Network Thinking: Some Examples

NetSci High 2014 Boston University

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What Is Network Science?

- A data-driven science that focuses on “how things are related”, rather than what things are in isolation.

- An interdisciplinary science that draws upon concepts and methods taken from mathematics, computer science, physics, social sciences, humanities, etc.
Astonishing Facts

- Various complex networks share a number of common features, despite their completely different origins.

- Most real-world networks are huge, complex and heterogeneous, yet very “small” and “efficient.”
From Liu & Xu 2011; networks were generated from the following three sentences:

This professor is writing a book.
Our professors have given us many books.
We wrote a book and gave it to the professor.
Network of Words (Semantic)
Network of U.S. Poets (1924-25)

Network of Fictional Characters

Harry Potter's character network (Calderone et al., 2011)
Networks in Math
Networks of Numbers (1)

Transitivity network ($i \rightarrow j$ if and only if $i < j$)

Associativity network (about multiplication)
Networks of Numbers (2)

Collatz sequence \((x \rightarrow y ; y = x/2 \text{ if } x \text{ is even, or } 3x+1 \text{ otherwise})\)
Networks in Math Puzzles

Seven bridges of Konigsberg (images from Wikipedia)

42 bridges in Bristol, UK (images from Bristol Post / Dr. Thilo Gross)
Networks in Science
Network of Genes

Costanzo et al., 2010
Network of Diseases

Goh et al., 2007
Network of Disease Propagation

H1N1 activities illustrated according to distance from MEX airport (Brockmann, 2013)
Network of the Brain

Van J. Wedeen, M.D., MGH/Harvard U.
Food Webs

Food web in El Verde Rainforest, Puerto Rico by J. Dunne (from foodwebs.org)
Causal Loop Diagram

Causal loop diagram of climate change (from siswebs.org)
Networks in Social Studies
Network of People Around You
Network of Human Migration

Davis et al., 2013
Network of Air Transportation
Network of Corporations

Vitali et al., 2011
Network of Historical Events

Network of events constructed from narratives on Chinese village Liu Ling (Bearman et al., 2003)
Networks in Technology
The Internet
Network of Java Classes

Cavlin, 2012
(from simplethoughtsonline.com)
Network of Product Design

Information flows between computer OS development tasks (Braha & Bar-Yam, 2004)
Networks in Other Disciplines
Network of Saints in Iconography
Network of Top Tennis Players

Radicchi, 2011
Flavor Network

Yong-Yeol Ahn, Sebastian Ahnert, James P. Bagrow, and A.-L. Barabási
“Flavor network and the principles of food pairing”, Scientific Reports 1, 196 (2011)

Flavor network. Culinary ingredients (circles) and their chemical relationship are illustrated. The color of each ingredient represents the food category that the ingredient belongs to, and the size of an ingredient is proportional to the usage frequency (collected from online recipe databases: epicurious.com, allrecipes.com, micasp.com). Two culinary ingredients are connected if they share many flavor compounds. We extracted the list of flavor compounds in each ingredient from the book “Fenaroli’s handbook of flavor ingredients” (5th ed.) and then applied a backbone extraction method by Secano et al. (PNAS 2016, 113) to pick statistically significant links between ingredients. The thickness of an edge represents the number of shared flavor compounds. To reduce clutter, edges are bundled based on the algorithm by Danny Holten (http://www.win.tue.nl/~dholten).
Take-Home Message

- Anything can be understood as a network if you pay attention to “connections” among things.