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Unscented Kalman filter with unknown input and weighted global iteration for health assessment of large structural systems

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SUMMARY

A novel concept denoted as unscented Kalman filter with unknown input and weighted global iterations (UKF-UI-WGI) to assess health of large structural systems is proposed. It incorporates the basic features of UKF to identify systems in the presence of severe nonlinearity but then added a few desirable features to increase its implementation potential. Because the information on excitation and unknown initial state vector is necessary to implement any UKF-based approach, a substructure concept is introduced to generate them. The traditional UKF concept attempts to identify small structural systems using large duration of response histories in one global iteration. Because it fails to assess the defective states of large structures in most cases, a weighted multiple global iterations procedure with objective functions using short duration responses is introduced. The superiority of UKF-UI-WGI over the traditional UKF is demonstrated with the help of several illustrative examples using single and multiple substructures in identifying both defect-free and defective states. With the help of the same examples, the superiority of the proposed method over the extended Kalman filter-based method developed by the team earlier is conclusively documented. With the help of parametric studies, it is documented that the proposed method is robust, accurate, and stable. The study confirms that UKF-UI-WGI can identify large structural system using only limited response information measured at a small part of a structure without using any excitation information. The concept significantly advances the state-of-the-art in UKF-based nonlinear system identification and considerably improves its implementation potential.

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KEY WORDS: unscented Kalman filter; weighted global iteration; unknown input; system identification; structural health assessment

1. INTRODUCTION

Health assessment of civil infrastructures (CIs) is essential to maintain our way of life. However, they deteriorate with time and continuously accumulate damage during normal operation due to natural aging process, harsh environmental conditions, and often inadequate maintenance. They also deteriorate when exposed to natural hazards like earthquakes, high winds, and so on or man-made events like blast, explosion, and so on. Furthermore, some of them are over their design lives. Based on the statistics of 2013 by the U.S. Department of Transportation Federal Highway Administration, more than 30% of existing bridges have exceeded their 50-year design life. And based on the ASCE's 2013 Report Card for America's Infrastructure, the nation's infrastructure received an overall grade of D+, and estimated investment needed to bring them up to the current standard would be about \$3.6 trillion by 2020.

The primary purposes of structural health monitoring and assessment are to ensure their longevity and safety and to optimize the maintenance cost. In fact, malfunctioning of CIs can often have serious consequences resulting in the loss of human life. Even when there is no loss of life, communities suffer

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