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Performance comparison of Kalman–based filters for nonlinear structural finite element model updating

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Abstract

Finite element (FE) model updating has emerged as a powerful technique for structural health monitoring and damage identification of civil structures. Updating mechanics-based nonlinear FE models allows for a complete and comprehensive damage diagnosis of large and complex structures, but it is computationally demanding. This paper first introduces an Iterated Extended Kalman filter (IEKF) to update mechanics-based nonlinear FE models of civil structures. Different model updating techniques using the Extended Kalman filter (EKF), Unscented Kalman Filter (UKF) and IEKF, are then compared for their performance in terms of convergence, accuracy, robustness, and computational demand. Finally, a non-recursive estimation procedure is presented and its effectiveness in reducing the computational cost, while maintaining accuracy and robustness, is demonstrated. An application example is presented based on numerically simulated response data for a three-dimensional 5-story 2-by-1 bay reinforced concrete (RC) frame building subjected to bi-directional earthquake excitation. Excellent estimation results are obtained with the EKF, UKF, and IEKF used in conjunction with the proposed non-recursive estimation approach. Because of the analytical linearization used in the EKF and IEKF, abrupt and large jumps in the estimates of the model parameters are observed with these filters, which may lead to divergence of the nonlinear FE model solution procedure. The UKF slightly outperforms the EKF and IEKF, but at a higher computational cost.

Keywords: Nonlinear finite element model, Parameter estimation, Kalman-based filter, Damage identification

1. Introduction

Finite element (FE) model updating is the most popular model-based method for condition assessment and damage identification (DID) of civil structures using input-output or output-only vibration data. In this methodology, an initial FE model of the structure is updated by tuning a

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