Research Project Name: Automated knowledge graphs for life-cycle management of coastal bridge networks

Improving the Durability and Extending the Life of Transportation Infrastructure

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Project Description: With the advancement of computational resources and the emergence of big data, digital twins have become increasingly popular as tools to enable the digital transformation of our cities. In terms of managing coastal bridge networks, digital twins show the potential to better monitor the life-cycle risk of the bridge networks by fusing the big data from disparate sources with the traditional life-cycle risk assessment models.

To construct such a digital twin, a prerequisite and a main challenge are to establish a knowledge graph. The objective of this project is hence to generate a city-scale knowledge graph to represent the relationships between the needed variables related to data-driven life-cycle risk analysis of a coastal bridge network. In contrast to existing knowledge graphs developed for digital twins, the knowledge graph in this project will consider statistical correlations within a system (e.g., spatially correlated climate-related hazards) and across different systems (e.g., correlations between flooding and bridge failure).

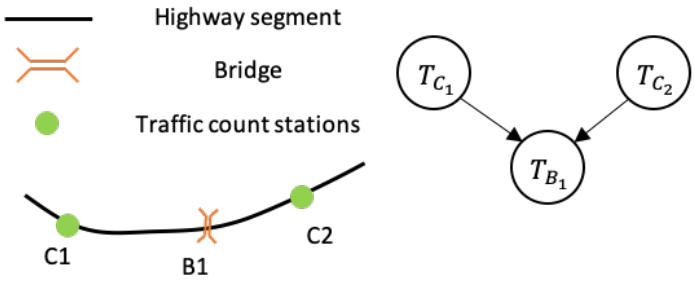

Fig. 1. A simple knowledge graph showing the traffic on a bridge is monitored and updated by two nearby traffic count stations. T_{B_1}, T_{C_1}, and T_{C_2} are the traffics of bridge B_1 and traffic count stations C_1 and C_2, respectively.

The project will tackle the issues of scalability and complex correlations based on a preliminary work, AutoGraCS. AutoGraCS is a framework to automate the generation of knowledge graphs given three types of user inputs, including an ontology, a set of rules, and databases. AutoGraCS will be further developed for the project. Specifically, new functions will be added so that when scaling up the knowledge graph, we can simply increase the sizes of databases, such as adding more bridges to the bridge database, without the need to modify the ontology and rules. To consider complex correlations, the knowledge graph will be generated in such a way that it can be easily turned into Bayesian networks for probabilistic and Bayesian analysis. A bridge network in Miami-Dade County will be used as an illustrative example. The project will establish the three types of inputs for AutoGraCS. Specifically, an ontology for data-driven life-cycle risk analysis of coastal bridge networks will be defined, while a set of rules to determine

the addition and removal of links will be developed. Data sources, including bridge inspections, traffic monitoring systems, and streamflow gages in the county, will be used. Hence, the corresponding three databases will be built.

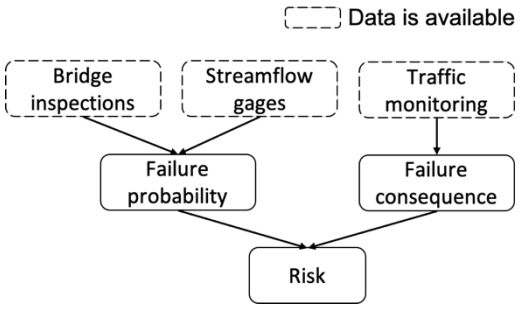

Fig. 2. Illustration of data-driven life-cycle risk analysis of bridges

US DOT Priorities: This project aligns with the US DOT priority of *Transformation*. The knowledge graph developed in this project is used to evaluate the life-cycle risk of coastal bridge networks subject to climate-related hazards, including hurricanes and flooding. The established knowledge graph is a prerequisite for system digital twins of transportation networks, which aim at the digital transformation of our transportation systems. Hence, the project engages in revolutionary studies and assists in the priority *Transformation.*

Outputs: The main output of this project will be a knowledge graph for data-driven life-cycle risk analysis of a coastal bridge network in Miami-Dade County. The knowledge graph has the potential to be turned into a system digital twin to better monitor the risk given available data.

Two important byproducts of the knowledge graph are an ontology and a set of rules. They serve as inputs for AutoGraCS and can be reused to develop the same type of knowledge graphs to manage coastal bridge networks in other cities and regions. The potential outside partner is Prof. Oliver Gao's research group at Cornell University. One of the PIs has worked with the group to establish the performance-oriented system digital twin framework. Prof. Gao's group is interested in continuing the collaboration and using AutoGraCS to help develop a system digital twin for transportation emissions modeling.

Outcomes/Impacts: One of the PIs has developed a prototype of AutoGraCS. Based on the prototype, it is anticipated that an AutoGraCS with more functions and features will be developed. The knowledge graph for the management of the coastal bridge network in Miami-Dade County will be generated and stored for future work to build a system digital twin. Moreover, the impacts of the project are broader than Miami-Dade County. The ontology and rules are reusable for life-cycle risk analysis of coastal bridge networks. Hence, constructing a KG for the same analysis in another region only requires creating databases specific to the region. This can facilitate the development of knowledge graphs and digital twins at the state or national level.

Final Research Report: https://rosap.ntl.bts.gov/view/dot/82617