After Cascades: Optimal Restoration Processes for Interdependent Networks

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While our understanding of cascading failure processes within and across complex systems is rapidly expanding, the study of processes to restore systems back to function lags far behind. This talk focuses on methods that take damaged interdependent networks as inputs and reveal sequences of restoration actions that minimize time and costs as outputs. We first pursue this restoration process via mathematical optimization. In particular, we introduce a new problem dubbed the interdependent network design problem (INDP), and develop mixed-integer programming models whose solution strategies exploit the problem's remarkable algebraic structure. A solution for INDP is concerned with finding the minimum-cost reconstruction strategy of a partially destroyed system of infrastructure networks, subject to budget, resources, and operational constraints, while considering interdependencies between them. We also show variants of this INDP that consider time-dependency, as well as stochasticity in network supply and demands. In addition, recognizing that solving INDPs scales exponentially with instance size, we present two scalable solution alternatives. One alternative focuses on reduced-order representations of the problem via recovery operators. The form of the operators is assumed to be a time-invariant linear dynamic model apt for infrastructure restoration, generated by applying system identification techniques to disaster and recovery scenarios. This compact representation provides simple yet powerful information regarding systemic recovery dynamics, and enables generating fast suboptimal recovery policies in time-critical applications. The other alternative focuses on percolation models that mimic recovery processes by introducing commodity deficit as a new percolation parameter. We illustrate our methods with the restoration of a set of interdependent infrastructure networks after hypothetical earthquakes in Shelby County, TN, United States. We confirm models capabilities to efficiently restore systems with ideal graph systems and synthetic power grids. Our ability to restore systems serving modern communities after failures and cascades is step towards controllable and resilient critical networks.

<u>References</u>

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