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NxGen Toolbox: Overview

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The NxGen Toolbox is a C++ library which implements the Dynamic and Dependent Tree Theory (D^2T^2) for the reliability, safety and resilience analysis of complex systems (Andrews and Tolo, 2022). The library implements a range of well-established modelling techniques (e.g., Markov Models, Fault Trees, etc.) accompanied by novel algorithms providing their mutual integration. These results in an umbrella methodology aimed at overcoming the limitations of traditional safety analysis solutions, and hence able to model dependencies, component wear out as well as complex asset management strategies.

An overview of the toolbox capabilities is presented and demonstrated through its application to purposely developed case studies and examples.

Toolbox Structure

The fifteen classes enclosed by the NxGen Toolbox can be classified in three main categories:

- Traditional Techniques;
- D^2T^2 extensions;
- Support Classes;

The first category includes five classes implementing as many methodologies commonly adopted in safety modelling. These are:

- MM class: implements Markov Models (MMs) and their steady-state computation;
- PN class: provides tools for the construction and Monte Carlo simulation of Stochastic Petri Nets (PNs). This class also offers solutions purposely developed for the integration of PNs within the D^2T^2 framework;
- BDD class: includes tools for the storage and manipulation of Binary Decision Diagrams (BDDs), as well as for their automatic implementation through Fault Tree (FT) conversion;
- FT class: allows the implementation and analysis of user-defined FT structures, as well as the manipulation of the FT structure, such as through reduction and modularization;
- ET class: includes tools for the implementation and computation of user-defined ET structures; in the current implementation of the toolbox, although falling in the category of traditional techniques, the class offers a generalization of common ET algorithms, allowing the use of Petri Nets (PNs) and Markov Models (MMs) as independent sub-models of the ET, but also the inclusion of dependencies between FTs or Dynamic and Dependent Trees (D^2Ts) associated with ET branches.

The second category includes instead two classes implementing the core functionalities required by the D^2T^2 framework:

- CBDD class: this provides a generalization of the BDD class and structure, referred to as Conditional Binary Decision Diagram (CBDD), and hence methodology, allowing for dependent nodes and their characterization through the use of joint probabilities. The class implements novel algorithms (Tolo and Andrews, 2023) for the processing of such dependencies and hence the computation of the CBDDs.

- D2T class: includes algorithms for the implementation, manipulation and computation of Dynamic and Dependent Trees (D2Ts), which generalize traditional FT structures allowing for basic and intermediate events dependencies through the integration of dynamic models (e.g., MM, PN) or experimental data.

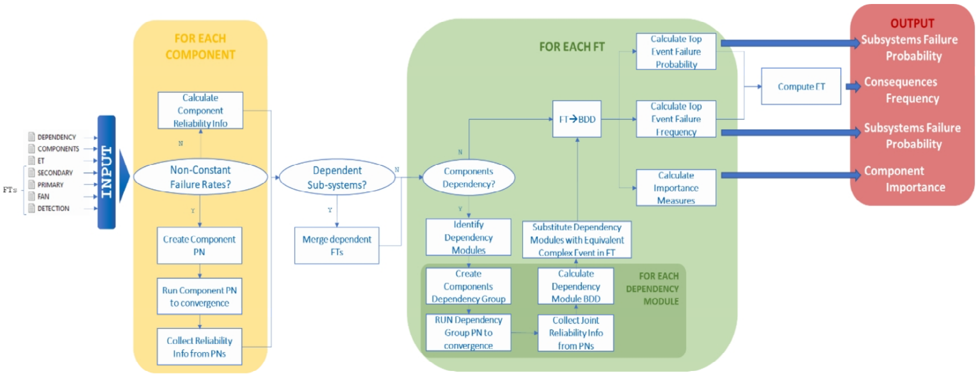

Fig. 1 Overview of the D^2T^2 methodology.

Finally, two additional classes implement data structures to be accessed by FT and D2T objects:

- BE class: the implemented objects are designed to store reliability metrics associated with basic events included in FT or D2T objects;
- DG class: implements Dependency Groups (DGs) data structure consisting of closed sets of interdependent basic events included within D2T or ET user-defined models. The events enclosed in a DG object, are dependent between each other but independent by any other event in the same model.

The toolbox is designed to provide independent access to individual techniques as well as to the integrated framework, allowing the implementation of traditional as well as D^2T^2 analysis.

The functionalities of the toolbox are demonstrated across the different classes and methodologies through their application to simple case studies. The advantages and limitations of the tools are investigated and discussed throughout.

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