Full Scale Bridge Damage Detection Using Sparse Sensor Networks, Principal Component Analysis, and Novelty Detection

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Abstract

Over the decades, visual inspection has been adopted as a means to monitor infrastructure health. While visual inspection provides insights on bridge condition, it has been generally agreed that it is insufficient and inefficient. This has called for creating autonomous, robust, continuous and quantitative Structural Health Monitoring systems to detect damage early using machine learning algorithms and monitor future condition. Various methods have been explored that associate changes in condition with changes in the structure vibration characteristics. These methods have been mostly tested on laboratory specimens experiencing simulated damage. There is need for more validation of these SHM methods on in-situ structures experiencing real damage under operational and environmental conditions. This paper summarizes a full-scale experiment exploring bridge damage detection effectiveness under variable traffic loads. Three different types of damage were introduced into a full-scale, bridge deck mock-up. These included crash-induced bridge barrier damage, controlled barrier damage, and damage to the deck slab. At the end of each introduced damage case, bridge response to the multiple passages using specific vehicles specifications was recorded. Data was extracted and analyzed to identify damage using Principal Component Analysis (PCA) and Independent Component Analysis (ICA) as damage sensitive features. The extracted damage features were thereafter used as input for unsupervised learning (novelty detection). One interesting observation was how PCA revealed possibly significant damage after crash, which under visual inspection appeared to be minor cracking. Novelty detection using PCA as its damage feature was shown to provide robust damage detection irrespective of load, speed variation and signal noise levels.

Keywords: Principal Component Analysis; Damage Detection; Variable Traffic Load; Strain Measurement; Crash Test; Novelty Detection; Output Only.