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Abstract

Bayesian Networks (BNs) have emerged as an appealing alternative to simulation-based methods for the risk assessment of infrastructure systems. This is mainly due to their ability (i) to explore extreme loss events if an exact inference algorithm is used and (ii) to carry out backward analyses, thus acting as a decision support system for the studied event. However, the complete probabilistic description of a spatialized infrastructure generates computational costs which increase exponentatially with the number of components present in the system, despite recent efforts to design smart BN formulations that decompose the size of the problem. Moreover, such approaches have only been demonstrated for connectivity problems; unfortunately, more elaborate performance indicators based on capacity or serviceability are essential to properly capture the degraded response of a system.

Therefore this paper demonstrates the ability of a hybrid simulation-based/Bayesian approach to tackle real-world systems, also accounting for their serviceability. This hybrid method, referred to as "thrifty-naïve" formulation, may be decomposed into the following steps:

- Simulation of a given number N of deterministic scenarios for the whole system (e.g. n components), by sampling various sources of uncertainties;
- Selection of a reduced number k of components that have a significant influence on the performance of the infrastructure, by evaluating the correlations of the Monte Carlo outcomes with the system's response;
- Construction of the corresponding BN following a naïve formulation, with only the selected k components linked to the BN nodes, P, representing the system's performance;
- Assembly of the conditional probability tables for P nodes by counting the Monte Carlo outcomes, without requiring any specific connectivity or capacity rules.

The proposed approach presents the merit of accessing any type of performance indicator, as long as it has been generated in the simulation phase. Moreover, the inference abilities of the BN are still exploitable in order to integrate field observations and to provide a decision support to the physical layer, which is represented by the Monte Carlo simulations.

After obtaining encouraging results with virtual networks, the robustness of the thrifty-naïve BN formulation is demonstrated on a real-world application. The studied infrastructure is a road network connecting a dozen of small towns in the Pyrénées mountains (France), while being exposed to earthquakes or earthquake-triggered landslides. Informative performance measures such as the elongated travel distance or the additional travel time (if an adequate traffic model is available) may be accessed thanks to the hybrid BN method.