Integration of model- and data-based approaches for reliable structural health monitoring of bridges

Summary

Bridge structural health monitoring (SHM) gained great momentum in the recent decades, as a consequence of the collapse of some important bridges, such as Hintze Ribeiro Bridge, I35-W Bridge or Morandi Bridge, just to name a few. The SHM emphasizes the importance of monitoring and preserving the existing structures, rather than building new structures after the existing ones had exceeded the safety thresholds or even collapsed.

The SHM of bridges is usually conducted following either data- or model-based approaches. The former involves gathering data from monitoring systems installed on the undamaged bridge and training unsupervised machine learning algorithms (MLA) for novelty detection. The latter is rooted in finite element (FE) models of the real bridge and various model updating techniques.

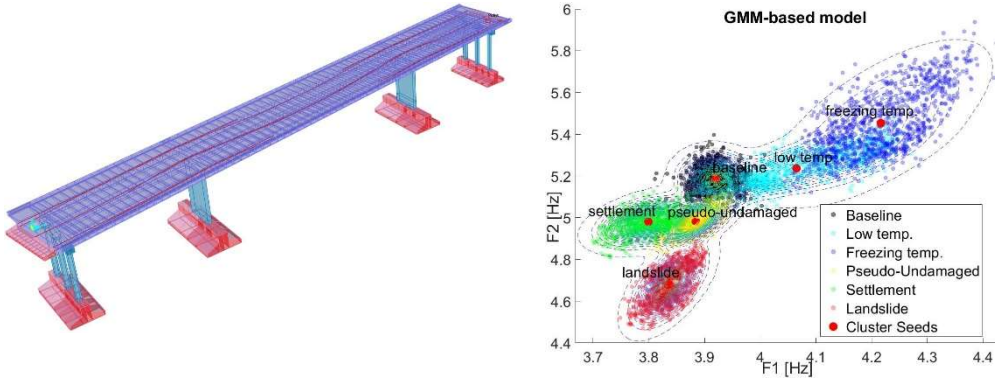
This PhD proposes a hybrid approach, which integrates both model- and data-based approaches in an attempt to overcome their inherent drawbacks. FE models are used as proxies for damaged scenarios and uncommon undamaged scenarios, such as extreme temperatures. Therefore, combining monitoring with numerical data yields labelled hybrid data. The acces to labelled data enables the transition from unsupervised to supervised learning algorithms and greatly improves the damage identification process.

Z-24 Bridge is used for validation. A well-known benchmark in the SHM community, it was subjected to controlled damage scenarios and the changes in its dynamic response were recorded. The hybrid approach involves integrating monitoring data corresponding to undamaged scenarious with numerical data corresponding to both undamaged and damaged scenarios. The numerical data is obtained form FE models, which are automatically generated and run from an API that links MATLAB with CSiBridge. The models consist mainly of beam elements and are not exceedingly detailed, as probabilistic variation of the uncertain parameters is employed, and the number of offspring models is of the order of thousands.

Once hybrid data is obtained, supervised learning algorithms are used to build classification models. These models are trained with the hybrid data and subsequently tested, in order to validate the approach.

Keywords

Structural health monitoring; machine learning algorithms, finite element modelling, hybrid approach, damage identification, environmental variability.



FE model of Z-24 Bridge (left); Classification based on hybrid data and Gaussian Mixture Models (right).

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