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Conditional independence in risk analysis of engineered systems.

Abstract: Risk analyses of engineered systems commonly rely on probabilistic descriptions of component reliabilities in combination with models of system performance. This approach has proven effective in determining (small) probabilities of (extreme) system failure events. However, in many industrial and academic applications of the theory, independence among component (sub-system) performances is assumed, mainly for two reasons: (a) data for determining statistical dependence is sparse, and (b) the inclusion of statistical dependence into the analysis leads to more demanding computations. In recent years, Bayesian networks (BNs) have become popular in risk analysis, partly because they provide an answer to these challenges. The graphical structure of a BN is an intuitive tool to consistently describe dependence among random variables when a purely data-driven approach is infeasible. By relying on conditional independence assumptions, it has the potential to represent dependence efficiently, i.e. with smaller data requirements and reduced computation. This not least facilitates the use of the models in the context of (near-)real-time risk management.

In this contribution, I will review recent applications of BNs for risk analysis, and on this basis discuss fundamental challenges and opportunities faced in this domain. Application examples include transportation infrastructure risk management [1], warning systems and emergency response for natural hazards [2,3], and risk assessment of technical systems with human interaction [3]. Through these examples I will demonstrate how the model building process is supported by the graphical structure and highlight the importance of fast inference in these models. I will also discuss the limitations of the approach, which are mostly associated with dependence structures that do not facilitate exploiting conditional independence.

References:

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