Regeneration engineering for weapon system availability assessment

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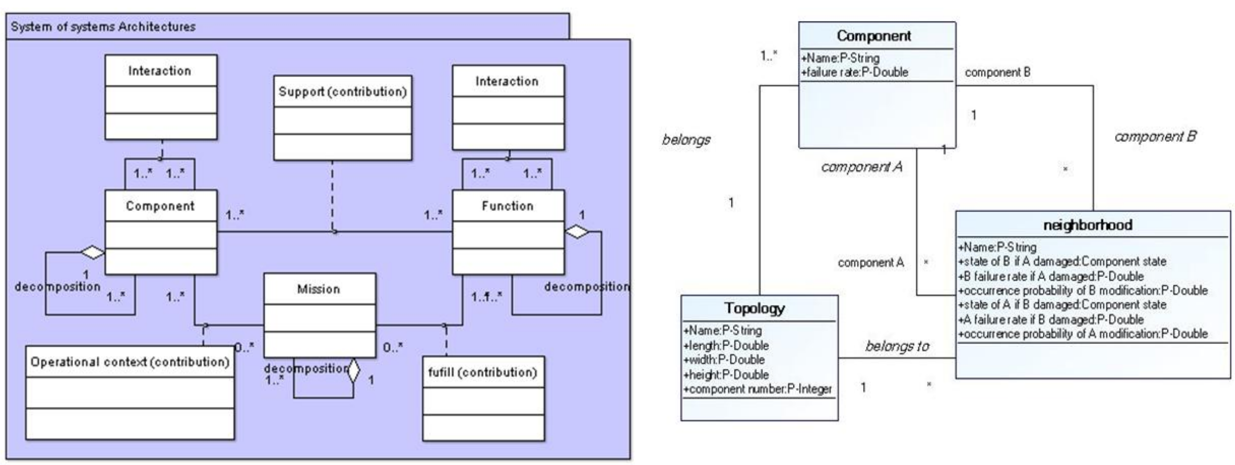
These days, controlling system availability is a key factor in industry, which makes dependability important as well. Many systems that perform critical missions have to function in hostile environments where operational availability can be affected by internal system failures and external factors such as damage. This is increasingly the case for weapon systems that operate in a battle context. Accomplishing the mission is thus directly linked to system reliability, vulnerability, and regenerability. This last item, system regenerability, is defined as the capacity of a system to recover operational capabilities after failure or damage; this characteristic has become a requirement in the design of weapon systems. According to recent work supported by the Resilience Engineering Network (http://www.resilience-engineering.org/intro.htm), system regeneration contributes to adaptive capacities of systems to enhance system resilience. Traditionally, system dependability has focused on internal causes (e.g., failures), while system survivability has focused on external factors such as damage to the system and these two types of studies tend to be considered separately. However, working on system regeneration in order to improve system availability, implies assessing the impact of both failure and damage to the system. Research considering both failure and damage is scarce, and as Campbell and Starbuck have mentioned (2005), there are currently no methods for modeling or simulation that allow the impact of regeneration actions to be assessed dynamically.



a. Conceptual structural model

b. Example of component interaction refinement

Figure 1. Conceptual view of the structural model and refinement

To deal with this problem, we have previously proposed a unified, multi-step failure/damage modeling approach (Monnin, Senechal, Iung, Lelan, and Garrivet 2006), developed in partnership with NEXTER Group, a French weapons systems manufacturer, and the French Procurement Agency. When following a systems engineering process, the regenerability potential of new systems must be assessed in the design phase during dependability studies, but tools and methods are still needed for both the modeling and evaluation processes. In that way, during Mr. Monnin's PhD research, we developed a technique of regeneration engineering provides systems designers a modeling methodology to assess operational availability. The method extends notions of dependability studies to allow failure, damage, and regeneration to be taken into account in a unified way. We propose to analyze the following factors in the same way: (1) the functional impact of failure (failure mode and effect analysis), (2) both the functional and the physical impact of aggression (damage mode effect analysis) and (3) the functional impact of regeneration. Indeed, the way a system or component can be regenerated strongly depends on both its functional and physical state. In order to formalize the knowledge related to the system itself and the extended dependability studies, we developed a static model called the Structural Model, derived from the architecture view of the systems engineering data model of AFIS, the French chapter of INCOSE. The structural model is based on relationships defined according to three modeling axes, namely, the decomposition axis, the interaction axis and the contribution axis (figure 1 a.). It is then refined according to both the application handled and the precision level required. The refinement allows the engineer to define specific regeneration patterns from the system description: for example, a component's interaction is refined to accommodate the system topology (i.e., the component's location) in order to allow damage propagation to be considered (figure 1 b.). Once the refined structural model obtained, it is instantiated in a database in order to provide the description of a specific architecture (figure 2).

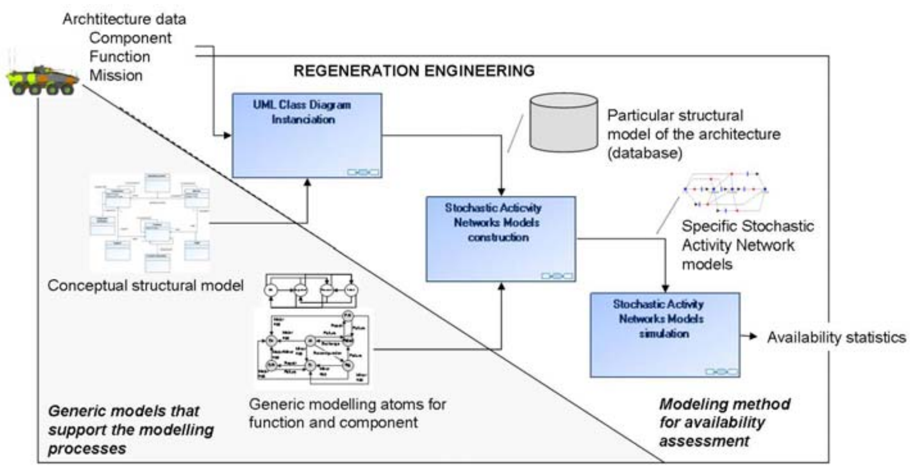


Figure 2. Process diagram of an application of the regeneration engineering modeling method

To support the availability assessment, we define a dynamic model based on state-space modeling using stochastic activity networks. Generic modeling atoms representing the dynamic behavior of components are aggregated to catch the behavior of the overall system. These atoms allow the failed and damage state to be represented in a unified way for the availability assessment. We use discrete-events simulations to evaluate the dynamic model and to obtain availability statistics. Since the structural model holds the knowledge that will be needed for the availability assessment, the dynamic model is built using construction rules that we derived from the structural model. We have developed specific applications with our partners NEXTER and the French Procurement Agency to show the added value and the feasibility of our modeling approach (Monnin, Senechal, Iung, and Lelan 2008). Since the French Procurement Agency is currently developing architectures for systems of systems, it is necessary to carry out further implementations of those architectures to first highlight the gaps, and then define future prospects for filling the gaps.

References

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