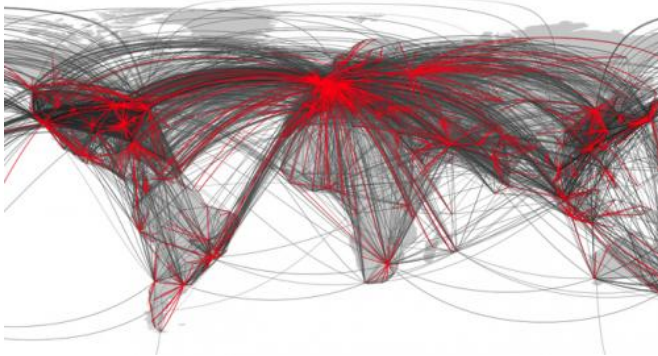


Researchers develop method that shows diverse complex networks have similar skeletons

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The worldwide air transportation network. Each grey link resembles traffic of passengers between more than 1,000 airports worldwide; the entire network has more than 35,000 links. The red lines represent the network's skeleton, a tree-like structure of only 1,300 links that represents the core structure of the network. Links in the skeleton are the most important connections in the network.

Northwestern University researchers are the first to discover that very different complex networks -- ranging from global air traffic to neural networks -- share very similar backbones. By stripping each network down to its essential nodes and links, they found each network possesses a skeleton and these skeletons share common features, much like vertebrates do.

Mammals have evolved to look very different despite a common underlying structure (think of a human being and a bat), and now it appears real-world [complex networks](#) evolve in a similar way.

The researchers studied a variety of biological, technological and social networks and found that all these networks have evolved according to basic [growth mechanisms](#). The findings could be

particularly useful in understanding how something -- a disease, a rumor or information -- spreads across a network.

This surprising discovery -- that networks all have skeletons and that they are similar -- was published this week by the [journal Nature](#) Communications.

"[Infectious diseases](#) such as H1N1 and SARS spread in a similar way, and it turns out the network's skeleton played an important role in shaping the global spread," said Dirk Brockmann, senior author of the paper. "Now, with this new understanding and by looking at the skeleton, we should be able to use this knowledge in the future to predict how a new outbreak might spread."

Brockmann is associate professor of engineering sciences and applied mathematics at the McCormick School of Engineering and Applied Science and a member of the Northwestern Institute on [Complex Systems](#) (NICO).

Complex systems -- such as the Internet, Facebook, the [power grid](#), human consciousness, even a termite colony -- generate complex behavior. A system's structure emerges locally; it is not designed or planned. Components of a network work together, interacting and influencing each other, driving the network's evolution.

For years, researchers have been trying to determine if different networks from different disciplines have hidden core structures -- backbones -- and, if so, what they look like. Extracting meaningful structural features from data is one of the most challenging tasks in network theory.

Brockmann and two of his graduate students, Christian Thiemann and first author Daniel Grady,

developed a method to identify a network's hidden core structure and showed that the skeletons possess some underlying and universal features.

The networks they studied differed in size (from hundreds of nodes to thousands) and in connectivity (some were sparsely connected, others dense) but a simple and similar core skeleton was found in each one.

"The key to our approach was asking what network elements are important from each node's perspective," Brockmann said. "What links are most important to each node, and what is the consensus among nodes? Interestingly, we found that an unexpected degree of consensus exists among all nodes in a network. Nodes either agree that a link is important or they agree that it isn't. There is nearly no disagreement."

By computing this consensus -- the overall strength, or importance, of each link in the network -- the researchers were able to produce a [skeleton](#) for each network consisting of all those links that every node considers important. And these skeletons are similar across networks.

Because of this "consensus" property, the researchers' method does not have the drawbacks of other methods, which have degrees of arbitrariness in them and depend on parameters. The Northwestern approach is very robust and identifies essential hubs and links in a non-arbitrary universal way.

More information: The paper, titled "Robust Classification of Salient Links in Complex Networks," is available at [www.nature.com/ncomms/journal/...full/ncomms1847.html](http://www.nature.com/ncomms/journal/full/ncomms1847.html).

Provided by Northwestern University

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