Designing for Robustness: the Role of Bridging Nodes

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Abstract

To reduce costly design changes, it is desirable to understand a complex engineered system's failure tolerance in the early stages of design. This research introduces a new approach to the identification of critical design parameters through the concept of bridging nodes. Using a network-based perspective in which design parameters are modeled as nodes, it is found that vulnerable parameters tend to be bridging nodes, which are nodes that connect two or more modules that are organized together in order to perform particular functions. The behavioral degradation of bridging and non-bridging nodes, as measured by topological network metrics, are compared in network models of forty engineering systems as well as in synthetically generated networks. Bridging nodes are associated with significantly larger changes in behavioral degradation than non-bridging nodes when subject to attack ($p < 0.001$). This finding indicates that the modular structure of a system's behavioral network could be key to understanding the system's failure tolerance. The presence of bridging nodes provides an early-stage indicator of the robustness of complex engineered systems.

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