Enhancement of the robustness of evolving open systems by the bidirectionality of interactions

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An essential and universal feature of many social, economical, ecological, and biological systems is that they are open. In these complex systems the constituting elements are not fixed and the complexity emerges or at least persists under successive appearances or introductions of new elements and disappearances or eliminations of old elements. Those systems sometimes grow or are stationary, but also some other times they collapse or go extinct. Hence one can ask a fundamental question why and when, in general, can such open and complex systems exist.

A recently proposed simple model has revealed a general mechanism by which such systems can become robust against inclusion of elements with random interactions when the elements have a moderate number of uni-directional links ([1], [2], [3] and talk in SigmaPhi2014). This happens as a result of two opposing effects such that while the inclusion of elements with more interactions makes each individual element more robust against disturbances, it also increases the net impact of the loss of any element in the system. The interaction is, however, in many systems often intrinsically bidirectional like for mutual symbiosis, competition in ecology, and the action-reaction law of Newtonian mechanics, etc.

This presentation reports the strong reinforcement effect of the bidirectionality of the interactions on the robustness of evolving systems. We show that the system with purely bidirectional interactions can grow with two-fold average degree, in comparison with the purely unidirectional system. This drastic shift of the transition point comes from the reinforcement of each node, not from a change in structure of the emergent system. For systems with partially bidirectional interactions we find that the area of the growing phase gets expanded. In the dense interaction regime, there exists an optimum proportion of bidirectional interactions for the growth rate at around 1/3. In the sparsely connected systems, small but finite fraction of bidirectional links can change the systems growth behaviour from non-growing to growing (F. Ogushi, J. Kertesz, K. Kaski, and T. Shimada, arXiv:1703.04383).

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