DCS/CSCI 2350: Social & Economic Networks

What can we say about a network having friends as well as enemies?

Structural Balance

Reading: Ch 5 of EK

Mohammad T. Irfan

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World War I

The New York Times

The Opinion Pages

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The Enemy of My Enemy

By STEVEN STROGATZ FEBRUARY 14, 2010 5:30 PM

It's traditional to teach kids subtraction right after addition. That makes sense — the same facts about numbers get used in both, though in reverse. And the black art of "borrowing," so crucial to successful subtraction, is only a little more baroque than that of "carrying," its counterpart for addition. If you can cope with calculating 23 + 9, you'll be ready for 23 – 9 soon enough.

At a deeper level, however, subtraction raises a much more disturbing issue, one that never arises with addition. Subtraction can generate negative numbers. If I try to take 6 cookies away from you but you only have 2, I can't do it — except in my mind, where you now have negative 4 cookies, whatever that means.

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- Rock Groups (Feb. 7, 2010)
- From Fish to Infinity (Jan. 31, 2010)

Subtraction forces us to expand our conception of what numbers are. Negative numbers are a lot more abstract than positive numbers — you can't see negative 4 cookies and certainly can't eat them — but you can think about them, and you *have* to, in all aspects of daily life, from debts and overdrafts to contending with freezing temperatures and parking garages.

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Steven Strogatz is the Schurman Professor of applied mathematics at Cornell University. Among his honors are MIT's highest teaching prize, membership in the American Academy of Arts and Sciences, and a lifetime achievement award for communication of math to the general public, awarded by the four major American mathematical societies. A frequent guest on National Public Radio's "Radiolab," he is the author, most recently, of "The Joy of x," which grew out of his previous Opinionator series "The Elements of Math." He lives with his wife and two daughters in Ithaca, N.Y. Follow him on Twitter @stevenstrogatz

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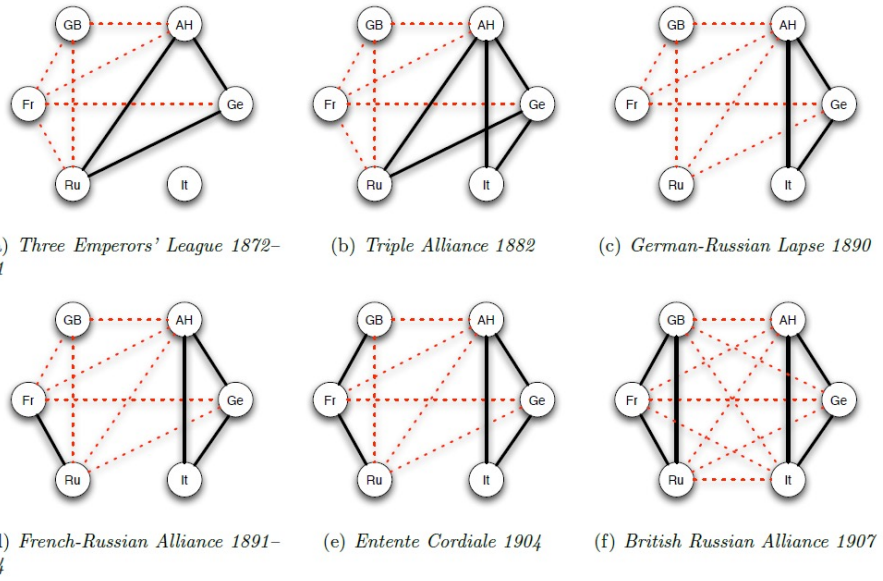
Evolution of international relationship



(a) *Three Emperors' League 1872–81* (b) *Triple Alliance 1882* (c) *German-Russian Lapse 1890*

(d) *French-Russian Alliance 1891–94* (e) *Entente Cordiale 1904* (f) *British Russian Alliance 1907*

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Agenda

- Network of friends and enemies
  - Balanced/stable configurations
- Local (a few nodes) → global (whole network)

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Founders

- Fritz Heider (1940s)
- Cartwright and Harary (1950s)

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First model (to be relaxed later)

- Complete graph (edge between each pair of nodes)
- Each edge: either + or –
- Example: sports team, countries, etc.

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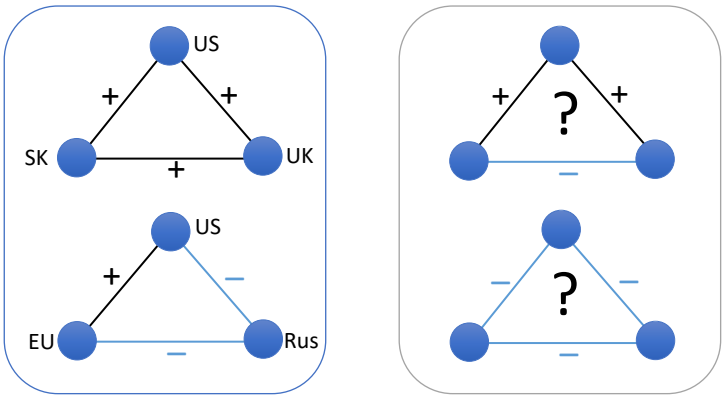
Def. Balanced triangle

Graph with just 3 nodes



Balanced

Unbalanced

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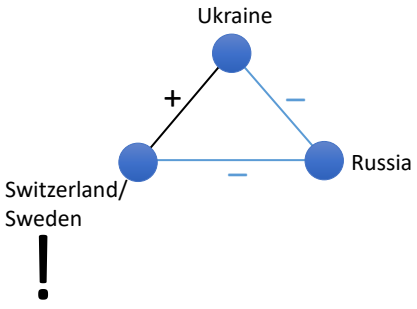
More examples (January 2022)



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Def. Balanced complete graph

A complete graph is balanced
if and only if
every triangle in it is balanced

- Q1. Draw a balanced and an unbalanced complete graph.
- Q2. Is this definition a little extreme?

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Characterization of balanced complete graphs

Balance Theorem (Harary, 1953)

A labeled complete graph is balanced
if and only if
either (i) all edges are + or
(ii) graph consists of two battling factions

Local (triangle) →
Global (either everyone gets along or there are two battling factions)

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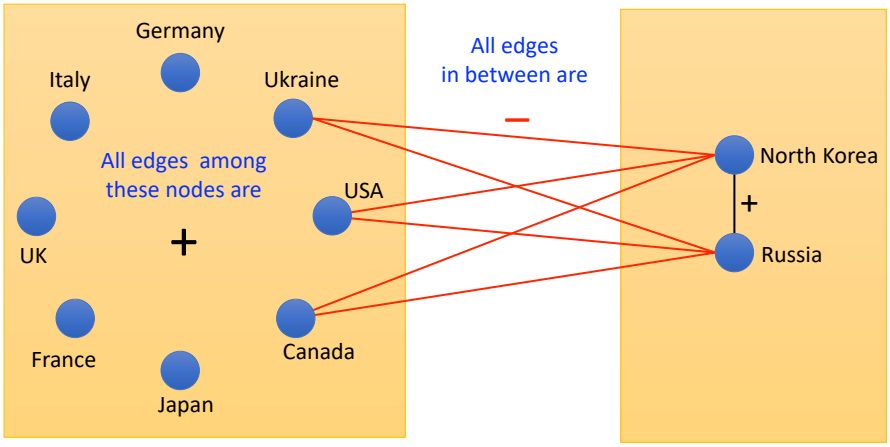
Example (January 2022)



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Extensions

1. Relax strict definition of balance
   - Weakly balanced complete graphs
2. General graphs (non-complete)

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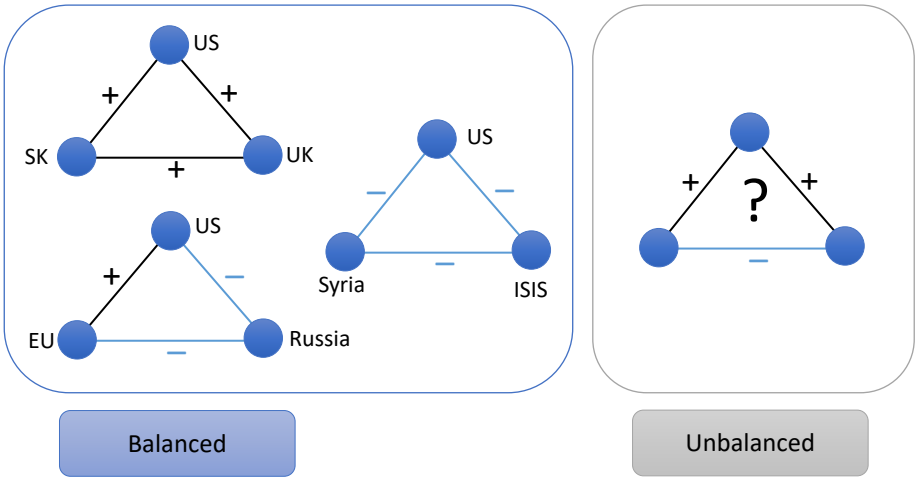
Ext.# 1: Weakly balanced networks



Balanced

Unbalanced

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Characterization of weak balance

- Complete graph is weakly balanced

  if and only if

  either (i) all + or (ii) multiple battling factions

- Proof. Very similar to the previous characterization (with strict def. of balance)

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Ext.# 2: General graphs

AKA signed graph

- may not be a complete graph!

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Def: Balanced signed graph

A general signed graph is called balanced if it consists of two battling factions

- Definition is not based on triangles

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Characterization: balanced signed graph

- A signed graph is balanced
  if and only if
  there exists no cycle with odd number of negative edges

- Q. What goes wrong otherwise?

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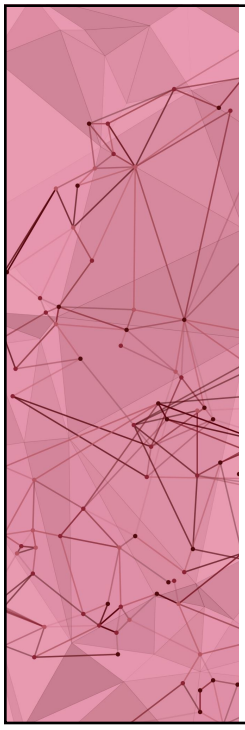

Real-world examples

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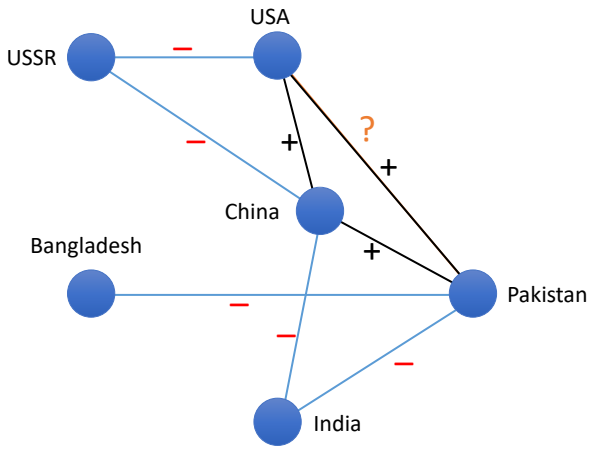
Liberation of Bangladesh in 1971

(Michael Moore, Journal of Social Psychology, 1978)



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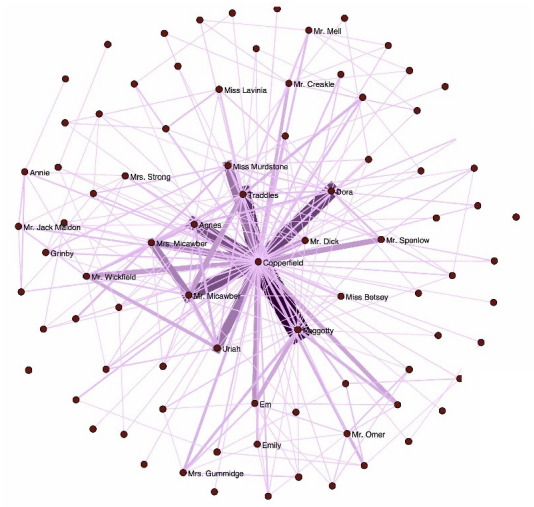
Social network among characters Graham Sack, 2013



(b) David Copperfield (Charles Dickens)

• Nodes:	83
• Graph Density:	0.07
• Clustering Coeff:	0.80
• Avg. Degree:	5.81
• Stdev. Degree:	9.05
• Stdev / Avg. Degree:	1.56
• Avg. Shortest Path:	2.03
• Diameter:	4

jimhutton

AI question: generate narrative from the evolution of stability

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