Dynamic Time Warping for Temperature Compensation in Structural Health Monitoring

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Guided wave analysis is a structural health monitoring technique for inspecting large structural areas. Many guided wave methods analyze the similarities between measurements through baseline subtraction. These baseline methods rely on the assumption of constant environmental conditions. Yet, in practical situations, environmental variations are unavoidable. For example, temperature variations perturb wave velocities and cause misalignments between baseline and measurement data. These variations significantly reduce the effectiveness of current structural health monitoring techniques.

Temperature has a predictable approximate stretching-like effect on the guided wave data. Algorithms, such as optimal signal stretch (OSS) and the scale transform, have been used to optimally re-stretch and fit data to a baseline. While the methods are effective for small perturbations, their performance deteriorates for large temperature variations and long propagation distances. This deterioration occurs because the stretching approximation is not valid in these circumstances. As a result, there is a need for algorithms to better align guided wave data and adapt to larger changes.

This paper utilizes dynamic time warping (DTW) to accurately align guided wave data. By utilizing dynamic programming, an optimal alignment is found which maximizes the correlation of the measurements with the baseline. In Figure 1, we show that dynamic time warping successfully aligns data while preserving the damage signatures with experimental data from an aluminum plate. The plate was heated in temperatures ranging from roughly 75 °F to 130 °F. Figure 1 illustrates the correlation coefficient between the first measurement and all following measurements after applying two methods: dynamic time warping and optimal stretching. Damage is simulated by attaching a magnet to the plate just before measurement 122. While optimal stretching improves correlation, the changes caused by the magnet are not distinguishable. The magnet is only identifiable in the dynamic time warping result, providing a steadier correlation coefficient of approximately 0.9 prior to the damage with the expected decrease post-damage. This shows the increased performance of dynamic time warping over optimal stretching.

Figure 1. Correlation Coefficients with baseline. Damage is applied at measurement 121, as indicated by the red, vertical line.