool with Graphical User Interface and enhance operational features and functionalities to help CDOT bridge engineers with accurate data-driven prediction of bridge and culvert deterioration into the future
2. Develop enhanced physics-guided deep learning models, to be integrated into i-BM along with the other purely data-driven deep learning models

Incorporate anomaly detection functionality into i-BM to automate identification of anomalous bridge performance behavior, such as those leading to bridge accidents.

Background

Bridges and culverts deteriorate with time and use. While in the past, various data-driven deterioration models, including Bayesian models, probit model, and Markov chains are proposed in the literature to model bridge deterioration, these models either suffer from low accuracy or are too complex to be applicable. Recently deep learning (DL) AI models are shown to significantly outperform other analytical modeling methodologies in a variety of application domains. In the past we have developed several novel DL models for enhanced bridge and culvert deterioration forecasting. Our results show that DL-based models outperform other existing models.

Methods

With this project, we have developed i-BM, a web-based software tool that allows for bridge engineers to effectively use DL models for deterioration forecasting with guaranteed prediction confidence. I-BM also offers new physics-guided DL models (i.e., hybrid models that can benefit from both physics models and DL models for deterioration forecasting) with enhanced forecast accuracy, as well as anomaly detection models that can identify anomalous bridge performance behavior such as those leading to bridge accidents.

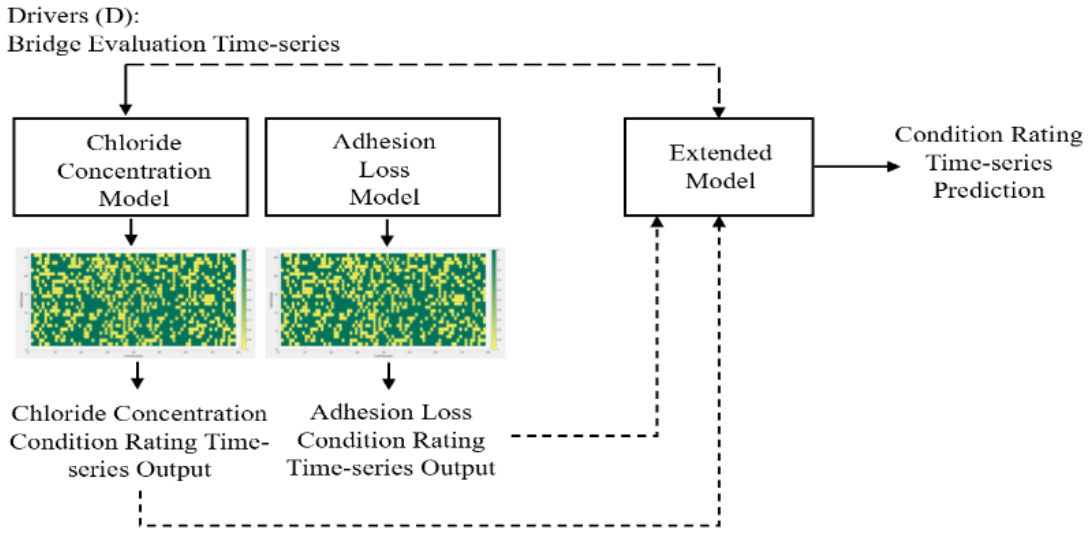

Figure 1 – Hybrid physics-guided deep learning forecast model

Results

The validation process is on-going and it shows a high rate of accuracy. The application will be ready for use by the end of this project.

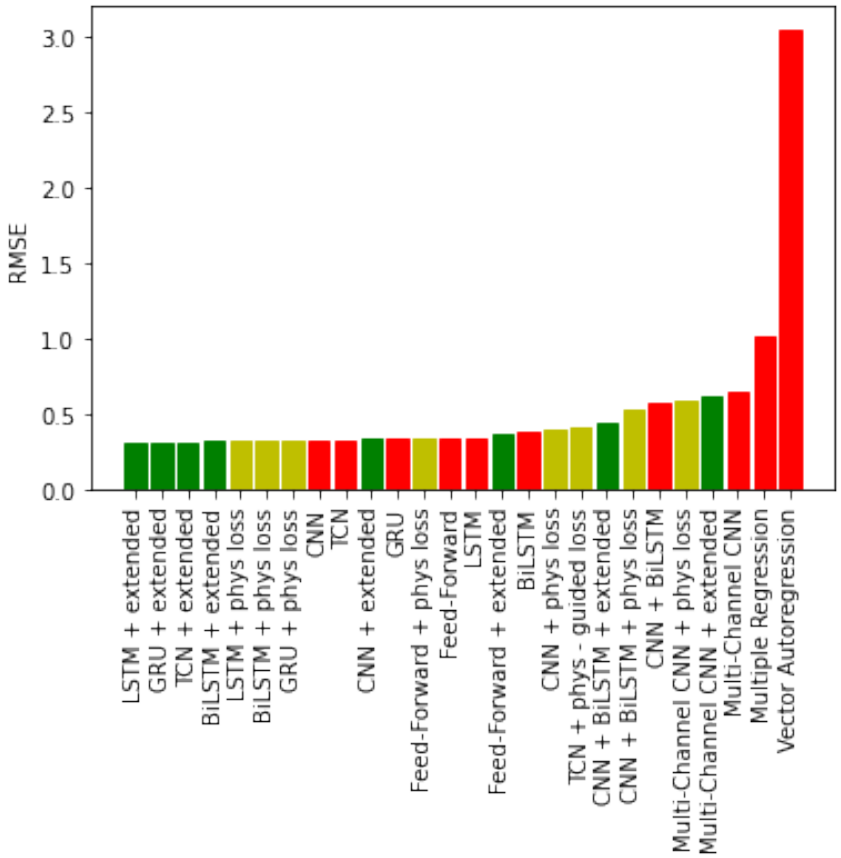

Figure 2 - Accuracy of all i-BM models

Research Benefits

Unlike existing bridge management tools such as BrM, to the best of our knowledge our proposed tool is the first to make accurate deterioration forecasts based on historical data, in a similar way weather forecasts are generated.

Recommendations for Implementation (or Next Steps)

We propose to add work order optimization capabilities to i-BM to allow for leveraging the forecasting capability of i-BM to enable cost-efficient preventive maintenance.