Structural Health Diagnosis Under Limited Supervision

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Abstract

Structural health diagnosis has been investigated following a data-driven machine learning paradigm. However, the model accuracy and generalization capability highly rely on the quality and diversity of datasets. This study established a framework for structural health diagnosis under limited supervision. Firstly, an image augmentation algorithm of random elastic deformation, a novel neural network with self-attention and subnet modules, and a task-aware few-shot meta learning method were proposed for vision-based damage recognition. Secondly, deep learning networks were established to model intra- and inter-class temporal and probabilistic correlations of different quasi-static responses for condition assessment. Finally, a two-stage convergence criterion merging with the subset simulation and Kriging surrogate model was designed for reliability evaluation. Real-world applications on large-scale infrastructure demonstrated the effectiveness.

Keywords: intelligent infrastructure; structural health diagnosis; machine learning; computer vision; small data

1 Introduction

During the long-term service period of civil infrastructure, damage accumulation and resistance deterioration will inevitably occur due to coupled effects of material erosion and cyclic fatigue loads, especially for large-scale bridges and tunnels. Following the paradigm of damage prognosis established by Farrar and Lieven (2007) [1], structural damage recognition, condition assessment, and reliability evaluation were the most significant issues towards health diagnosis. For past decades, one of the most commonly used ways was manual inspection, which had the shortcomings of high dependence on subjective judgment and engineering experience, severe unreliability, and low efficiency [2].

Since the 1990s, structural health monitoring techniques have been widely adopted in large-scale infrastructure. Conventional non-destructive testing and vibration-based methods have been investigated for damage detection and condition assessment. The measured signals were directly compared with peak values or statistical indices with thresholds regulated by the design code. However, the following challenges remained to be addressed: these techniques required the dense deployment of sensors on bridges and faced the ill-posedness of the reverse problem; the modal parameters were insensitive to minor damage in a

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