Time-Frequency Based Adaptive Learning for Structural Health Management

by

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ABSTRACT

In the last few decades, several statistical signal processing techniques have been used to deal with uncertainty when detecting, identifying and classifying structural damage. One of the key challenges in integrating signal processing techniques in real-world structural health management systems is how to incorporate diversity in the damage state and variability in environmental and operational conditions. While conventional learning methods are adequate for characterizing the underlying mechanism of damage nucleation and evolution, they are of limited use in highly complex and rapidly changing environments. This is especially the case when the amount of available data is insufficient.

In this dissertation, time-frequency based methods and hidden Markov model based methods are used for the detection and classification of structural damage. Time-frequency techniques are also used to extract damage features; these techniques are chosen as they are well-matched to the time-varying spectral characteristics of waveforms measured using sensors on the structures. The proposed methodologies are adaptively learned by allowing the stochastic models to continuously evolve from experience with the time-varying environment. Damage-related features extracted from periodically-buffered structural data are modeled using Dirichlet process mixture models that provide for a growing number of mixture components or damage classes. Coupled with input from physics-based models in a Bayesian filtering framework, the adaptively-identified classes can be traced to different types of damage. An active data selection technique is used to optimize the adaptive identification of damage classes. The proposed adaptive learning methodology is baseline-free in the sense that it does not require any a priori damage training.

A novel information-transfer learning methodology is also proposed that reuses parameters that are learned from similar previous experiments. An inductive transfer mechanism is considered to aid damage classification when the available training data is statistically insufficient.

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