LECTURE 11:NETWORKS WITH SIGNED EDGES

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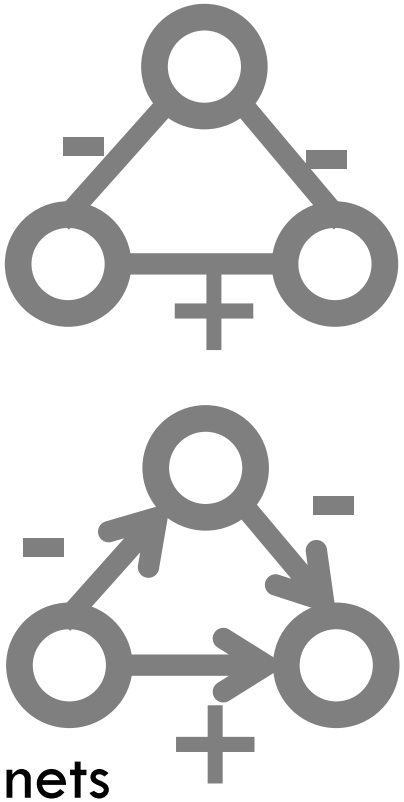
CSIT 6000K: Social Networks and Social Computing: A Data Science Perspective
Thursdays 07:30 PM - 10:20 PM

Signed Networks

- **Networks with positive and negative relationships**
- Our basic unit of investigation will be **signed triangles**
- First we talk about **undirected** networks then **directed**
- **Plan for this lecture:**
  - **Model:** Consider two soc. theories of signed nets
  - **Data:** Reason about them in large online networks
- **Application:** Predict if A and B are linked with + or -



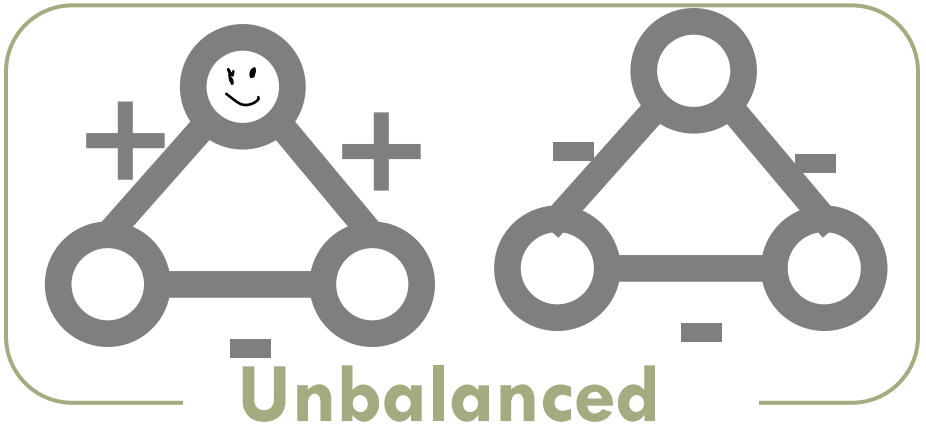
Signed Networks

- Networks with positive and negative relationships
- Consider an **undirected complete graph**
- Label each edge as either:
  - **Positive:** friendship, trust, positive sentiment, …
  - **Negative:** enemy, distrust, negative sentiment, …
- Examine triples of connected nodes A, B, C

Theory of Structural Balance

- **Start with the intuition** [Heider '46]:
  - Friend of my friend is my friend
  - Enemy of enemy is my friend
  - Enemy of friend is my enemy
- Look at connected triples of nodes:

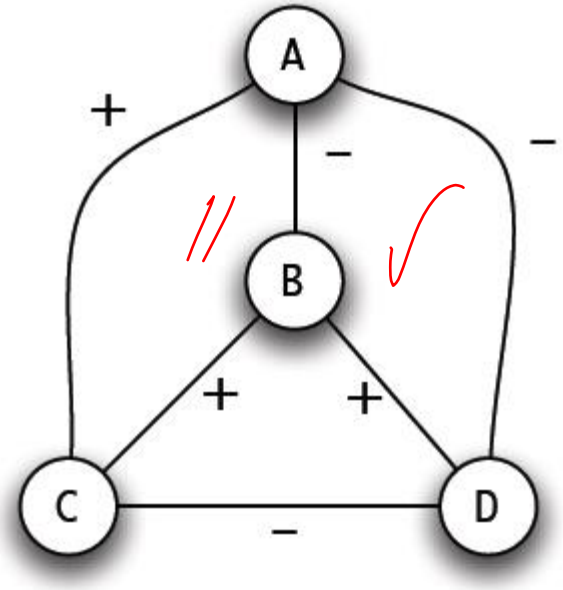
Consistent with "friend of a friend" or "enemy of the enemy" intuition



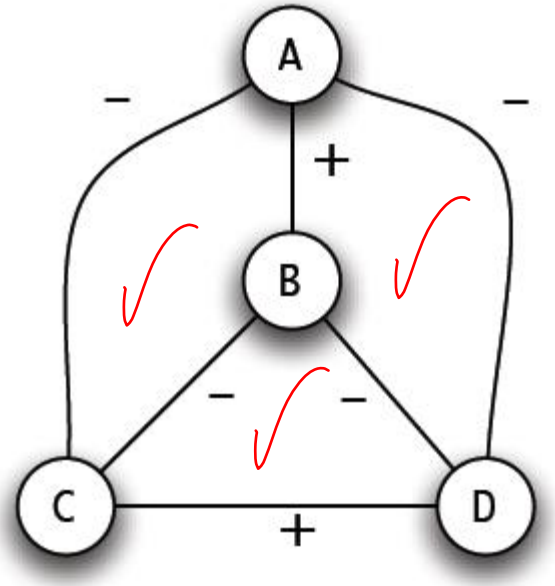
Inconsistent with the "friend of a friend" or "enemy of the enemy" intuition

Balanced/Unbalanced Networks

- Graph is **balanced** if every connected triple of nodes has:
  - All 3 edges labeled +, or
  - Exactly 1 edge labeled +



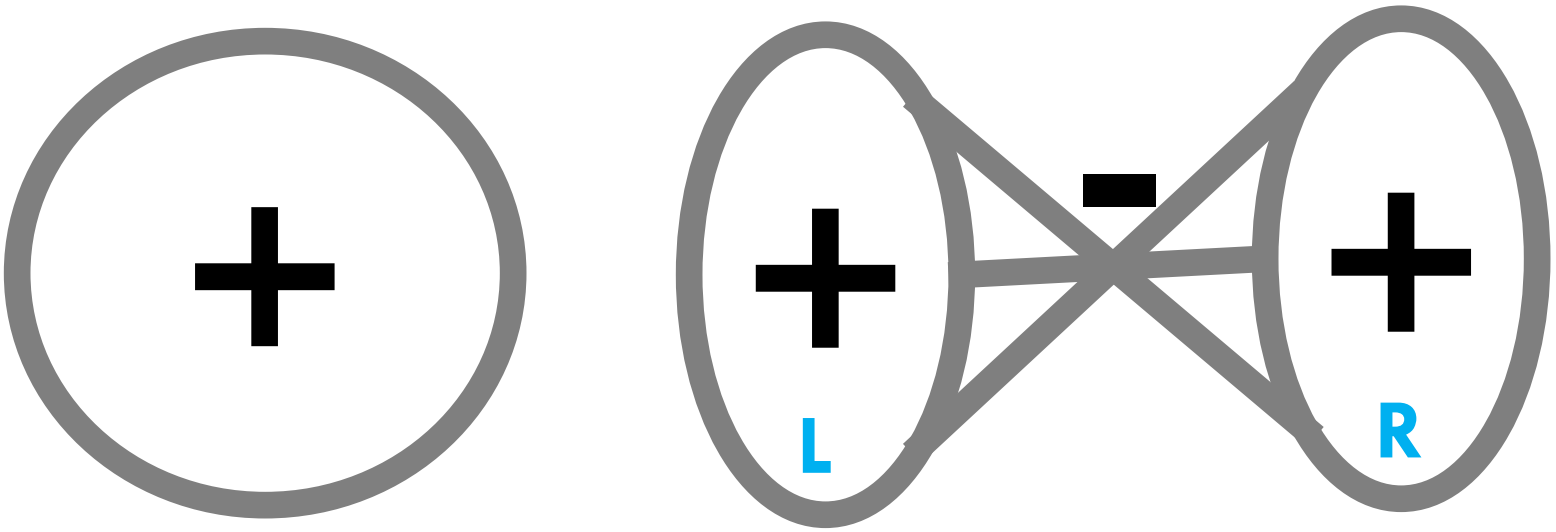
Unbalanced



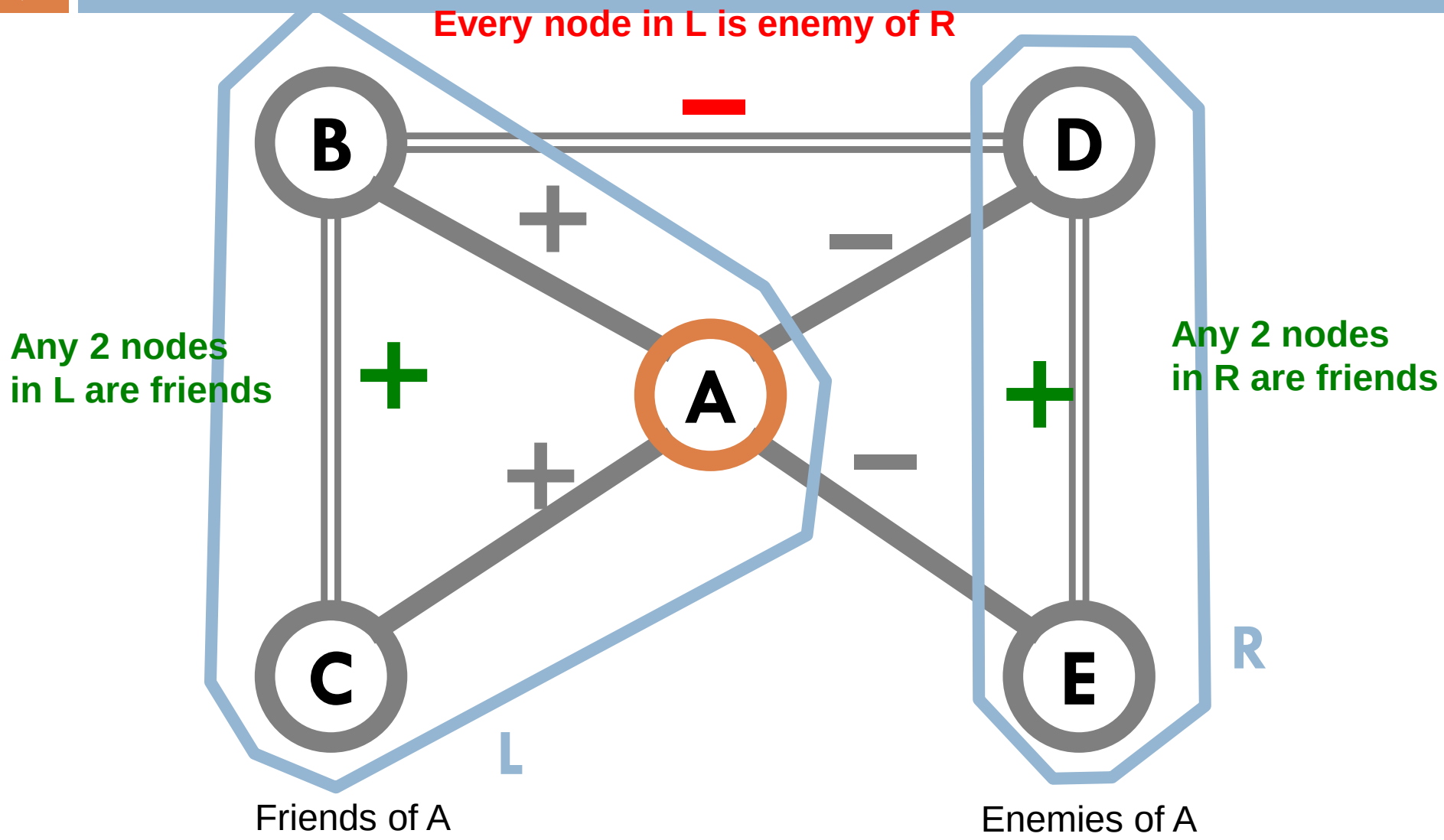
Balanced

Local Balance → Global Factions

- **Balance implies global coalitions** [Cartwright-Harary]
- If **all triangles are balanced**, then either:
  - The network contains only positive edges, or
  - Nodes can be split into 2 sets where negative edges only point between the sets

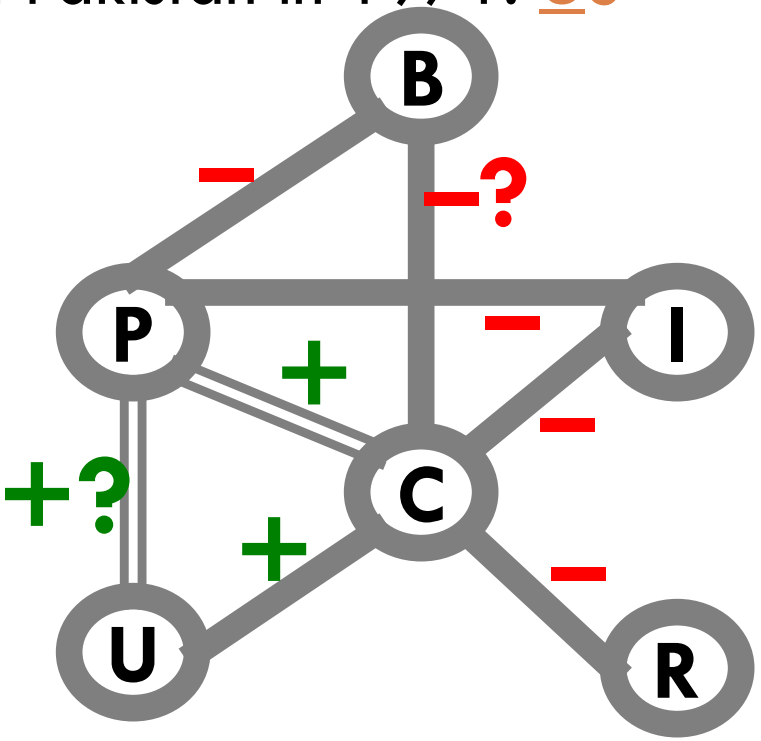


Analysis of Balance

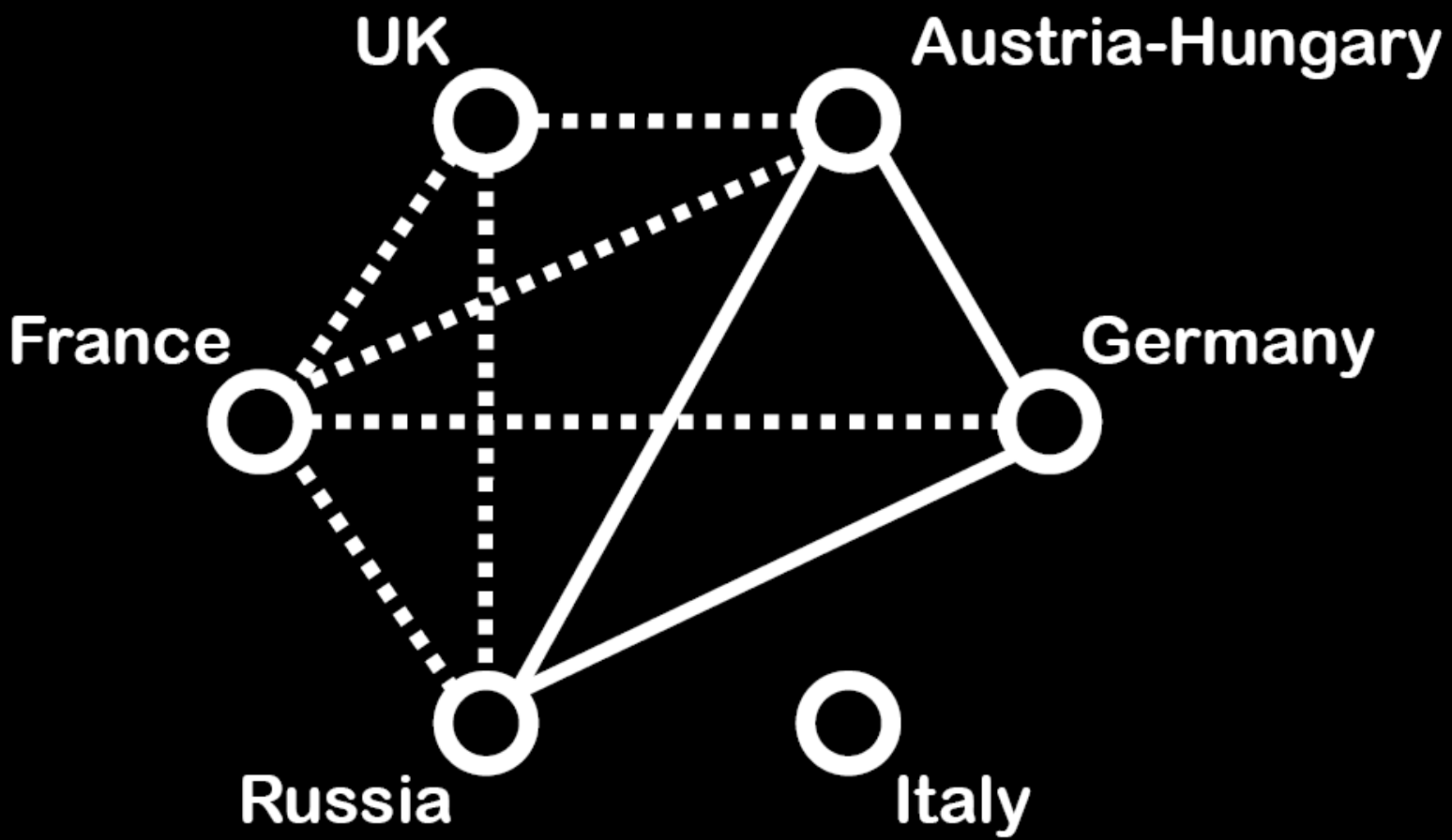


Example: International Relations

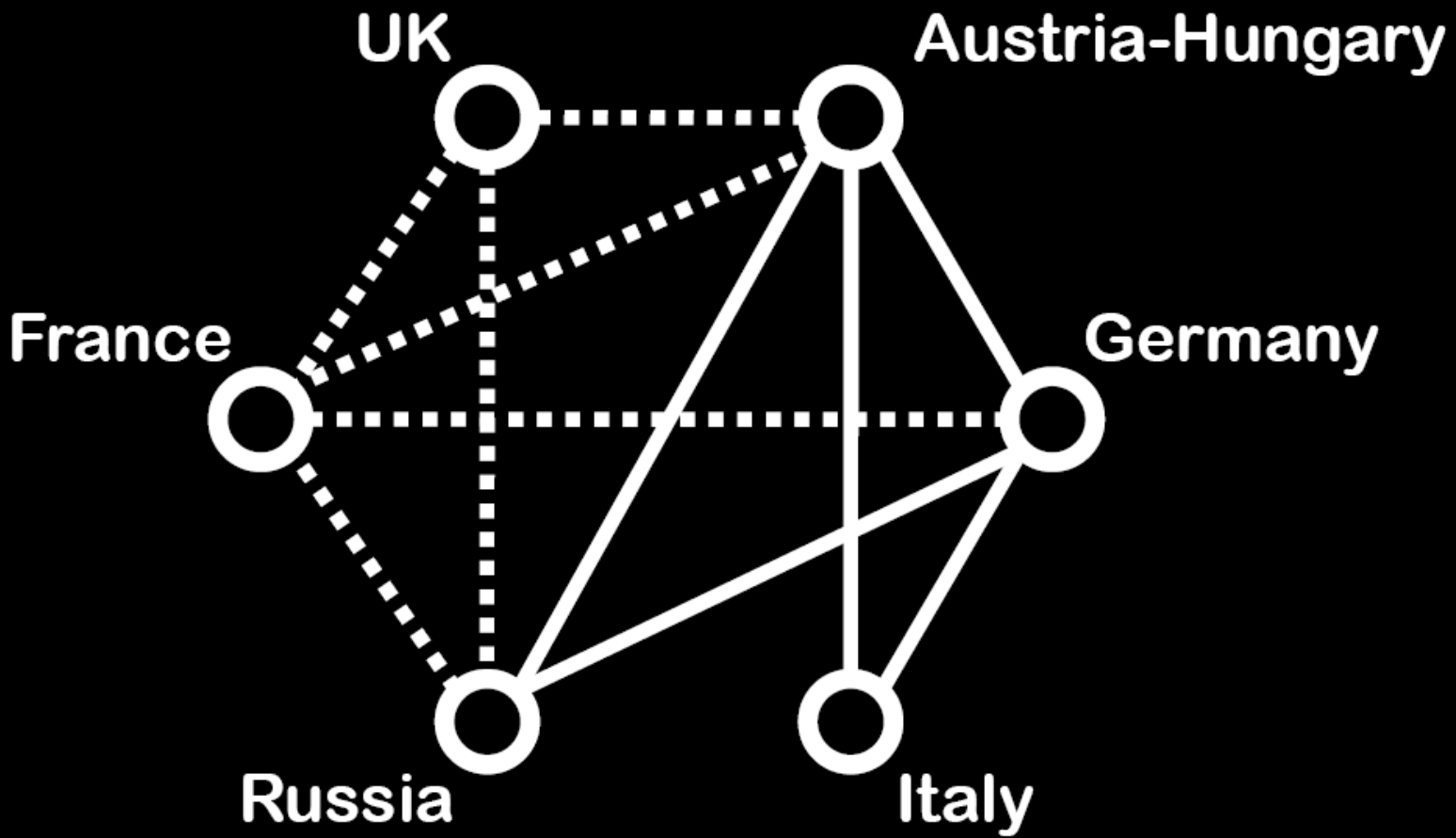
- **International relations:**
  - **Positive** edge: alliance
  - **Negative** edge: animosity
- Separation of Bangladesh from Pakistan in 1971: US supports Pakistan. **Why?**
  - USSR was enemy of China
  - China was enemy of India
  - India was enemy of Pakistan
  - US was friendly with China
  - China vetoed Bangladesh from U.N.



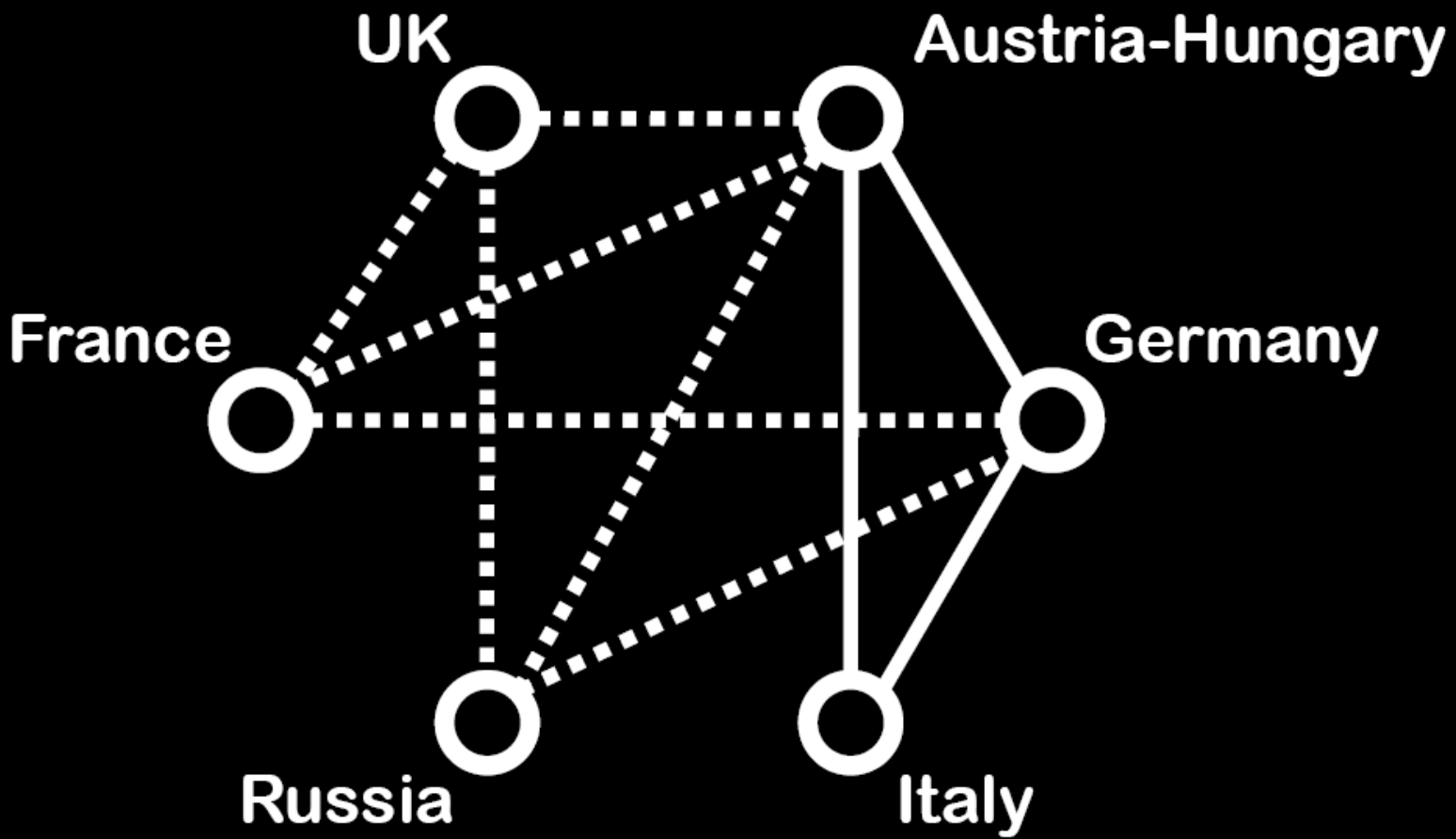
1872-1881



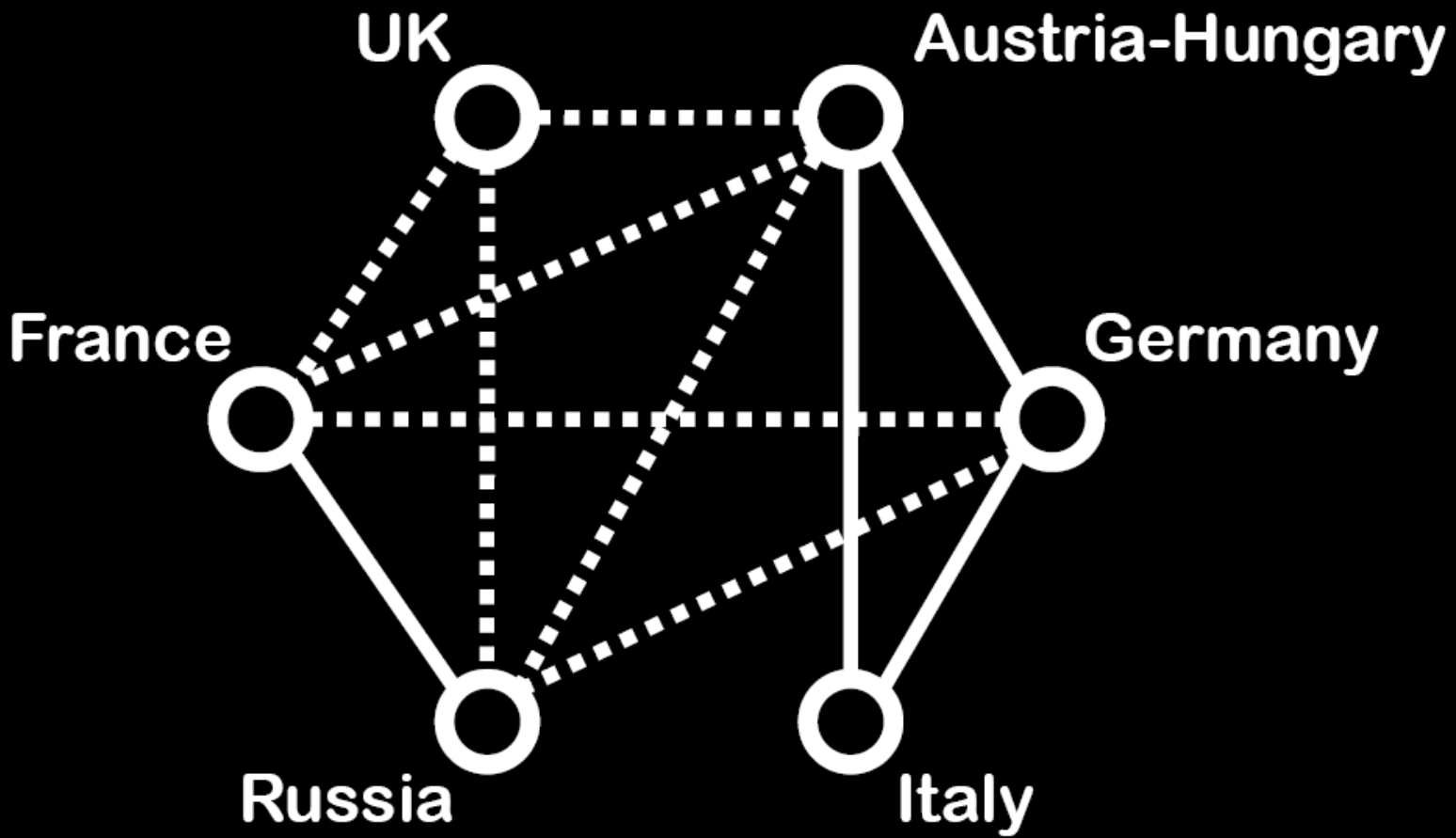
1882



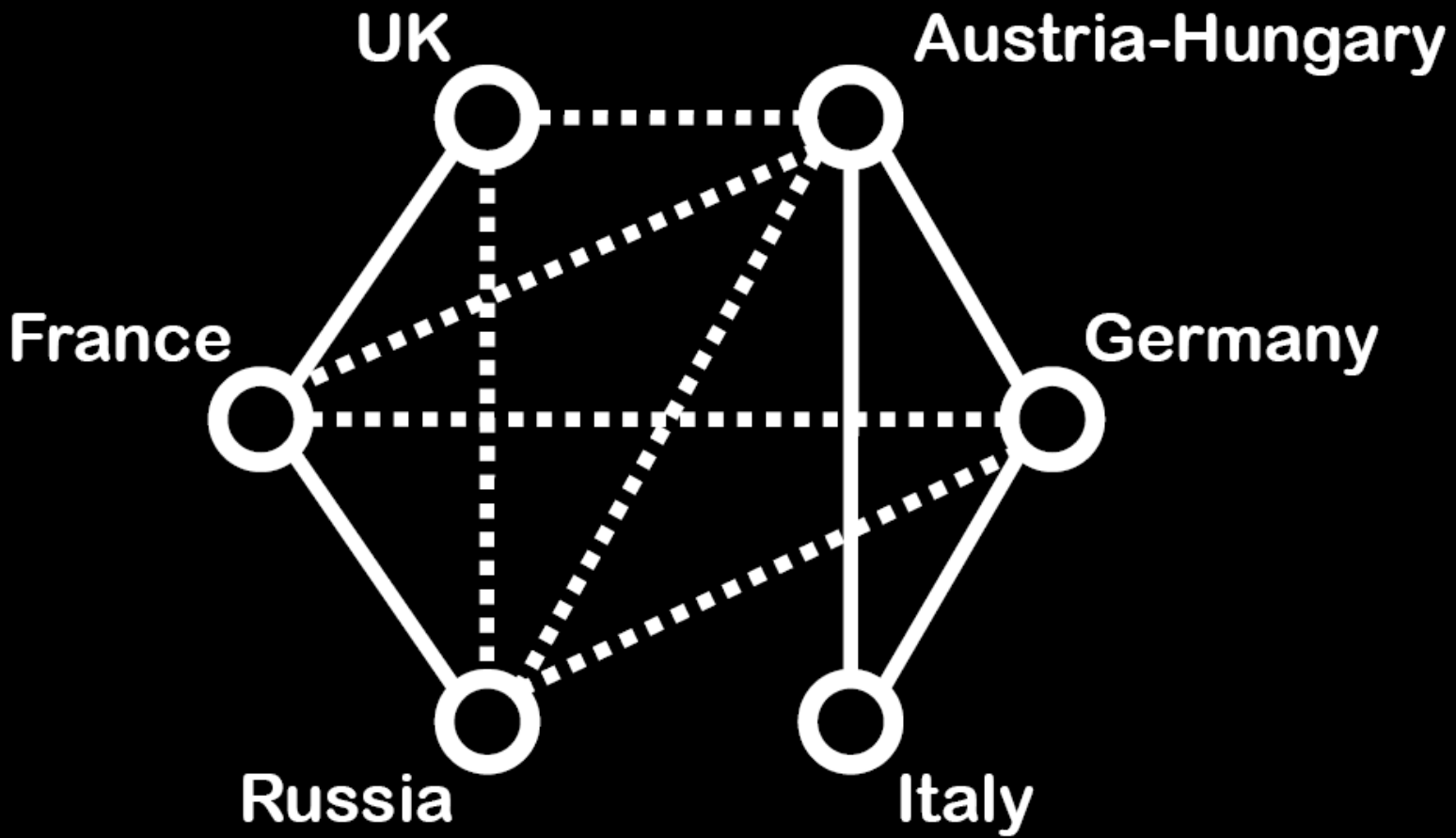
1890



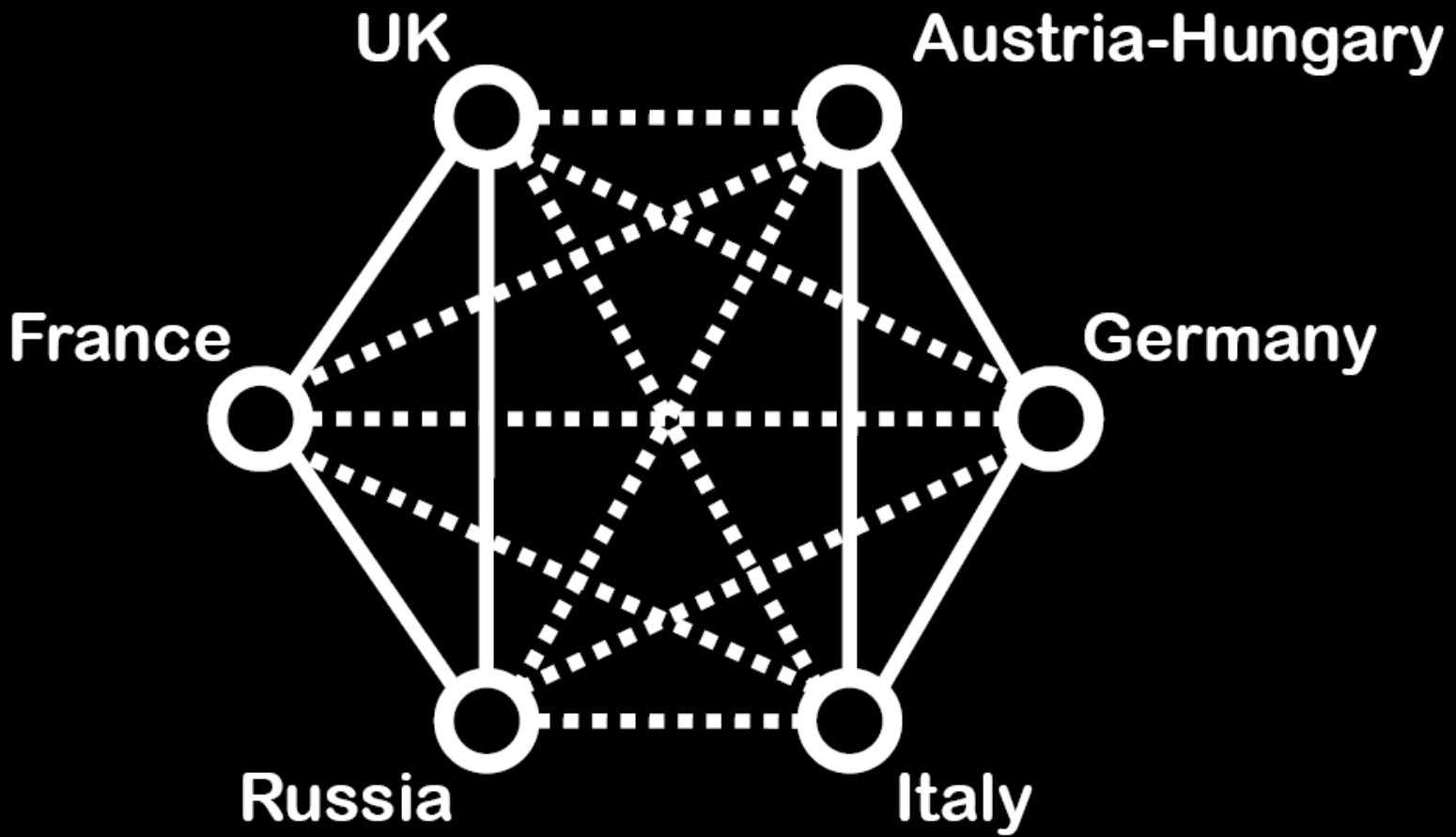
1891-1894



1904

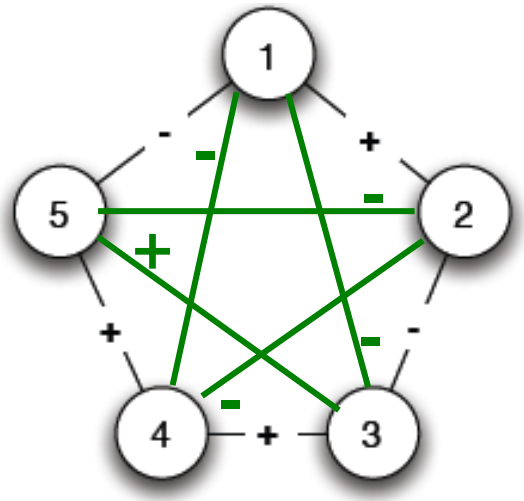


1907



Balance in General Networks

- So far we talked about complete graphs



Balanced?

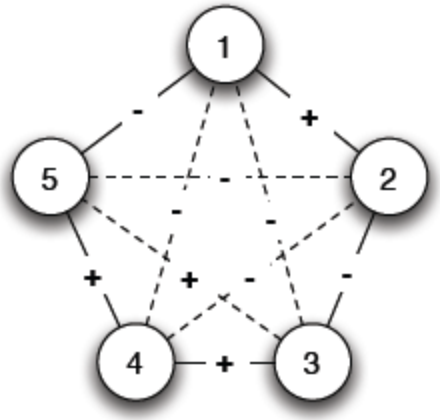
Def 1: Local view

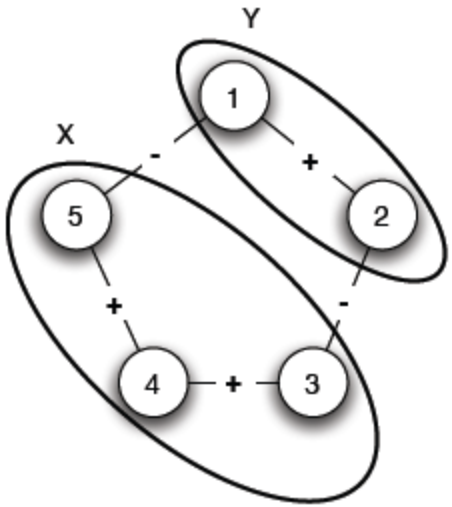
Fill in the missing edges to achieve balance

Def 2: Global view

Divide the graph into two coalitions

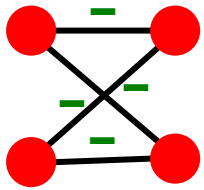
The 2 definitions are equivalent!



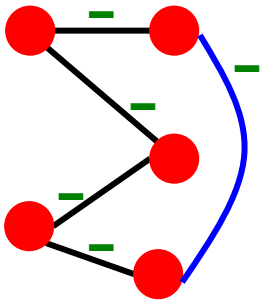


Is a Signed Network Balanced?

- Graph is **balanced** if and only if it contains **no cycle with an odd number of negative** edges
- **How to compute this?**
  - Find connected components on + edges
    - If we find a component of nodes on +edges that contains a –edge ⇒ **Unbalanced**
  - For each component create a super-node
  - Connect components A and B if there is a negative edge between the members
  - Assign super-nodes to sides using BFS

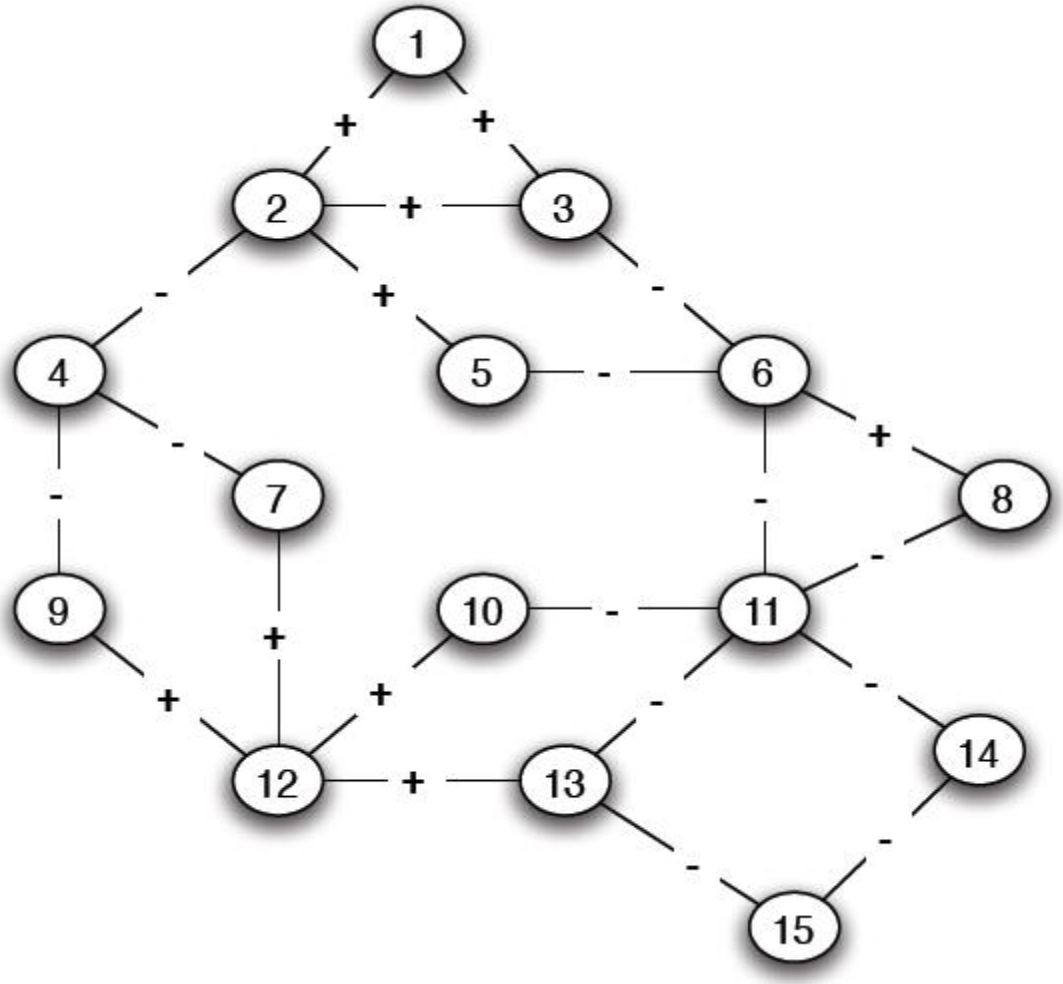


Even length cycle

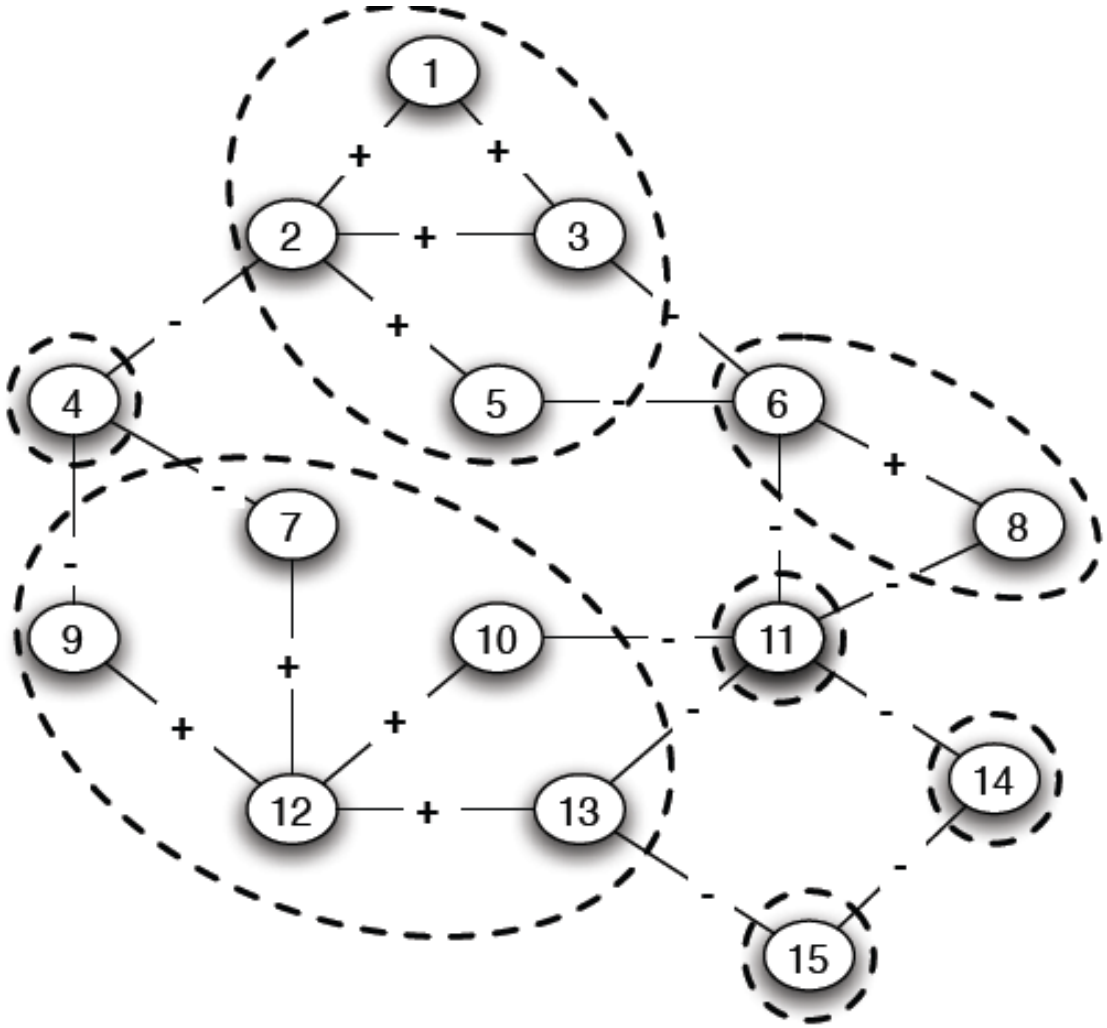


Odd length cycle

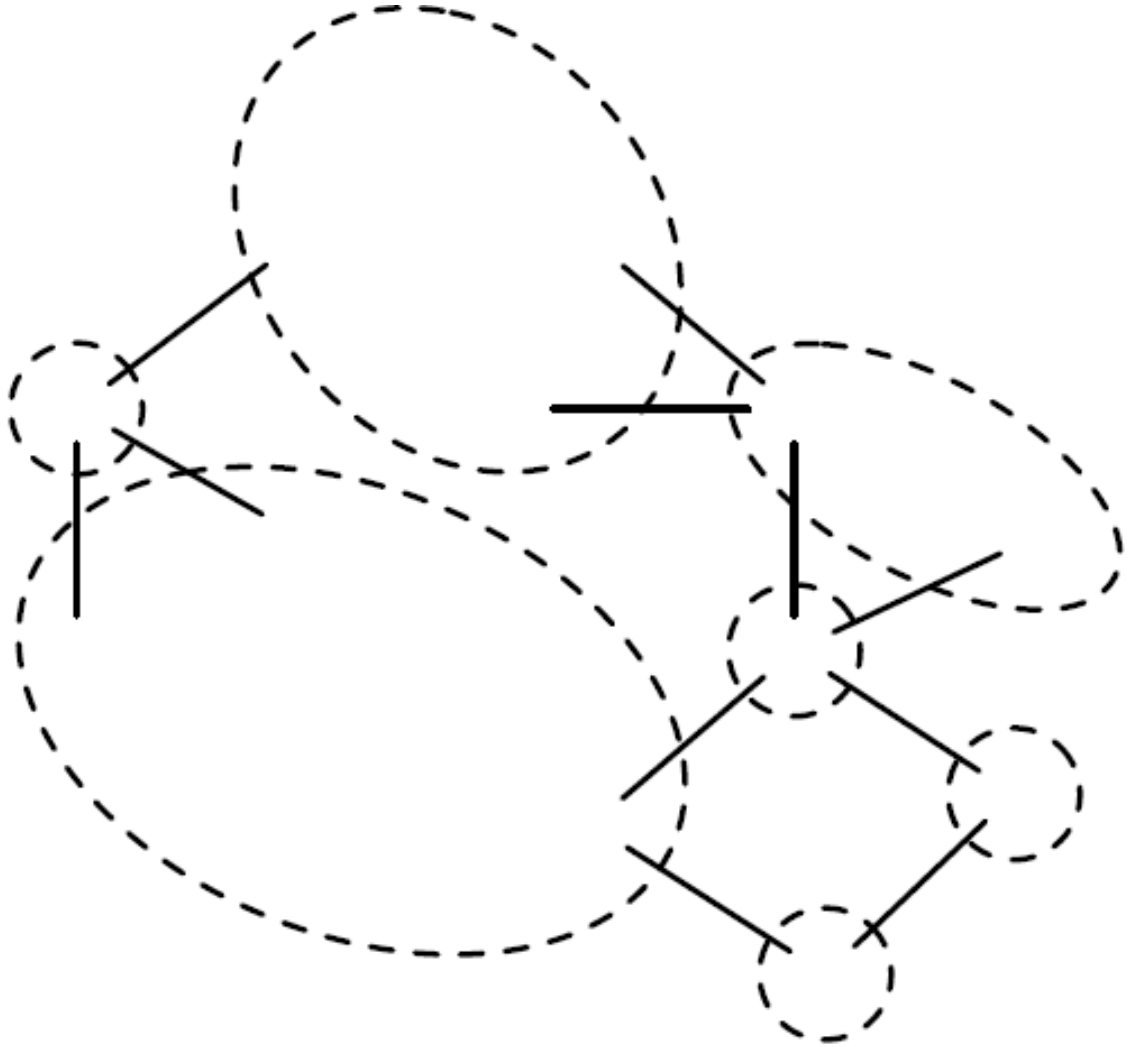
Signed Graph: Is it Balanced?



Positive Connected Components

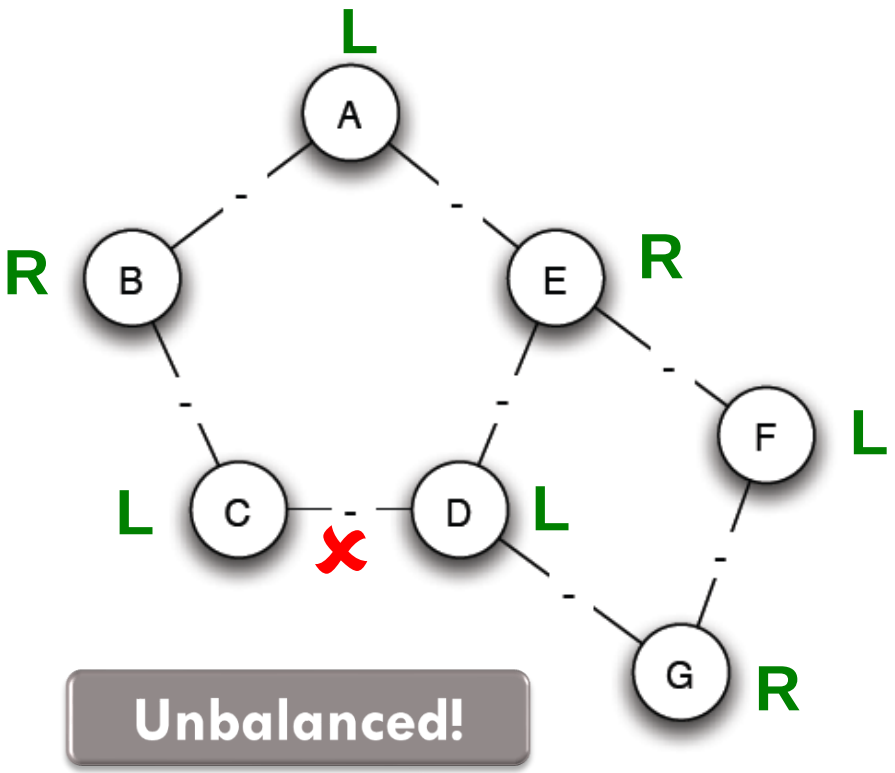


Reduced Graph on Super-Nodes



BFS on Reduced Graph

- Using BFS assign each node a **side**
- Graph is **unbalanced** if any two super-nodes are assigned the **same side**

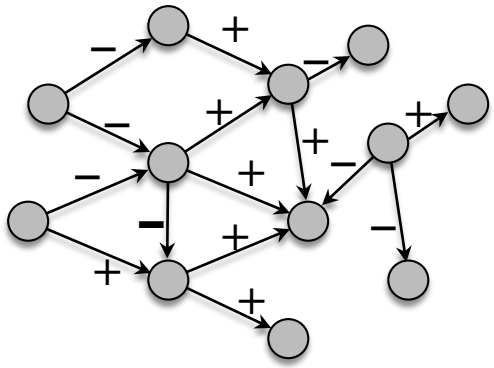


EXPLORING REAL DATA

4/7/2022

Real Large Signed Networks

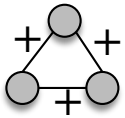
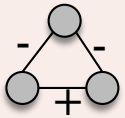
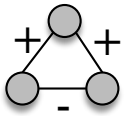
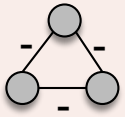
- Each link A→B is **explicitly** tagged with a sign:
  - **Epinions:** Trust/Distrust
    - Does A trust B's product reviews?
      (only positive links are visible)
  - **Wikipedia:** Support/Oppose
    - Does A support B to become Wikipedia administrator?
  - **Slashdot:** Friend/Foe
    - Does A like B's comments?
  - **Other examples:**
    - Online multiplayer games



	Epinions	Slashdot	Wikipedia
Nodes	119,217	82,144	7,118
Edges	841,200	549,202	103,747
+ edges	85.0%	77.4%	78.7%
− edges	15.0%	22.6%	21.2%

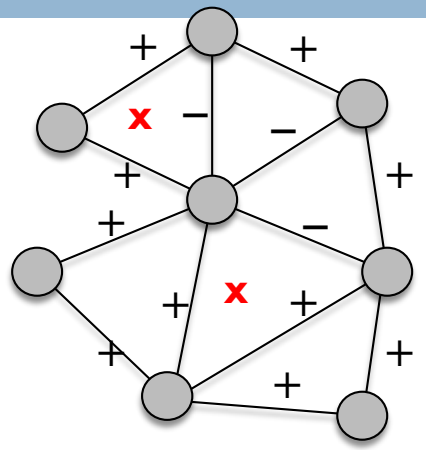
Balance in Network Data

- **Does structural balance hold?**
  - Compare frequencies of signed triads in real and "shuffled" data

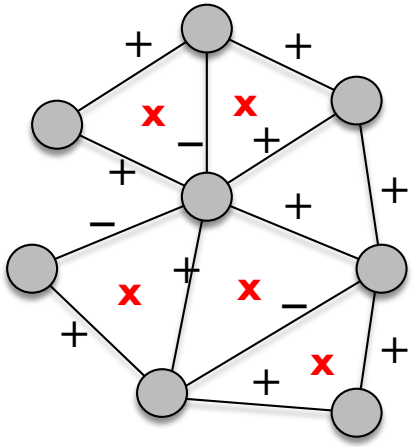
	Triad	Epinions		Wikipedia		Consistent with Balance?
		P(T)	$P_0(T)$	P(T)	$P_0(T)$	
Balanced		0.87	0.62	0.70	0.49	✓
Balanced		0.07	0.05	0.21	0.10	✓
Unbalanced		0.05	0.32	0.08	0.49	✓
Unbalanced		0.007	0.003	0.011	0.010	✗

P(T) … fraction of a triads

$P_0(T)$… triad fraction if the signs would be random



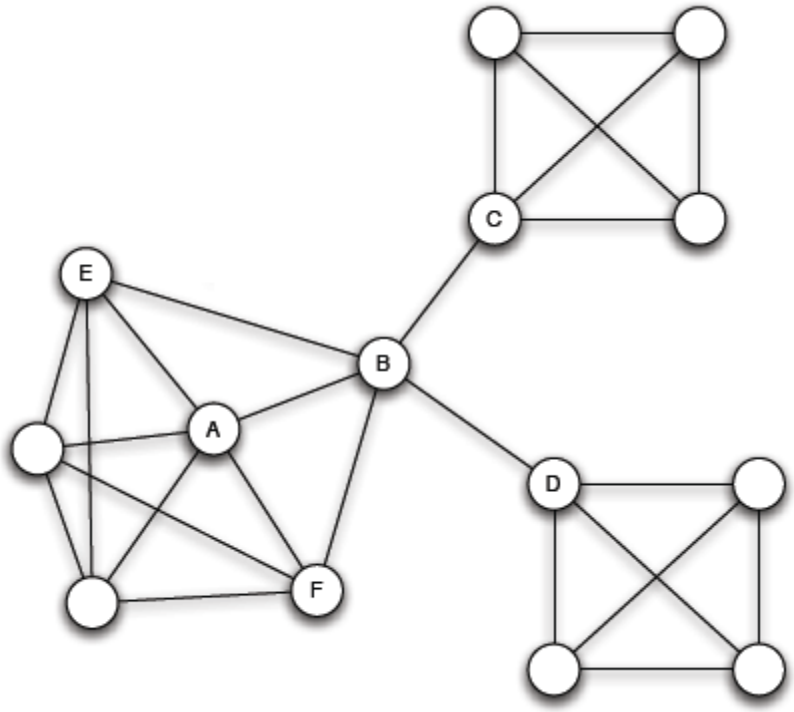
Real data



Shuffled data

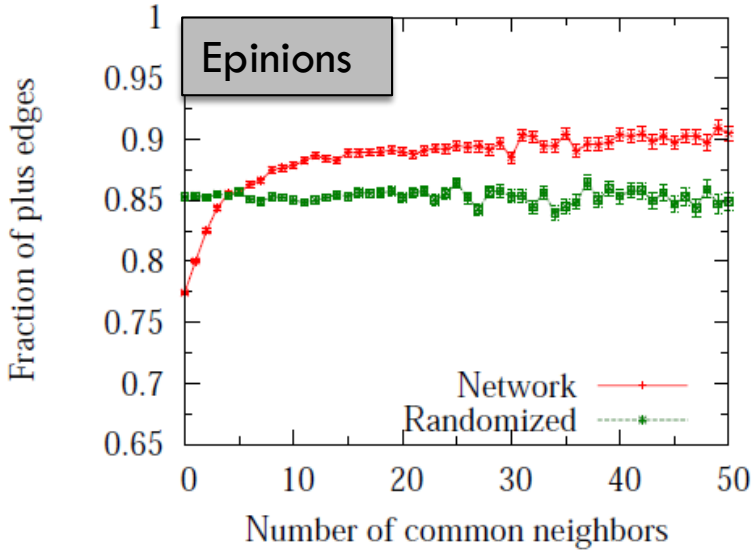
Global Structure of Signed Nets

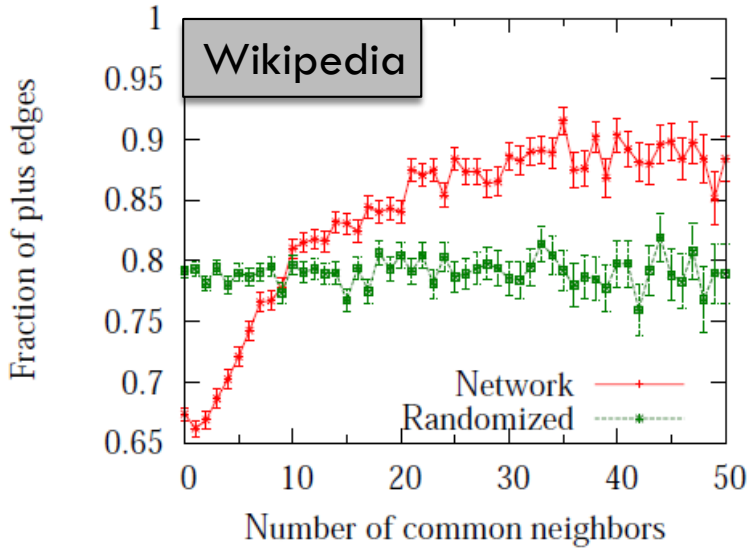
- Intuitive picture of social network in terms of densely linked clusters
- **How does structure interact with links?**
- **Embeddedness of link (A,B):** Number of shared neighbors



Global Factions: Embeddedness

- **Embeddedness of ties:**
  - Positive ties tend to be more embedded
- Positive ties tend to be more clumped together
  - Public display of signs (votes) in Wikipedia further attenuates this

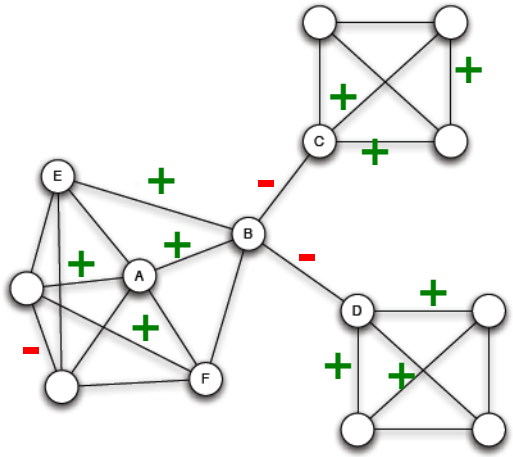




Global Structure of Signed Nets

	Size		Clustering		Component	
	Nodes	Edges	Real	Rnd	Real	Rnd
Epinions: −	119,090	123,602	0.012	0.022	0.308	0.334
Epinions: +	119,090	717,027	0.093	0.077	0.815	0.870
Slashdot: −	82,144	124,130	0.005	0.010	0.423	0.524
Slashdot: +	82,144	425,072	0.025	0.022	0.906	0.909
Wikipedia: −	7,115	21,984	0.028	0.031	0.583	0.612
Wikipedia: +	7,115	81,705	0.130	0.103	0.870	0.918

- **Clustering:**
  - +net: More clustering than baseline
  - –net: Less clustering than baseline
- **Size of max. component:**
  - +/–net: Smaller than the baseline



Directed Edges

- But, our networks can be really directed
- How many Δ are now explained by balance?
- Only half (8 out of 16) explained by Balance
- Can we do better?
  - Yes. theory of status