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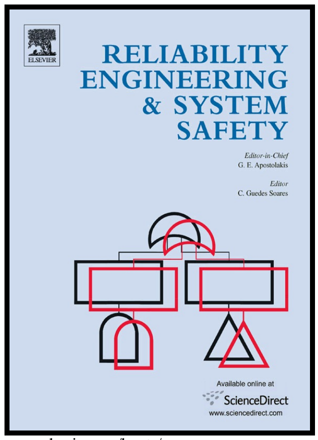

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A Framework for the Quantitative Assessment of Performance-based System Resilience

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Abstract

Increasing system complexity and threat uncertainty require the consideration of resilience in the design and analysis of engineered systems. While the resilience engineering community has begun to converge on a definition and set of characteristics for resilience, methods for quantifying the concept are still limited in their applicability to system designers. This paper proposes a framework for assessing resilience that focuses on the ability of a system to absorb disruptions, recover from them, and adapt over time. The framework extends current approaches by explicitly considering temporal aspects of system responses to disruptions, volatility in system performance data, and the possibility of multiple disruption events. Notional system performance data is generated using the logistic function, providing an experimental platform for a parametric comparison of the proposed resilience metric with an integration-based metric. An information exchange network model is used to demonstrate the applicability of the framework towards system design tradeoff studies using stochastic simulations. The presented framework is domain-agnostic and flexible, such that it can be applied to a variety of systems and adjusted to focus on specific aspects of resilience.

Keywords: System resilience, Resilience metrics, Adaptive networks

1. Introduction

The concept of resilience has expanded the focus of engineering complex systems beyond traditional discussions of robustness, reliability, and risk management. Since being introduced by Holling [1], resilience has placed greater emphasis on a system's adaptability and recoverability, in addition to its ability to absorb disruptions. This transition is readily observed across government and industry, and is beginning to alter the way in which we approach systems engineering. The need for resilience is especially strong for increasingly interconnected and complex systems such as those under the purview of the military [2], national infrastructures [3], and economic systems [4].

Traditional systems engineering attempts "to anticipate and resist disruptions through classical reliability methods, such as redundancy at the component level and use of preventative maintenance at the system level" [5]. In comparison, resilience shifts the focus towards sustaining and recovering critical system functions in the presence of potential threats or failures, often through adaptation. There has been much discussion regarding the meaning of resilience and appropriate metrics for quantifying it. Quantifying resilience is particularly motivated by the need to support design and decision making, enabling "system resilience to be considered as an attribute of a system's delivery system" [6].

This paper presents a framework for making quantitative assessments of system resilience using performance data. Current approaches for assessing resilience consider many of the foundational aspects of resilience, such as absorption, restoration, and adaptation. This paper seeks to extend those approaches by capturing additional features of complex system environments and behaviors, such as repeated disruptions and volatility in delivered system performance. These features are often observable characteristics of many complex systems and the environments in which they operate.

The remainder of this paper is organized as follows. Section 2 provides further background regarding definitions of resilience and metrics for quantifying it. Section 3 describes the proposed framework for assessing resilience. Section 4 describes a method for parametrically comparing potential resilience metrics using the logistic function, and implements the method to compare the developed resilience metric with a commonly used one from the literature. Section 5 describes the application of the framework to an information exchange network model. Section 6 summarizes contributions of this paper and opportunities for further advancing the field of resilience engineering.

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