Probabilistic system identification of spatial distribution of structural parameter using Bayesian network

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Abstract

System identification (SI) is a systematic process to estimate structural parameters by minimizing errors between measured and simulated responses of the structure. Existing SI algorithms have been suffering from ill-posedness, a well-known issue in inverse problems. To overcome challenges in SI, this paper investigates the potential use of Bayesian Network (BN) for the purpose of probabilistic identification of structural parameters. The relationships between the nodes in the BN graph are described by the conditional probability tables (CPT) obtained by Monte Carlo simulations of structural analysis. To depict the spatial distribution of deteriorating structural parameter in two-dimension effectively in a BN model, a bi-variate Gaussian function is employed. The performance of the proposed method is tested and demonstrated through comparison with the results by maximum likelihood estimation (MLE) using several assumed scenarios of structural deterioration.

Keywords: Bayesian network; structural deterioration; system identification; inverse analysis; Gaussian function; finite-element updating, maximum likelihood estimation

1 Introduction

In the research area called structural health monitoring (SHM), there have been many efforts to identify the actual condition of a structural system, which might have been deteriorated [1]. One of the major SHM techniques developed in past decades is system identification (SI), which generally refers to inverse analysis to estimate structural parameters based on the measured responses of a structure subjected to loads. SI problems are in general ill-posed, and thus SI algorithms may suffer from issues such as non-uniqueness and non-stability during the optimization process. As an effort to overcome the challenge, this paper explores an idea of applying Bayesian Network (BN) to SI problems. BN is a probabilistic graphical model in which random variables are represented as nodes and their relationships are expressed with arcs [2,3]. These arcs represent statistical dependence between the random variables in the form of conditional probabilistic table (CPT). Using efficient BN inference algorithm for available evidences, probability distributions of all nodes in BN are readily updated to the posterior distributions.

This paper focuses on developing an effective BN modelling framework to identify spatial distribution of a structural parameter as the first attempt of using BN for SI. For this purpose, the structural parameters and responses are represented by nodes in BN, and their CPTs are calculated using Monte Carlo simulations (MCS) of forward structural analysis. Then, posterior distributions of structural parameters given measured responses are obtained using a BN inference algorithm. The proposed BN-based SI is demonstrated and tested by numerical examples.

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