Networks in motion

April 19 2012

A new article by a Northwestern University complex networks expert discusses how networks governing processes in nature and society are becoming increasingly amenable to modeling, forecast and control.

The article establishes relationships between seemingly disparate topics such as the friendship paradox -- by which our friends have on average more friends than we do -- and why carbon can result in a hard diamond or the softer material graphite.

"Many broadly significant scientific questions, ranging from self-organization and information flow to systemic robustness, can now be properly formalized within the emerging theory of networks," said Adilson E. Motter, the Harold H. and Virginia Anderson Professor of Physics and Astronomy at Northwestern's Weinberg College of Arts and Sciences. "I was thus humbled to be invited to write such a timely piece."

Motter is first author of the article "Networks in Motion," published last week as the cover story in Physics Today, the membership journal of the American Institute of Physics. His co-author is Réka Albert, professor of physics and biology at Penn State University.

The authors argue that, as network research matures, there will be increasing opportunities to exploit network concepts to also engineer new systems with desirable properties that may not be readily available in existing ones. Examples include emerging areas such as synthetic biology and microfluidics, which could be radically changed by rational circuit design, but also established areas such as traffic and materials research.

Motter and Albert consider the problem of network control, particularly in the context of biological networks as a promising new avenue for disease treatment. Cascading processes, in particular, in which successive elements in a complex network fail, are shown to be not as unstoppable as previously thought.

They also discuss at length how collective behavior may depend on properties of the underlying network, even when composed of the exact same nodes -- as in the case of radically different materials made of the same chemical element.

By and large, the recent study of complex systems has been centered on the identification and analysis of network features relevant to a particular phenomenon of interest, ultimately reducing complexity. But, the authors ask, with so many conceivable possibilities, what if one simply fails to look for the right features? Researchers have been thinking about this, too, and, as a result, exploratory methods are now being devised to identify patterns not anticipated by pre-conceptions.

One such method mentioned in the article aims at resolving the internal structure of complex networks by organizing the nodes into groups that share something in common, even if researchers do not know a priori what that thing is.

"This is, of course, only the very tip of the iceberg," Motter said. "A broader undertaking concerns the development of similar exploratory approaches that can also systematically account for network dynamics, which remains widely unexplored."

More information: *Physics Today* doi: 10.1063/PT.3.1518