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Robust Baseline Subtraction for Ultrasonic Full Wavefield Analysis

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Full wavefield analysis can be effectively used to study and characterize the interaction between waves and structural damage. Wavefields are sequentially measured as damage evolves over time, and differences between each wavefield are then analyzed. Yet, as wavefields are measured and as damage evolves, environmental and operational variations can significantly affect wave propagation properties. As a result, wavefields are sensitive to variations in temperature, stress, sensor coupling, and other sources that can significantly distort data. Several approaches, including time-stretching and optimal baseline selection, can remove environmental variations, but these methods are often limited to removing specific effects, are ineffective for large environmental variations, and can require an unrealistic number of prior baseline measurements.

This paper presents a robust methodology for subtracting wavefields and isolating wave-damage interactions. The method is based on dictionary learning, is robust to multiple environmental and operational variations, and requires only one initial baseline wavefield. For this application, the dictionary represents a matrix of basis vectors that generally describe wave propagation for a particular wavefield. We learn or train the dictionary using multiple frequencies from the single baseline wavefield. We then statistically fit new measurements with the dictionary through sparse regression techniques. This effectively creates a new baseline with propagation properties (for example, velocities) according to the new data. The new baseline is then compared with the measured data.

Figure 1 illustrates results from applying our approach to two simulated full wavefield measurements. Figure 1(a) illustrates a snapshot of an ultrasonic Lamb wave. Figure 1(b) illustrates the same ultrasonic wave with a 1% increase in velocity and a barely-visible point scatterer located in the center of the frame. Figure 1(c) is the difference between Figure 1(a) and Figure 1(b), and is dominated by the change in velocity. Figure 1(d) shows the difference after applying our dictionary learning method. Our method allows us to successfully remove the velocity differences and isolate the reflections from the scatterer. In the paper, we further demonstrate this approach with experimental data.

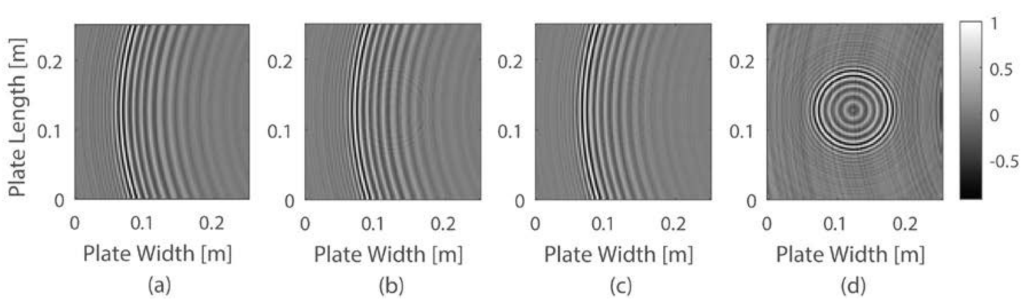

Figure 1. Wavefield snapshots. (a) Baseline measurement without damage. (b) Current measurement with damage and a 1% velocity change. (c) Direct difference of (a) and (b). (d) Difference using fitted baseline data.