# Origins of self-similarity in the growth of complex networks

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## ABSTRACT

The possibility of a unique growth mechanism for a variety of complex networks in different fields such as biology, technology or sociology is of interest, as it promises to uncover the universal origins of collective behavior. The emergence of self-similarity in complex networks raises the fundamental question of the growth process according to which these structures evolve. While in our previous work we discovered the fractal nature of organization in many real networks the question remained how these networks have evolved in time. We therefore launch a study of growth mechanisms to understand the simultaneous emergence of fractality, modularity, as well as the small world effect, and the scale-free property in real world complex networks.

We use the concept of renormalization as a mechanism for the growth of fractal and non-fractal modular networks. We show that the key principle that gives rise to the fractal architecture of networks is a strong effective "repulsion" (disassortativity) between the most connected nodes (hubs) on all length scales, rendering them very dispersed. Our models also show that when the repulsion between hubs is weak the resulting networks are non-fractal.

The renormalization growth naturally explains the emergence of modules in cellular networks, which is crucial in understanding the structure of the biochemical functional classes. More importantly, we find that the self-similar property of networks significantly increases their robustness against targeted attacks on hubs, as compared to the more vulnerable non-fractal scale-free networks. Thus we show that a robust network comprised of functional modules, such as a cellular network, necessitates a fractal topology, suggestive of an evolutionary drive for their existence.


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