MAR16-2015-020423

Abstract for an Invited Paper
for the MAR16 Meeting of
the American Physical Society

Novel percolation transitions and coupled catastrophes

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Collections of interdependent networks are at the core of modern society, spanning physical, biological and social systems. Simple mathematical models of the structure and function of networks can provide important insights into real-world systems, enhancing our ability to steer and control them. Here our focus is on abrupt changes in networks, due both to phase transitions and to jumping between bi-stable equilibria. We begin with an overview of novel classes of percolation phase transitions that result from repeated, small interventions intended to delay the transition. These new phenomena allow us to extend percolation approaches to modular networks, Brownian motion, and cluster growth dynamics. We then focus on abrupt transitions due to a system jumping between bi-stable equilibria, modeled as a cusp catastrophe in nonlinear dynamics. We show that when systems that each undergo a cusp catastrophe interact, we can observe a new phenomena of catastrophe-hopping leading to non-local cascading failures. Here an intermediate system facilitates the propagation of a sudden change or collapse, and we show that catastrophe hopping is consistent with the outbreak of protests observed during the Arab Spring of 2011.