A Comparison of Unscented and Extended Kalman Filtering for Nonlinear System Identification

Abdullah Al-Hussein
Graduate Student, Dept. of Civil Engineering and Engineering Mechanics, University of Arizona, Tucson, USA

Achintya Haldar
Professor, Dept. of Civil Engineering and Engineering Mechanics, University of Arizona, Tucson, USA

ABSTRACT: A nonlinear system identification-based structural health assessment procedure is presented in this paper. The procedure uses the unscented Kalman filter (UKF) concept. The weighted global iteration with an objective function is incorporated with the UKF algorithm to obtain stable, convergent, and optimal solution. An iterative least squares technique is also integrated with the UKF algorithm. The procedure is capable of assessing health of any type of structures, represented by finite elements. It can identify the structure using limited noise-contaminated dynamic responses, measured at a small part of large structural systems and without using input excitation information. In order to demonstrate its effectiveness, the proposed procedure is compared with the extended Kalman filter (EKF)-based procedure. For numerical verification, a two-dimensional five-story two-bay steel frame is considered. Defect-free and two defective states with small and severe defects are considered. The study shows that the proposed UKF-based procedure can assess structural health more accurately and efficiently than the EKF-based procedures for nonlinear system identification.

1. INTRODUCTION

Civil structural systems are expected to deteriorate with time during their normal use. They also suffer damages when exposed to natural events like large earthquakes or high winds. Man-made events like impacts or explosions can also cause different levels of damages to them. To maintain the intended use of the structures and economic activities of the region, it is important to detect the location and severity of defects as early as possible so that required remedial actions can be promptly initiated. Replacing them may not be the best option.

Structural health assessment based on nonlinear system identification (SI) in the presence of many sources of uncertainties in the state of the system is the main objective of this paper. To obtain the optimal solution to the nonlinear filtering problem, a complete description of the conditional probability density function is necessary. Unfortunately, a large number of parameters are required for its description. In the past decades, many techniques of suboptimal approximation have been developed for nonlinear structural SI (Kerschen et al. 2006).

For civil engineering applications, several methods are available for nonlinear SI using the extended Kalman filter (EKF) and the unscented Kalman filter (UKF) concepts. The EKF concept has been widely used for nonlinear system identification through linearizing nonlinear models. However, the derivation of the Jacobian matrices and the linearization approximations to the nonlinear functions can be nontrivial and can lead to implementation difficulties, particularly when the nonlinearities are severe. Furthermore, the level of severity will be unknown at the time of inspection. The linearization process can also introduce large errors which may lead to poor performance and divergence of the filter for highly nonlinear problems.