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Sparse Signal Reconstruction for Flaw Detection from Noisy Ultrasonic Data: A Bayesian Framework

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ABSTRACT
Structural health monitoring (SHM) has been a popular topic for last decade for which both global and local SHM techniques are required. Flaw detection, being a major nondestructive testing topic, plays important role in structural health monitoring for its ability to detect localized damage in structures. Localized damages like flaws are essentially sparse in the spatial domain thus may be represented sparsely by sparse representation techniques. In this study, a specified sparse inversion method for ultrasonic flaw signals based on Bayesian framework is proposed. Based on the latest sparse Bayesian representation principle, ultrasonic signal are represented effectively by a specially designed over-complete dictionary whose basis are characteristic wavelets of the signal. By explicitly quantifying the uncertainty in the reconstructed signal from noisy data, the Bayesian exhibits better efficiency and robustness compared to existing sparse learning methods, especially when the dictionary has a large number of basis. This superior performance is greatly helpful for the sparse representation problem in this study. Before postprocessings such as pruning and thresholding are implemented to the representation coefficients, prior information of flaw echo signal such as the range of frequency and bandwidth, which are the key parameters that controls the basis of the dictionary, are estimated. Pruning operation is implemented simultaneously to the frequency and bandwidth parameters such as those coefficients whose corresponding basis have parameters lie in the selected range are kept. The selected coefficients can be further enhanced by thresholding operation. The capability of the proposed method for flaw detection from noisy data is evaluated by both simulations and experimental data, where both white Gaussian noise and correlated noise are involved. Results indicate that the proposed method is effective for flaw detection from noisy data where both white Gaussian noise and correlated noise are presented.

KEYWORDS: *sparse Bayesian learning, ultrasonic nondestructive testing, flaw detection, signal reconstruction and denoising*