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Large Networks through the Eye of a Mathematician

It is becoming more and more clear that many of the most exciting structures and phenomena of our world can be described as large networks. The internet is perhaps the foremost example, where the internet itself is modeled by different networks (the physical internet, the network of hyperlinks, etc.). Various social networks, several of them inspired and supported by the internet, are studied by sociologist, historians, epidemiologists, economists etc. Other huge networks arise in biology (from ecological networks to the brain), physics, engineering etc.

These networks pose exciting and challenging problems for the mathematician. This may be surprising, since these networks are not the typical structures of classical mathematical studies; but the mathematical theory of networks (often called graphs) has been one of the fastest growing areas in mathematics. In "classical" graph theory we know (or assume to know) the full network, with an exact list of nodes and edges connecting them. Graph theory established interesting and deep connections between their properties (connectivity, subgraphs, coloring, etc.), and developed sophisticated algorithms to determine these properties.

The huge networks that are at the center of interest lately represent a new kind of challenge: these networks are never completely known, and indeed often they are not completely defined. At any time, we can only have partial information about them, through sampling locally, or observing the behavior of some global processes on them.

One approach to the study of such networks is to find compact approximate descriptions of them. This could be a procedure (usually randomized) that produces networks with similar behavior. The study of random graphs was initiated by Erdős and Rényi in the early 1960's, and took a new turn in 2002 when Barabási and Albert invented a simple random growth procedure that reproduced some of the unusual features of the internet. These approaches lead to the important, but only partially solved, question about how to define mathematically when two very large networks are similar.

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