京都大学 KYOTO UNIVERSITY

Research Summary: AY2024

A Novel Multiple-input Neural Operator for Surrogate Modeling of Vehicle-bridge Interaction

Name: Chen Rongxiu

Keywords: neural operator; surrogate model; vehicle-bridge interaction

【Background】

Simulating the coupled motion between vehicle and bridge, known as Vehicle-Bridge Interaction (VBI), is essential in bridge engineering. the sensitivity analysis of various vehicle parameters and bridge properties in bridge design, regular assessment of bridge conditions under damaged states in bridge maintenance, and stochastic dynamic analysis for a VBI system entails a significant number of numerical simulations. However, conventional VBI simulators are time-consuming and inefficient for practical applications.

【Objective】

・This study aims to develop an accurate and real-time surrogate model for the VBI system, with the potential to partially replace conventional simulators in practical applications.

【Approach】

・**Framework.** This study proposed a framework for developing surrogate models, that *recurrently* predicts future time-series based on *multiple inputs*.

・**Multiple-input neural operator.** A novel multiple-input neural operator is introduced to predict dynamic response fields of a bridge under random vehicle parameters or bridge properties.

【Publication plan】

・A journal paper that introduces the aforementioned method and summarizes its advantages over a baseline method;

・A journal paper that extends the proposed method to physics-informed learning and discusses the pros and cons of physics-informed learning by comparing it to data-driven learning.

【Results】

・**Accuracy.** The proposed surrogate models achieve high accuracy in predicting the dynamic responses of bridges.

・**Efficiency.** The surrogate models also exhibit real-time inference, achieving over 100x speedup compared to the conventional simulator.

・**Robustness.** Our method consistently shows good performance across various settings, showcasing its robustness.

・**Transferability.** The mesh-invariance property and physics-guided initialization enable efficient adaptation to finer meshes and different bridge structures with limited data.

・This contribution allow engineers to rapidly estimate bridge responses, having the potential to accelerate decision-making and optimization of bridge maintenance strategies.

A testing example of predicted time history (span center of a simply-supported beam)