

Resilience Quantification and Allocation for Design of Complex Engineered Systems

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Continued growth in terms of scale, complexity, and prolonged system useful lives has become increasingly apparent for complex engineered systems. This growing global trend has challenged system designers to design affordable and effective complex engineered systems. Previous research efforts have been focused on protecting an engineered system against failure events, in other words, ensuring high reliability. Improving reliability in a system is often associated with the exponential behavior of improvement costs. At one point, it is not affordable to improve system reliability because the improvement costs increase substantially as the system reliability level approaches the maximum achievable reliability. Therefore, most recent research have given attention towards developing an adaptive engineered system that is able to response to and recover from adverse disruptive events, such as natural disasters, man-made accidents, and vicious attacks. This type of system is also known as a resilient system. Resilience in an engineered system implies the capability of a system to autonomously sense adverse changes in health conditions, withstand failure events, and to recover from the effects of these unpredicted events.

This paper is dedicated to exploring the gap between quantitative and qualitative assessments of engineering resilience in the domain of designing complex engineered systems, thus optimally allocating resilience into subsystems level could be achieved. Engineering resilience can be quantified based on the probabilities of passive survival rate (Reliability) and proactive survival rate (Restoration). As the assessment tool of engineering resilience, Bayesian Network approach is proposed. The optimization of engineering resilience allocations are further employed at the subsystems level so that the system development cost could be minimized while satisfying a system target resilience level. A supply chain resilience allocation case study is employed to demonstrate the proposed approach. The proposed resilience quantification and allocation approach using Bayesian Networks would empower system designers in the conceptual design stage, to have a better grasp of the weakness and strength of their own systems against disruptions. This research also aims to provide a fundamental methodology to develop a more effective, readily-used design tool that can optimally allocate resilience attributes for complex engineered systems.