SHM-PPOGAN: Anomaly Classification in Structural Health Monitoring Data using Proximal Policy Optimization and Generative Adversarial Network

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Abstract

Data obtained from structural health monitoring (SHM) of civil infrastructure frequently experiences contamination due to sensor malfunctions, environmental noise, and data transmission failures. Such abnormal data can substantially hinder subsequent processes, including the identification of structural modes, damage detection, and condition assessment. Therefore, pinpointing and eliminating this data before analysis is vital. This study introduces a novel model, SHM-PPOGAN that merges data augmentation, ensemble learning, and proximal policy optimization (PPO) for the classification of anomalies in SHM data. The model employs a suite of convolutional neural networks (CNNs) to extract feature vectors from input images concurrently. These vectors are then synthesized for subsequent classification tasks. The efficiency of SHM-PPOGAN is confirmed through a dataset from a long-span cable-stayed bridge in China, supplied by the IPC-SHM community. Given the imbalanced nature of the dataset, we utilize a PPO-based algorithm. PPO, a type of reinforcement learning algorithm, offers a meaningful advancement by steering clear of extreme deviations from the previous policy, thus ensuring training stability. The training procedure is viewed as a chain of interconnected decisions where the samples act as states. Within this framework, the network serves as the agent. This agent then receives heightened rewards or penalties based on its accuracy in classifying the underrepresented class relative to the overrepresented one. For improved classification, we present a unique approach that employs generated images for data augmentation, leveraging the capabilities of the generative adversarial network (GAN). Moreover, we introduce a regularization strategy to mitigate the issues of mode collapse and unstable training inherent in GANs. Our findings indicate that our method adeptly identifies diverse anomalies in SHM data with remarkable precision.

Keywords: structural health monitoring, anomaly detection, proximal policy optimization, generative adversarial network, imbalanced classification.

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