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A combined model-free Artificial Neural Network-based method with clustering for novelty detection: The case study of the KW51 railway bridge

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Abstract

Clustering is one of the most commonly employed exploratory data analysis technique to get some valuable insight about the structure of data. It is considered to be an unsupervised learning method as there is no ground truth to compare the output of the algorithm with the true labels of the data. However, the intention in this work is not to evaluate the performance of the algorithm but to try to investigate the structure of the data and underlying patterns.

This paper proposes an approach for condition assessment of bridges based on Artificial Neural Networks (ANNs) combined with data clustering. The approach is developed and validated through a monitoring campaign. The one span ballasted railway bridge was subjected to retrofitting and in the course of the several states - before, during and after retrofitting - data on relevant properties of the bridge has been collected. The data collected in the before retrofitting state was used to train ANNs. Over time, new measurements are collected from the bridge under the new states and presented to the trained ANNs. The predictions by the ANNs can be compared to real measurements and prediction errors can be obtained. Based on statistical data analysis of the prediction errors by means of clustering techniques, the ANN is able to identify the different states of the structure.

Keywords: Structural Health Monitoring; novelty detection; data-driven methods; unsupervised learning; clustering analysis.

1 Introduction

Civil engineering structures are crucial elements in our societies, contributing for their sustainability and rapid development. Unfortunately, a significant share of the structures and infrastructures used these days are being used past the expected lifetime they were originally envisioned for. Out of approximately 576,600 bridges (2014) in the US national inventory, about a third are either “structurally deficient” and in need of repairs, or “functionally obsolete” and in need of replacement [1]. The prolonged operation may additionally take place under environmental and operational conditions that are very different from the initial ones (e.g. increase of traffic on a bridge). In this sense the natural deterioration process can even be accelerated and it is not uncommon that when damage is discovered it has already grown far and required reparations are extensive and expensive. In the utmost extreme case, if action is taken too late, the structure can even fail. As a consequence, the development of strategies for Structural Health Monitoring (SHM) has become increasingly important since these address the problem of aging structures by improving structural reliability and life-cycle management. The primary objective of SHM is to

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