Particle relaxation method of Monte Carlo filter for vibration-based structural system identification

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ABSTRACT

The Structural health monitoring of civil engineering structures is a fundamental issue for structural safety and integrity, due to the fact that they will deteriorate just after they are built and put into services. The failure of structures will not only result in severe economic lost but may threaten the lives of people. Hence maintaining safety and reliable civil engineering structures for daily use is an extremely important issue which has received considerable attention in literature in recent years.

One of the methods to detect damage to structures is the system identification technique to identify dynamic parameters of structural systems using observed responses, in which the Kalman filter has been a well-known technique. This is a recursive algorithm that estimates the first and second moments of the state vector for a linear system under the assumption of Gaussian uncertainty of observation and system noises. Therefore, Kalman filter has great difficulties in identification for nonlinear and non-Gaussian systems. To overcome this problem, the Monte Carlo filter [1] known as a particle filter was proposed to estimate the state variables with nonlinear and non-Gaussian distribution characteristics.

Up to now, many system identification algorithms using Monte Carlo filter have been developed and have achieved good successes in structural identification fields by many researchers, such as Sato and Kaji [2], Yoshida and Sato [3], Ching et al., Chowdhury et al. [4]. However, these methods have not been practical to apply to structural identification for large degree of freedom systems because of exponential increase of computation time as the system becomes very large.

An attempt in this study is made to develop a new algorithm applicable to large structural system identification by modifying the filtering process of the classical Monte Carlo filter. The idea is to calculate the likelihood of prediction particles for resampling of filtered particle by splitting prediction particle components into each set of structural node and structural element. The applicability of the proposed method is demonstrated through numerical simulation of large-scale structural model and laboratory experiments with 4-story frame structure.

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