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CLASSIFICATION OF COMPROMISED DOFS DATA WITH LSTM NEURAL NETWORKS

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Distributed optical fiber sensors (DOFS) are gaining momentum for in-situ condition monitoring and damage detection purposes. Although DOFS are a versatile sensing method enabling high-resolution strain and temperature mapping, they are also sensitive to mechanical vibrations. Vibrations are typically created by the ambient environment (e.g acoustic background, rotating equipment) which can produce high levels of measurement noise [1]. With physical access to DOFS installations, the principle of acoustic or mechanical vibrations can also be utilized for malicious sensor tampering.
The current lack of anomaly-detection systems suggests that practical DOFS applications would benefit from an automated analysis to detect and classify compromised measurements. Noise classification makes it possible to identify its source and potentially remove its effects from the measurement in the future. This would expand the commercial applications of DOFS systems significantly. Neural networks have been used for error detection in cyber-physical applications in numerous studies with high-accuracy results [2]. Specifically, long short-term memory (LSTM) neural network models have become popular in recent years to classify anomalies in sequential e.g time-series data.
Our investigation conducted a series of physical experiments using magnitude-controlled mechanical disturbances on bare free-hanging DOFS. Both random low-frequency vibrations at large displacement amplitudes and a constant high-frequency acoustic source at a low amplitude were employed. Experiments revealed that strain patterns are visually different with varying types and levels of disturbances. For the numerical analysis, statistics and machine learning-based approaches were applied for DOFS vibration noise classification, and their accuracy is discussed in detail. Results from the post-processing of compromised DOFS data suggest that it is possible to develop a vibration detection or classification system based on off-the-shelf DOFS interrogation equipment coupled with LSTM numerical tools.

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