Fault Trees into Credal Networks Adopting Imprecise Noisy-MAX Gate

Hector Diego Estrada-Lugo H.D.ESTRADA-LUGO@LIVERPOOL.AC.UK
Marco de Angelis MARCO.DE-ANGELIS@LIVERPOOL.AC.UK
Edoardo Patelli EDOARDO.PATELLI@LIVERPOOL.AC.UK
Institute for Risk and Uncertainty, University of Liverpool, United Kingdom

One of the most popular techniques for risk assessments of engineered systems is the Fault Tree analysis. Among the main advantages of this approach, we can find the acceptance of a broad range of data (e.g., historical records, technical reports, expert judgements) and the graphical representation of cause-effect relationships. However, this analysis is restricted to assess one fault event per model and usually, variables must be binary. Moreover, it is important noting the importance of the epistemic uncertainty related to conflictive data (different reported values in data sources or different opinions from experts) or lack of information that is frequently encountered in realistic risk analyses. Fortunately, credal networks (a probabilistic graphical model for imprecise and incomplete probability measures) can offer a more flexible technique that surpasses the aforementioned limitations and enhances the advantages of Fault Tree analysis. In this approach, variables are represented by sets of probability mass functions (credal sets) and they can adopt a number of different states. With credal networks, we can produce diagnostic and prediction of different fault events when modelling complex accidents or structures. However, credal networks are little known in the area of dependability and risk assessment, compared to Fault Trees, so missing the opportunity to produce more informative and exhaustive analyses.

In this work, we propose a technique to transform Fault Trees into credal networks extending the imprecise Noisy-OR gate of Antonucci in [2] to multi-valued variables. An attempt to generalize the Noisy-OR gate to the case of multi-state variables called Noisy-MAX has been developed previously by Díez [3]. However, this model is restricted to the precise probability domain. The novelty of the work here presented consists in the generalisation of the imprecise Noisy-OR gate (that only takes into account binary variables) to the case of multi-valued variables, i.e., imprecise Noisy-MAX gate. This is an effort to answer the open question raised by Antonucci [2] regarding the specification of a Fault Tree model with non-Boolean variables and to present credal networks as a more flexible option for risk assessments. Furthermore, our model seeks to provide the imprecise probability extension of the work done by Diez [3] and provide a framework that allows computing the probabilistic inference of the queried variable in the same way as it is done in a credal network [1].

Our methodology is implemented upon the open-source uncertainty quantification software called *OpenCossan*. The technique is applied to assess the probability of failure of the primary cooling system of a nuclear power plant in the general failure mode regarded as a loss-of-coolant accident. Thus, we provide a mathematical support tool to transform readily Fault Trees into credal networks representing, an important advantage over Fault Tree analysis which works only one-directional.

References

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