Structural health monitoring meets data mining

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English Summary

With the development of sensing and data processing techniques, monitoring physical systems in the field with a sensor network is becoming a feasible option for many domains. Such monitoring systems are referred to as Structural Health Monitoring (SHM) systems. By definition, SHM is the process of implementing a damage detection and characterisation strategy for engineering structures, which involves data collection, damage-sensitive feature extraction and statistical analysis. Most of the SHM process can be addressed by techniques from the Data Mining domain, so I conduct this research by combining these two fields.

The monitoring system employed in this research is a sensor network installed on a Dutch highway bridge, which aims to monitor dynamic health aspects of the bridge and its long-term degradation. Meeting these requirements is non-trivial, because the measurements collected with the sensor network are not only sensitive to traffic events, but also to varying environmental loadings, such as humidity, wind and most importantly, temperature.

I have explored the specific focus of each sensor type under multiple scales, and analysed the dependencies between sensor types. The obtained results have provided us with a thorough understanding of the sensor network, and helped us select the sensors that are sensitive to positive loads for modal analysis.

The measurements collected with a selected sensor are not always directly useful. During traffic-free time, the bridge is not excited, and the sensor just collects random noise, while during rush hour, the bridge is excited by multiple traffic events, which makes the measurements too complicated for modal analysis. To

obtain high-quality datasets, I have proposed to employ free-vibration periods, which are generated by single truck events.

In the measurements, a traffic event can be viewed as a pattern, so that the traffic event identification task can be addressed as a pattern detection problem. Based on landmarks and constraints, I have proposed a novel predefined pattern detection method.

To separate the temperature response from others, I have proposed a baseline correction method, the *most-crossing* method, which is based on the Probability Density Function (PDF). Combined with the principle of Minimum Description Length (MDL), the method can be used to detect useful patterns, potentially at multiple scales.

Based on the obtained high-quality datasets, I have conducted modal analysis with both the simple Peak-Picking method and the advanced Stochastic Subspace Identification method. The results of these two methods meet well. I have analysed the influence of temperature and traffic mass on natural frequencies, and verified that natural frequencies decrease with temperature increases, but the influence of traffic mass is not as obvious as that of temperature.