Ultrasonic Signal Detection and Recognition Using Dynamic Wavelet Fingerprints

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Abstract

A novel ultrasonic signal detection and characterization technique is presented in this dissertation. The basic tool is a simplified time-frequency (scale) projection called a dynamic wavelet fingerprint. Take advantage of the matched filter and adaptive time-frequency analysis properties of the wavelet transform, the dynamic wavelet fingerprint is a coupled approach of detection and recognition. Different from traditional value-based approaches, the dynamic wavelet fingerprint-based technique is pattern- or knowledge-based. It is intuitive and self-explanatory, which enables the direct observation of the variation of non-stationary ultrasonic signals, even in complex environments. Due to this transparent property, efficient detection and characterization algorithms can be customized to address specific application problems. Furthermore, artificial intelligence can be integrated and expert systems can be built on it.

Several practical ultrasonic applications were used to evaluate the feasibility and performance of this new idea. The echoes from the surface of five different plates were characterized by the dynamic wavelet fingerprint. After learning, 100% correct identification ratio was achieved.

The second application was ultrasonic periodontal probing. The dynamic wavelet fingerprint technique was used to expose the hidden trend of the complex waveforms. Based on the experiment results of a simplified phantom, the regular variation of the inclination of the dynamic wavelet fingerprints was related to reflection regions of interest. The depth of the periodontal pocket was then estimated by finding the third significant peak in the inclination curves. Taking the manual probing data as the “gold standard,” a 40% agreement ration is achieved with the tolerance of 1mm. Statistically however, a lack of agreement was found in terms of the “limits of agreement” of Bland and Altman.

The third application was multi-mode Lamb wave tomography. The dynamic wavelet fingerprint technique was used to detect and characterize each suspect through transmitted code. The area of the dynamic wavelet fingerprint was then used as the feature to identify false modes caused by noise and other interference. The overall qualities of the arrival times are acceptable in terms of smooth distribution and variation pattern corresponding to specific defects. The tomographic images generated with the estimated arrival times were also fine enough to indicate different defects in four plates.

The last application is ultrasonic thin multi-layers inspection. The dynamic wavelet fingerprint was generated at each sample point to achieve extreme time resolution. Based on observation of the simulated signals, a distinctive dynamic wavelet fingerprint was found to differentiate actual echoes from noise. High precision and robustness were proved by simulated signals. When applied to practical data obtained from a plastic encapsulated IC package, it was able to detect multiple interfaces in the package.