Positive and Negative Relationships

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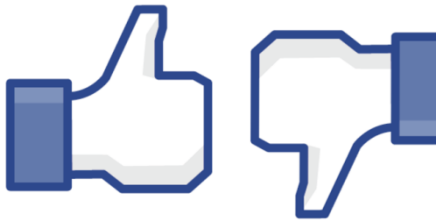
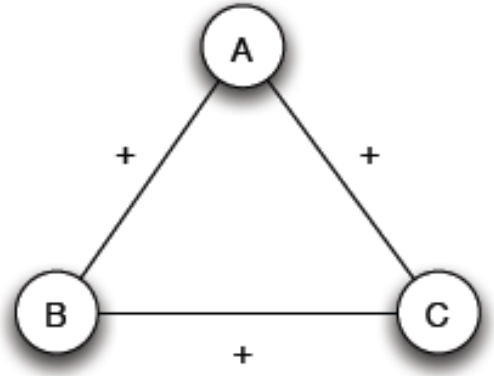


Redes com sinais

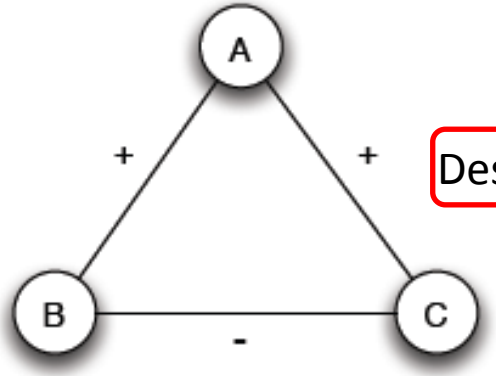
- Redes com relações positivas e negativas
- Considere um grafo completo não direcionado
- Cada aresta é rotulada como
  - Positiva: amigo, confiança, sentimento positivo
  - Negativa: inimigo, desconfiança, sentimento negativo
- Examine trios de nodos conectados

Structural Balance

Balanceado



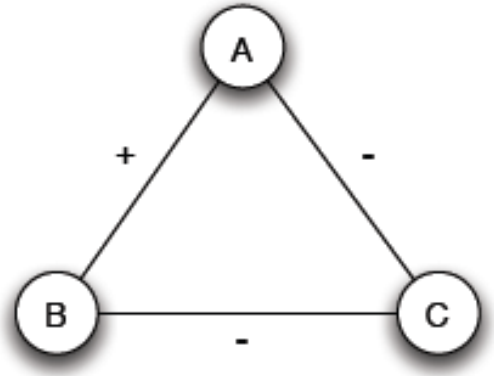
(a) *A, B, and C are mutual friends: balanced.*



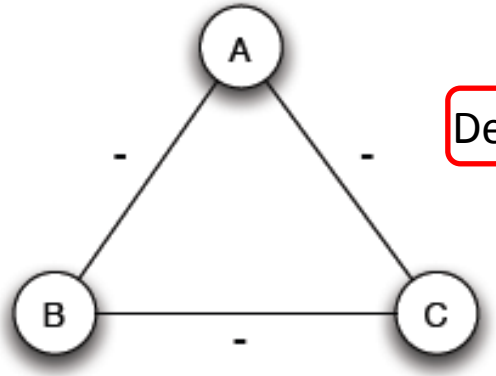
(b) *A is friends with B and C, but they don't get along with each other: not balanced.*

Desbalanceado

Balanceado



(c) *A and B are friends with C as a mutual enemy: balanced.*



(d) *A, B, and C are mutual enemies: not balanced.*

Desbalanceado

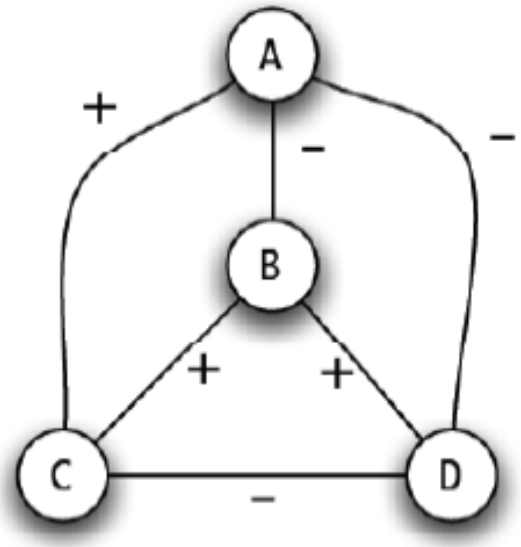
Figure 5.1: Structural balance: Each labeled triangle must have 1 or 3 positive edges.

Theory of Structural Balance

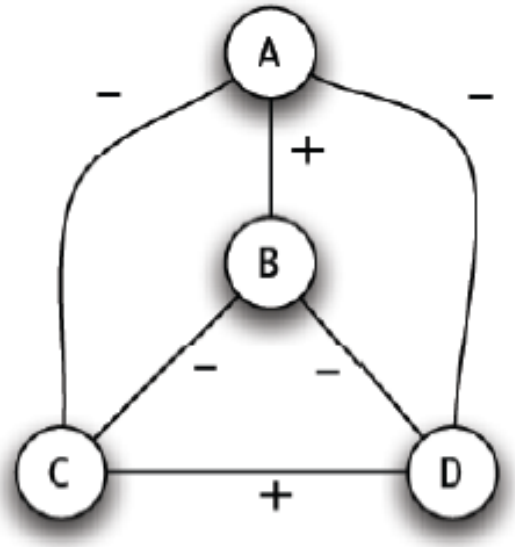
- Three-Node Signed Triads [Heider '46]

Balanced/unbalanced networks

- Graph is balanced if every connected triple of nodes has all 3 edges labeled +, or else exactly 1 edge is labeled +.



Unbalanced



Balanced

Um grafo balanceado pode ser dividido em dois grupos antagônicos

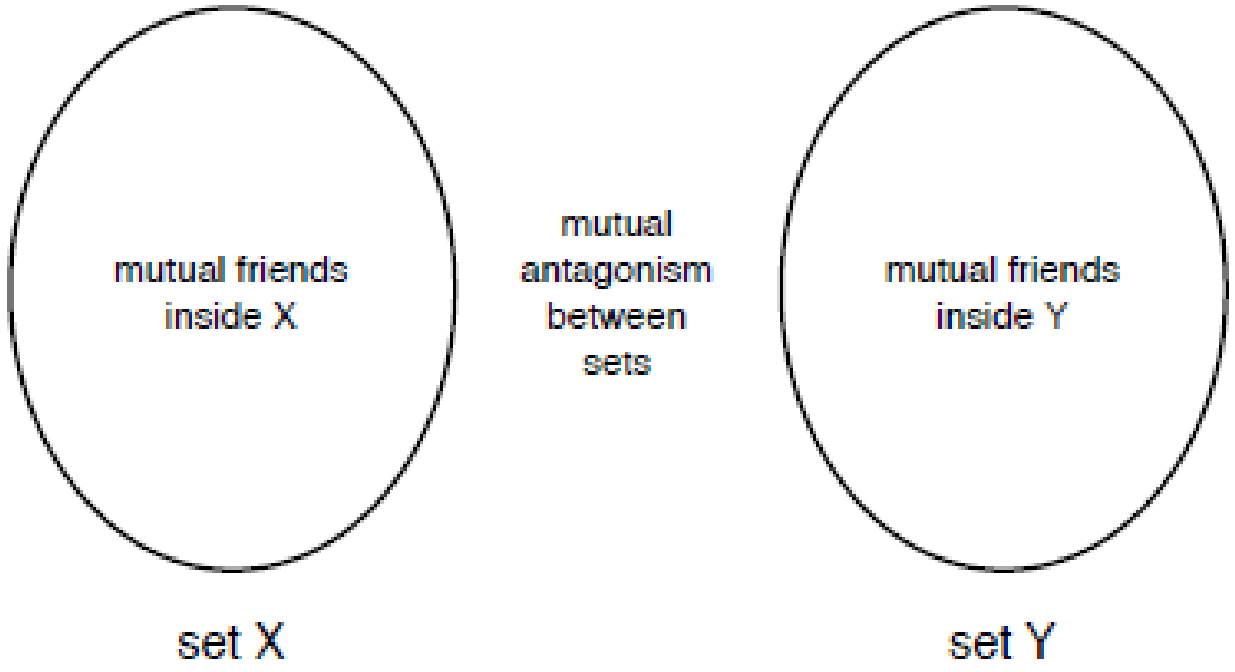
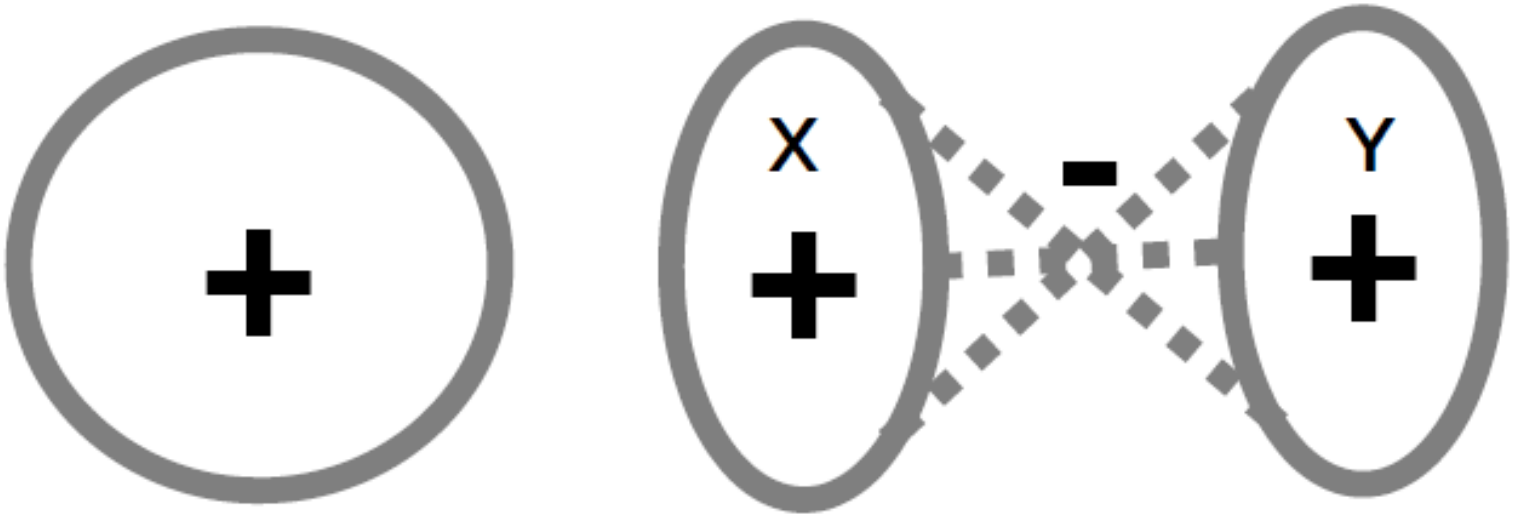


Figure 5.3: If a complete graph can be divided into two sets of mutual friends, with complete mutual antagonism between the two sets, then it is balanced. Furthermore, this is the only way for a complete graph to be balanced.

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 factions linked by negative edges



The Balance Theorem

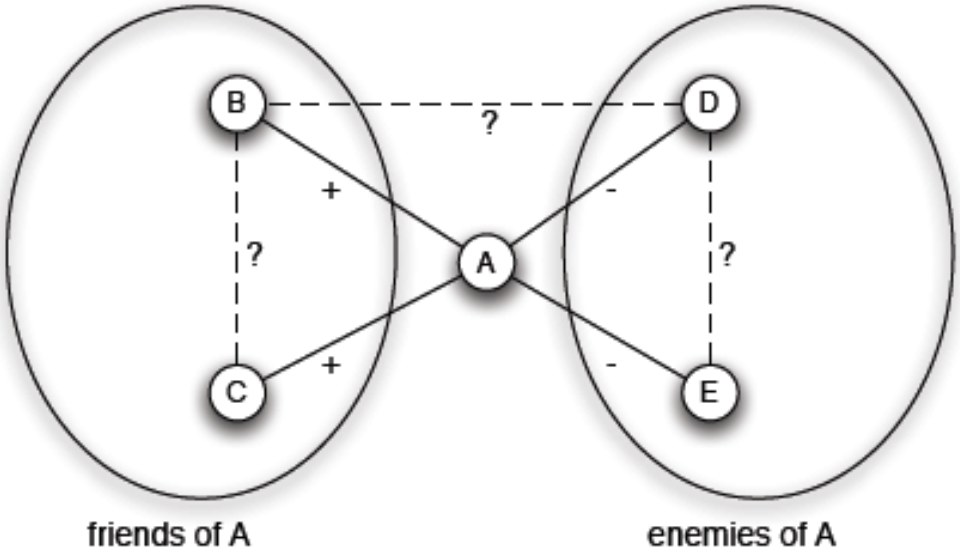
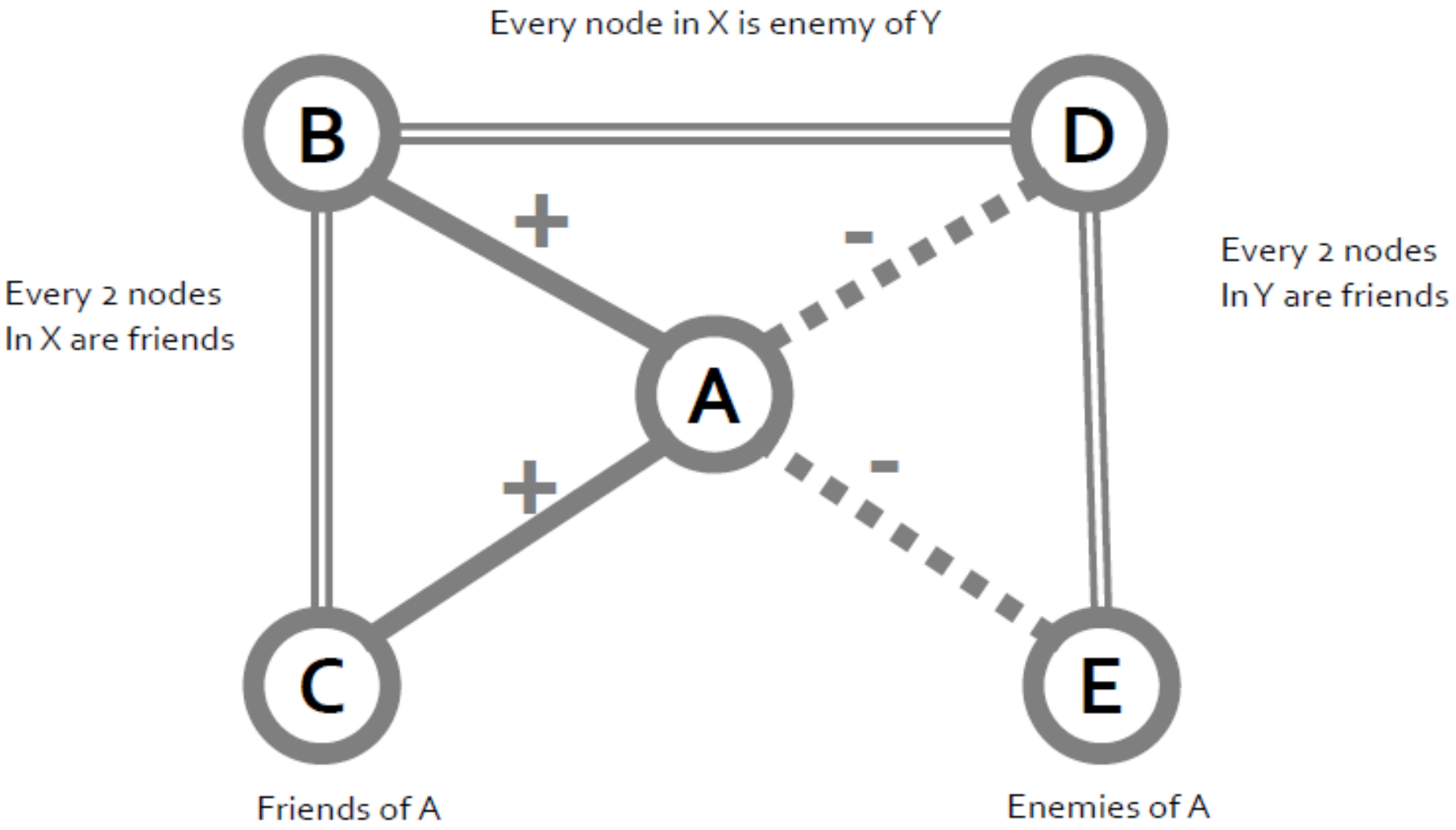
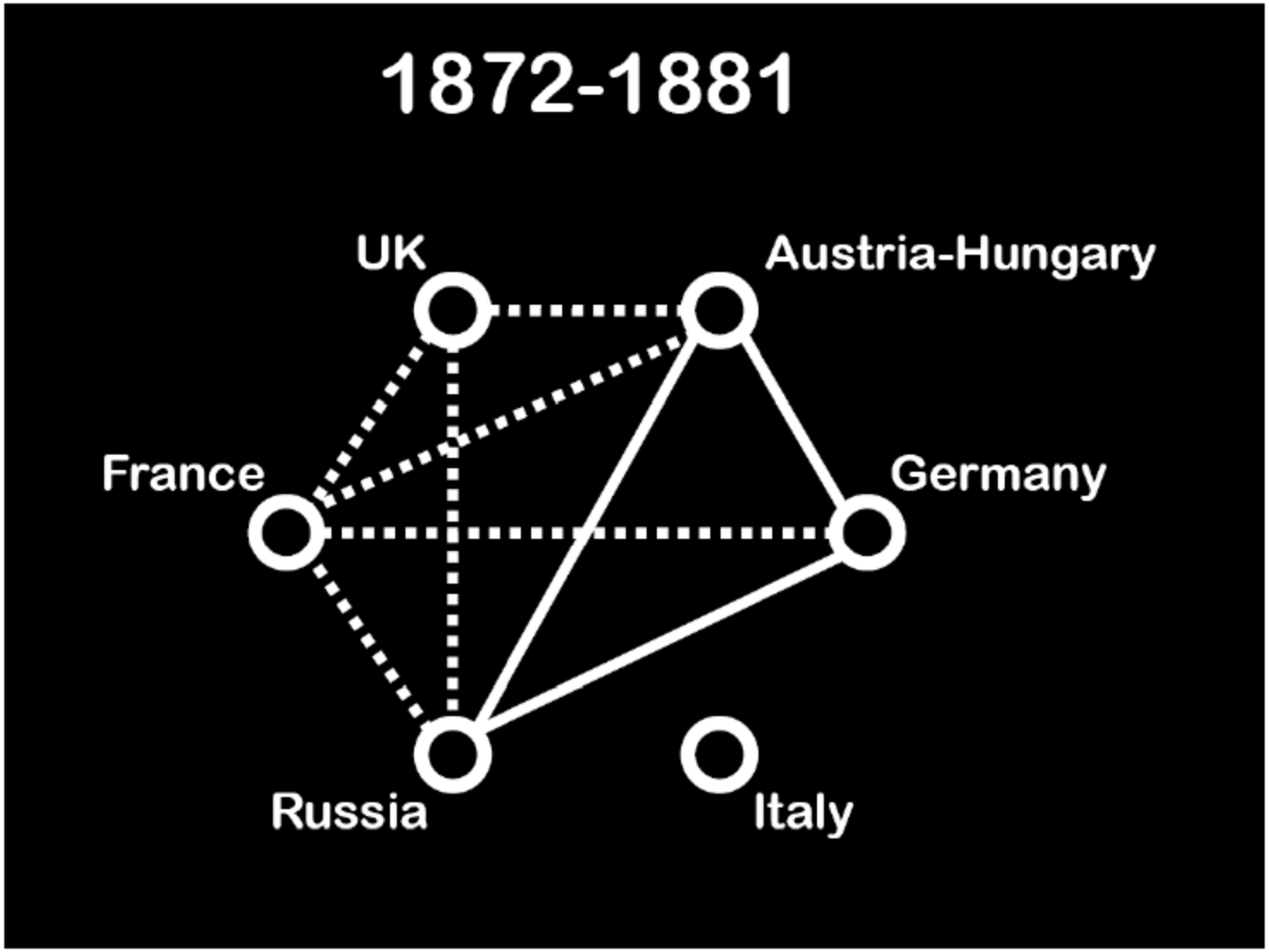
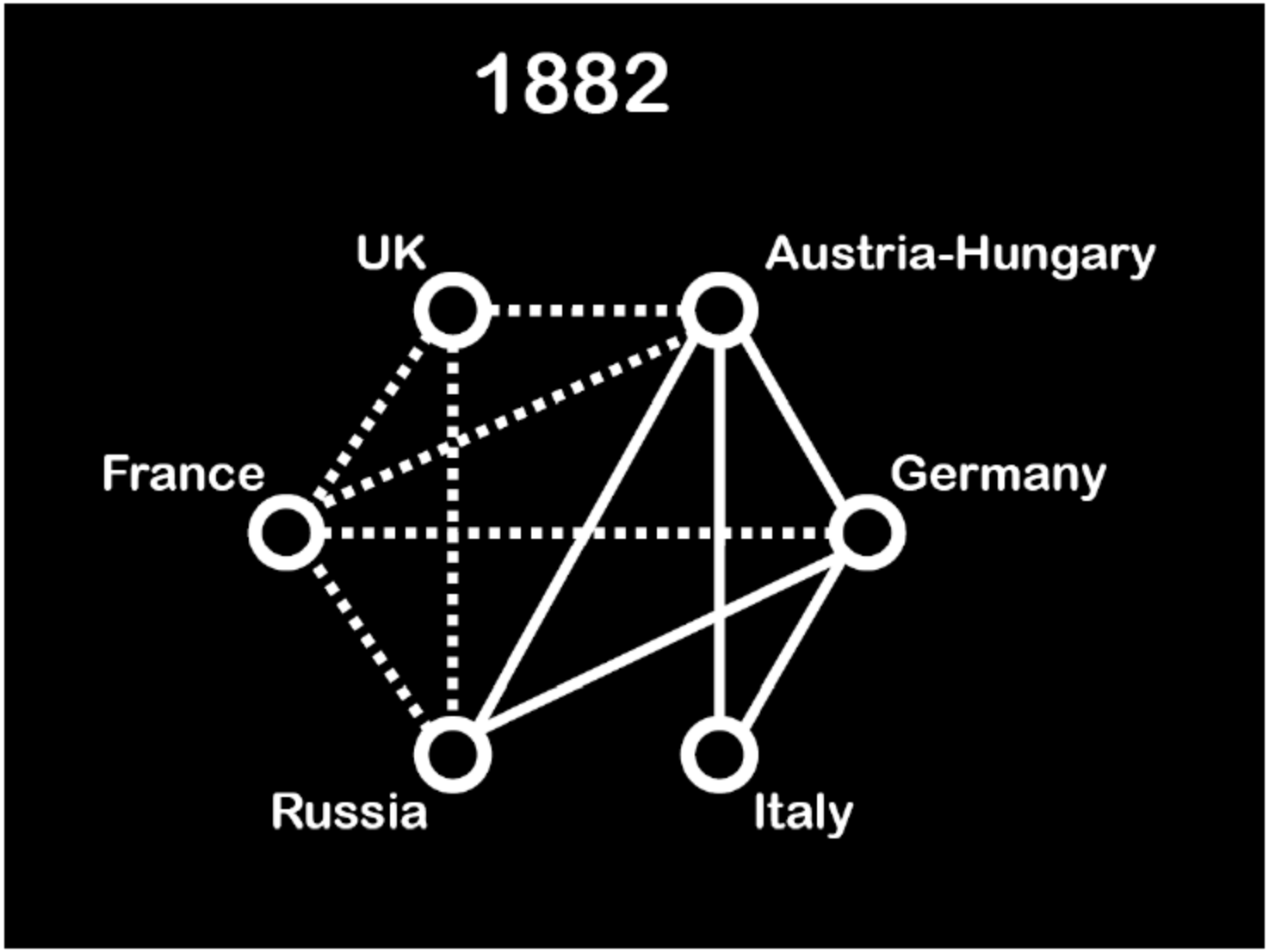


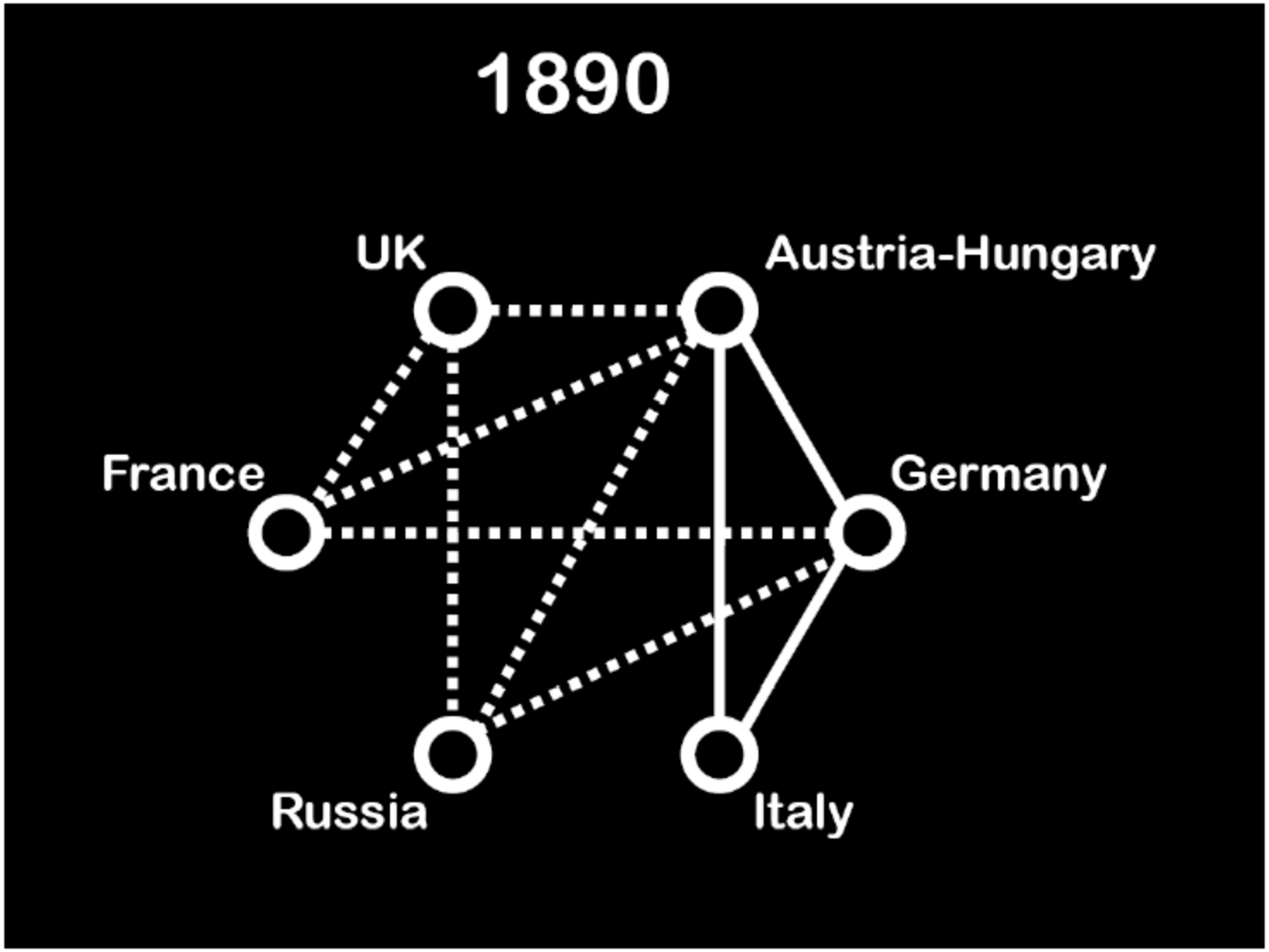
Figure 5.4: A schematic illustration of our analysis of balanced networks. (There may be other nodes not illustrated here.)

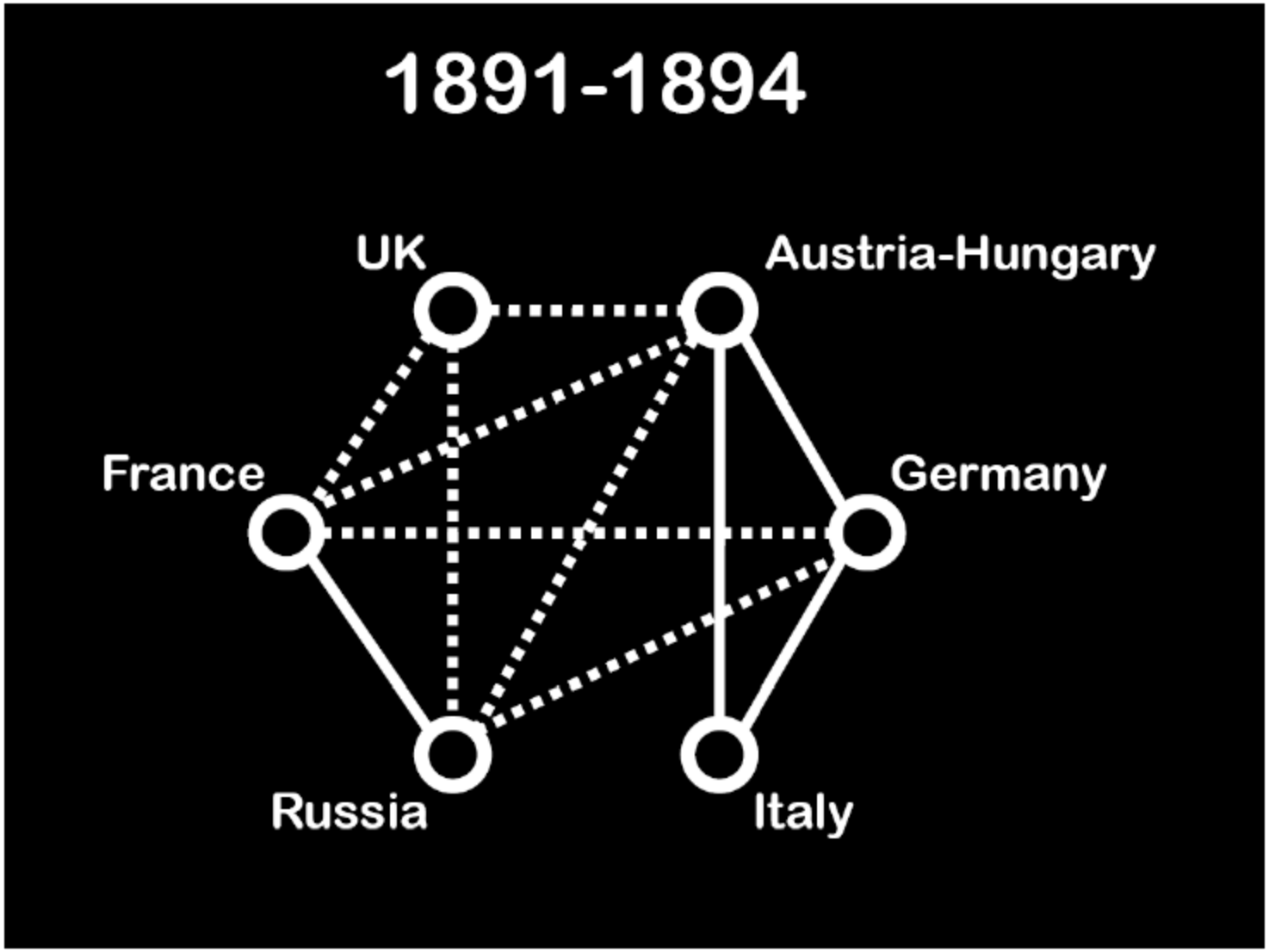
Analysis of balance

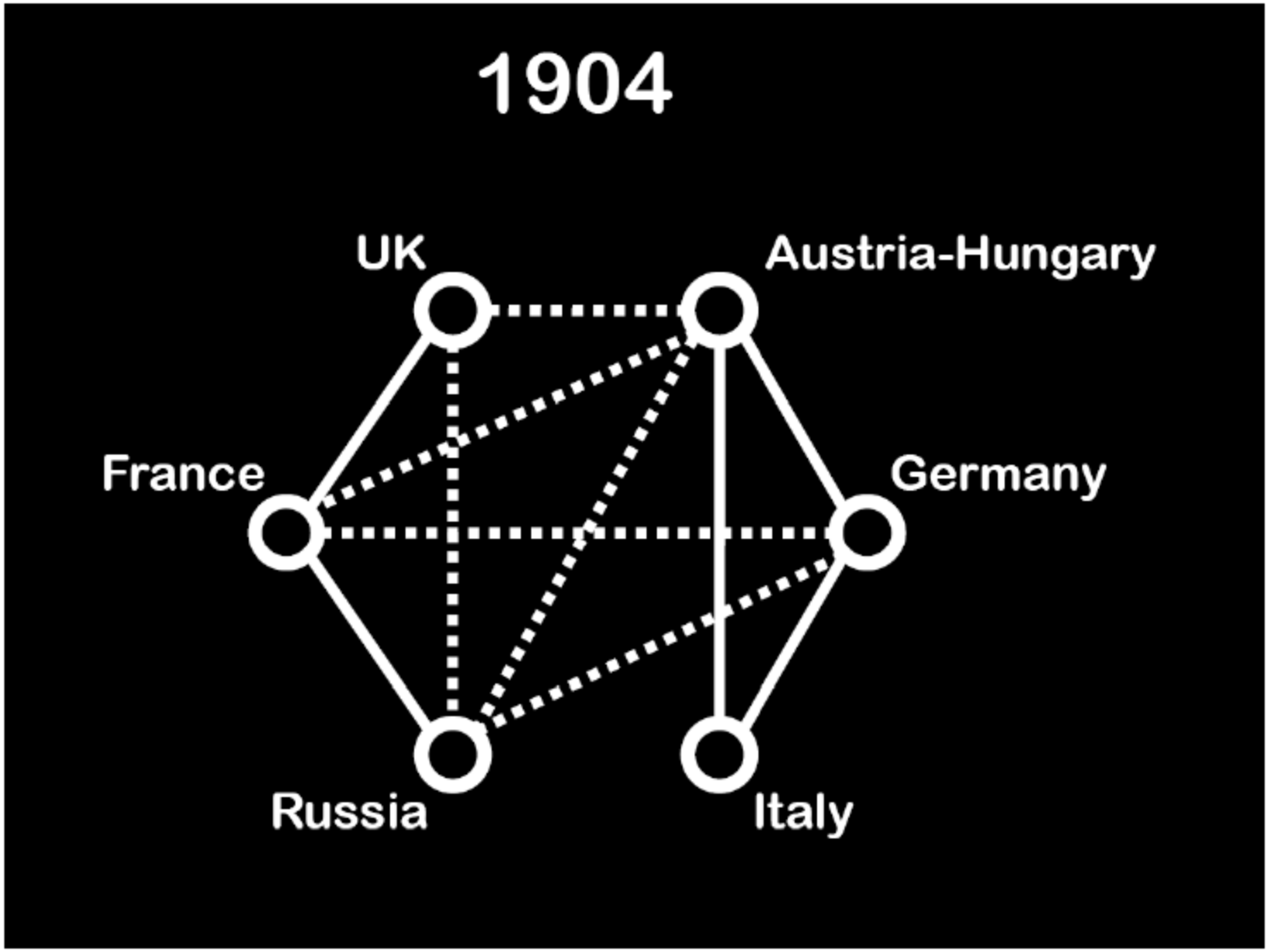


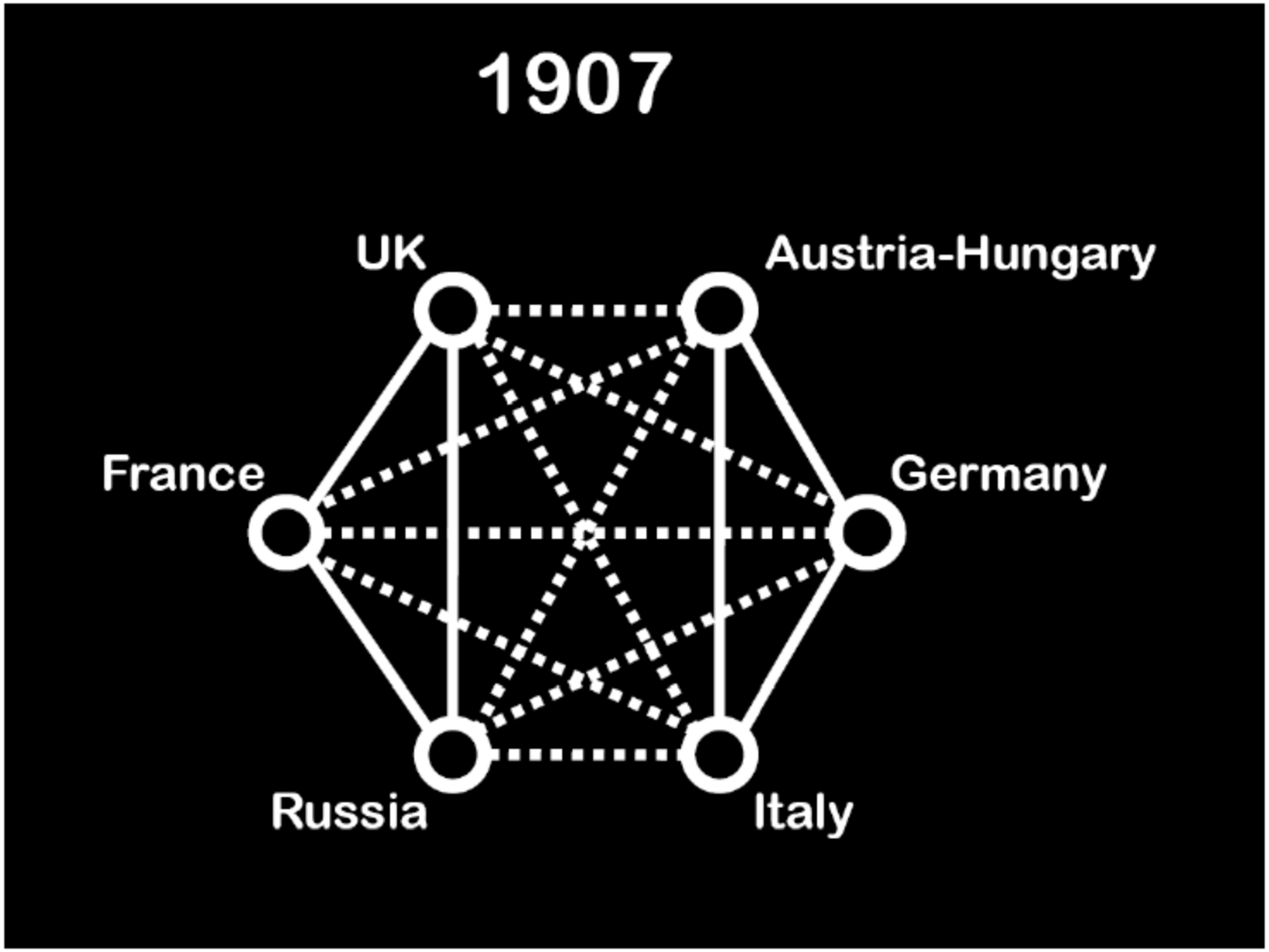

1872-1881
UK
Austria-Hungary
France
Germany
Russia
Italy


1882
UK
Austria-Hungary
France
Germany
Russia
Italy

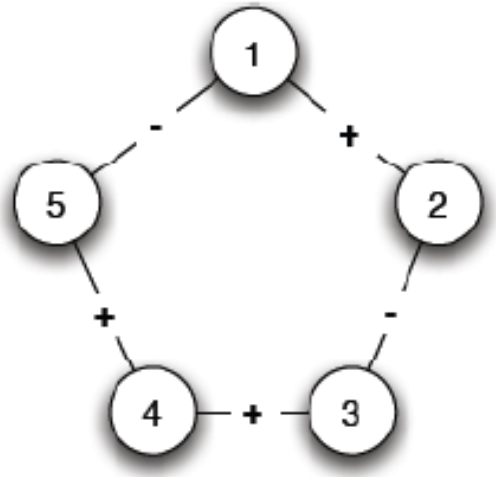

1890
UK
Austria-Hungary
France
Germany
Russia
Italy


1891-1894
UK
Austria-Hungary
France
Germany
Russia
Italy


1904
UK
Austria-Hungary
France
Germany
Russia
Italy

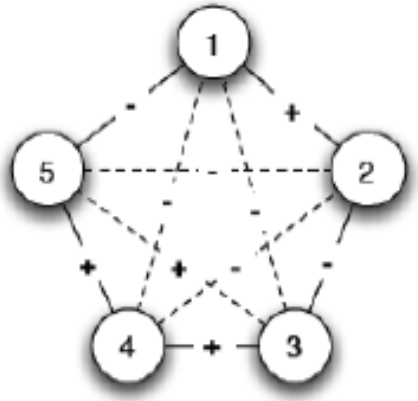

1907
UK
Austria-Hungary
France
Germany
Russia
Italy

Balance in general networks

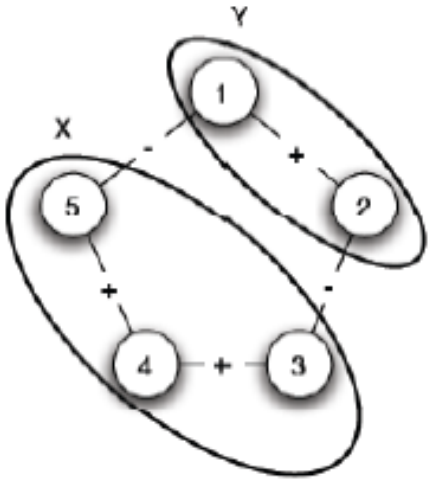


Balanced?

- Def 1: Local view
  - Fill in the missing edges to achieve balance



- Def 2: Global view
  - Divide the graph into two coalitions

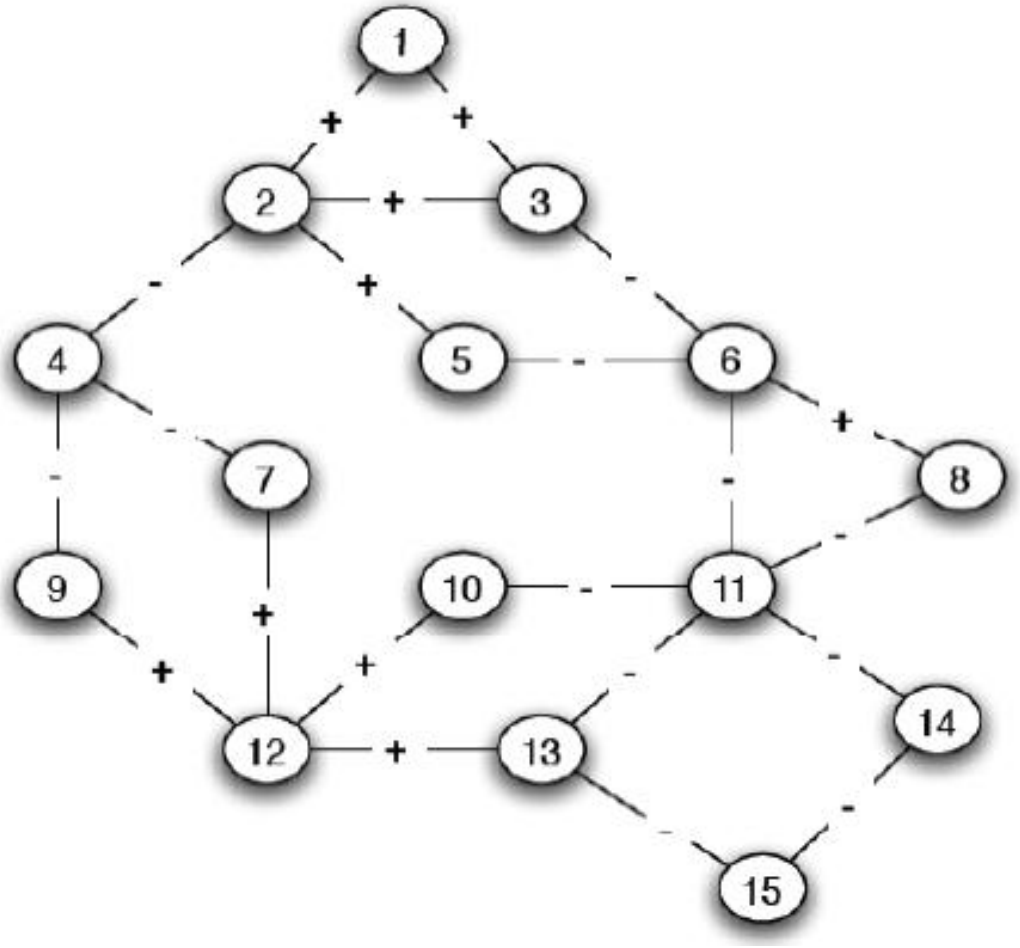


- Defs are equivalent!

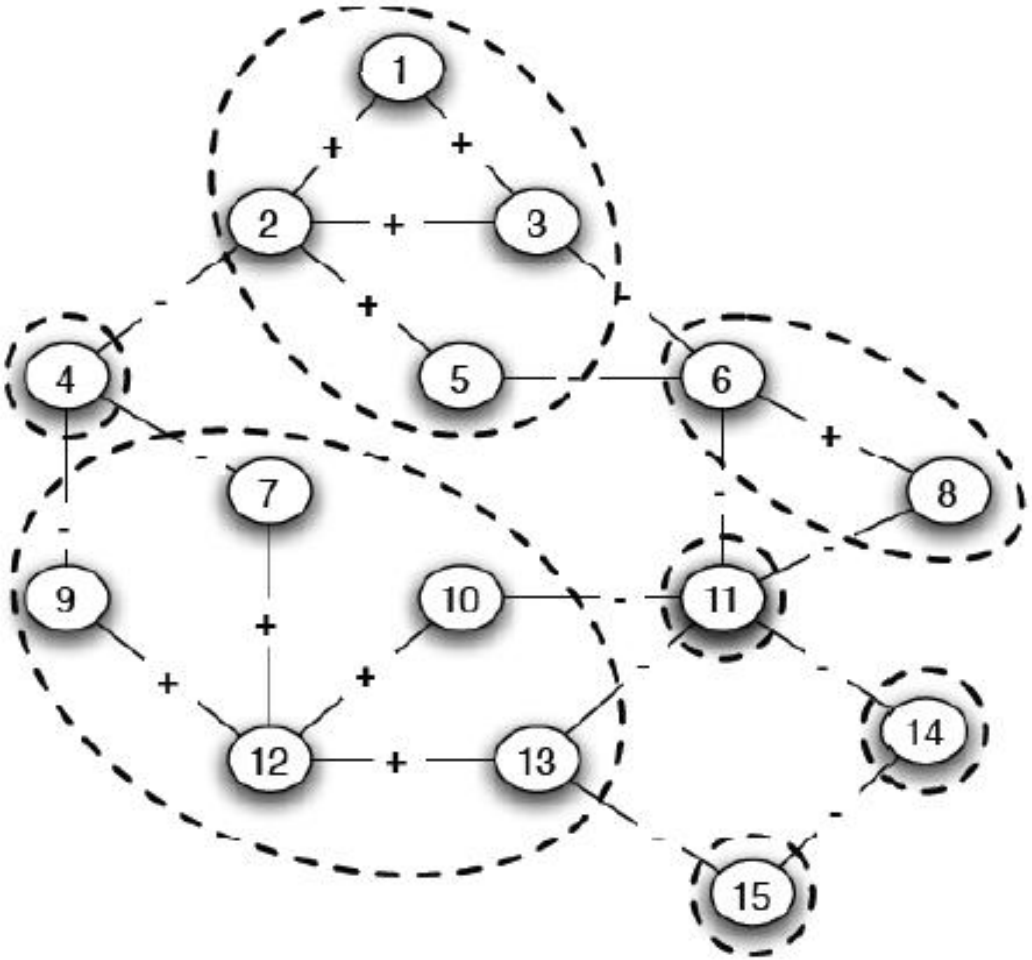
Is a signed network balanced?

- A 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
  - 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

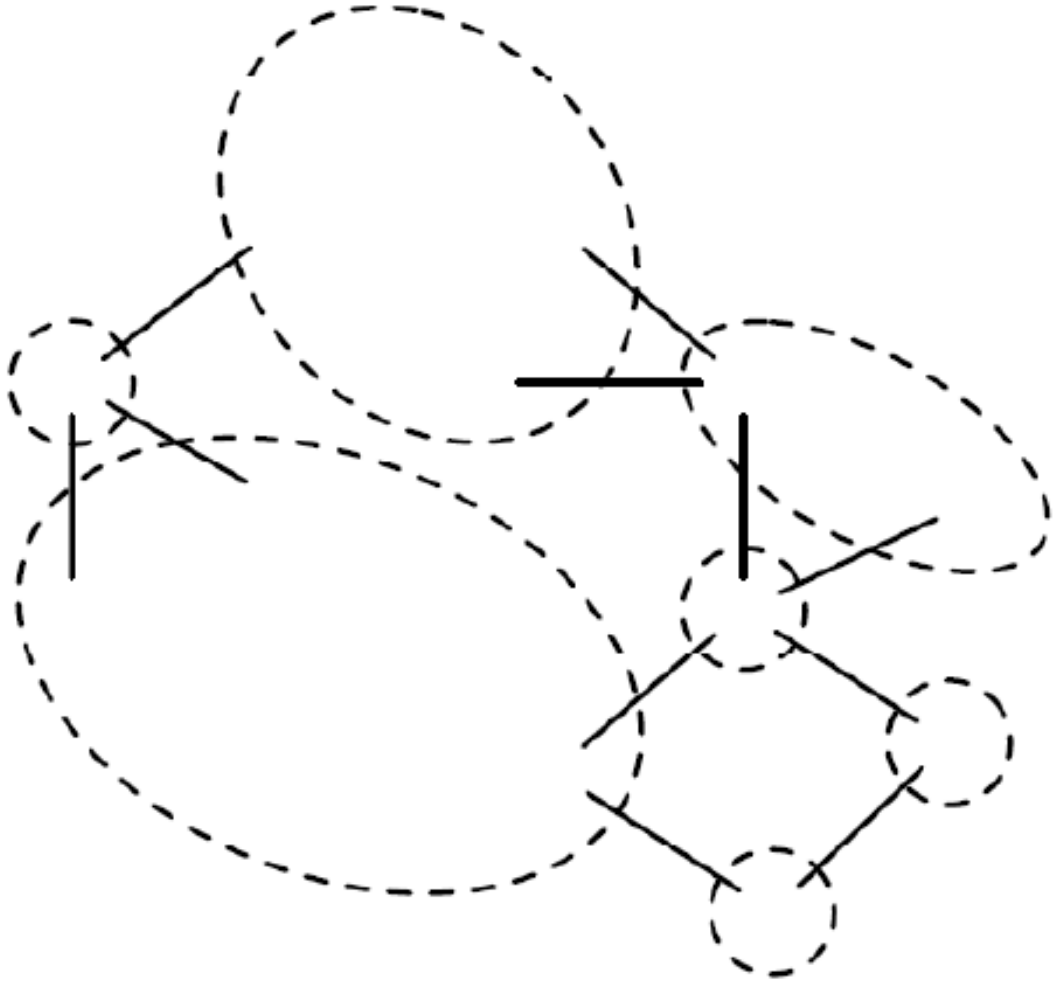
Signed Graph



Positive connected components

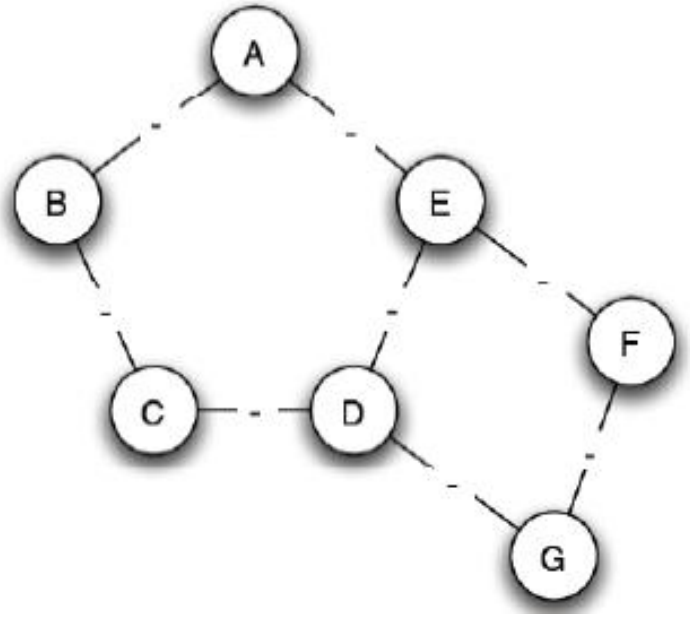


Reduced graph on super nodes



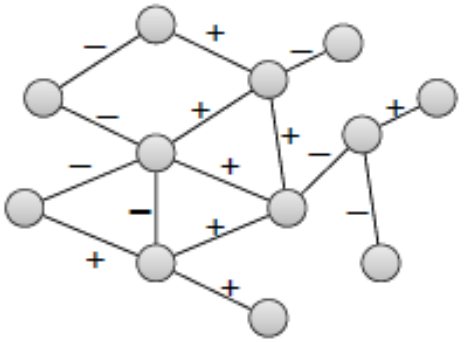
BFS on reduced graph

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



Real Large Signed Networks

- Each edge has a sign (+ or –)
- Meaning of signs can be:
  - Support/Oppose (Wikipedia)
  - Trust/Distrust (Epinions)
  - Friend/Foe (Slashdot)
- Questions:
  - How do edge signs and network structure interact?
  - What theories explain signs of edges?
  - Can we accurately predict signs of edges?



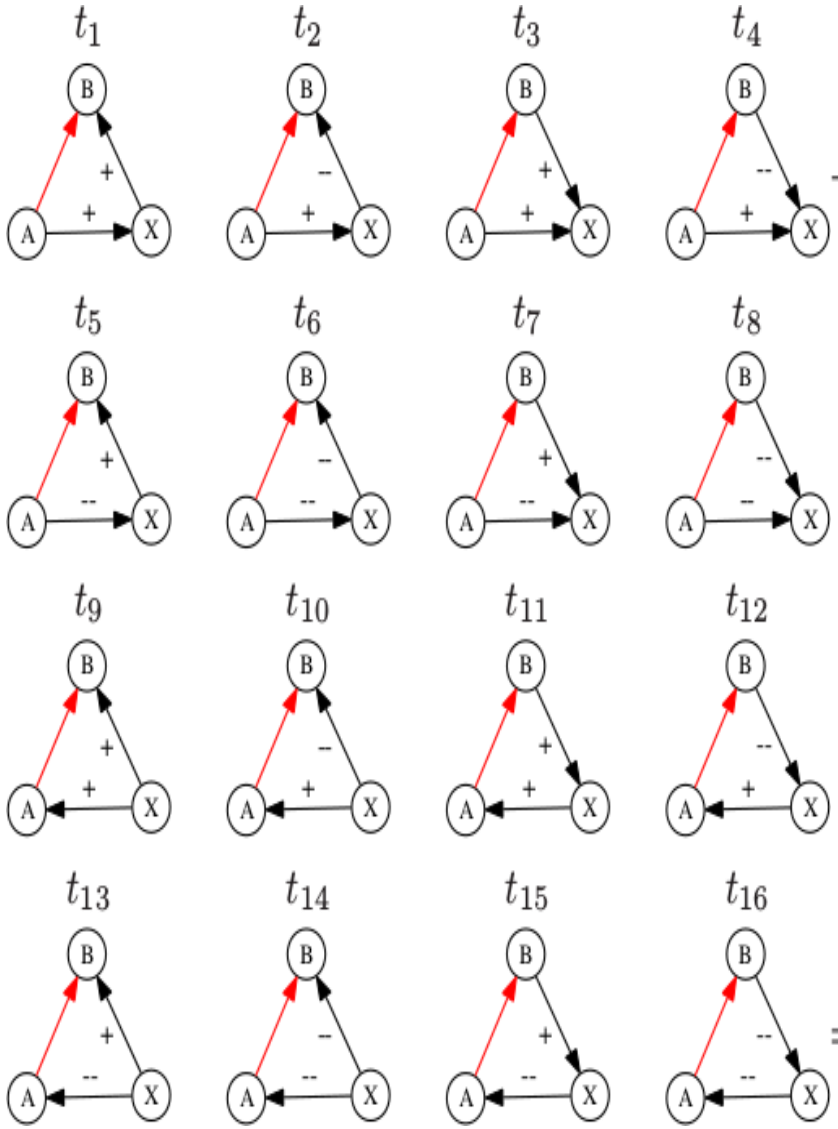
	Epinions	Slashdot	Wikipedia
Nodes	119,217	82,144	7,118
Edges	841,200	549,202	103,747
+ edges	85.0%	77.4%	78.7%
− edges	15.0%	22.6%	21.2%

Dataset - Statistics

Triad T_i		$\lvert T_i \rvert$	$p(T_i)$	$p_0(T_i)$	$s(T_i)$
Epinions					
T_3	$+++$	11,640,257	0.870	0.621	1881.1
T_1	$+--$	947,855	0.071	0.055	249.4
T_2	$++-$	698,023	0.052	0.321	-2104.8
T_0	$---$	89,272	0.007	0.003	227.5
Slashdot					
T_3	$+++$	1,266,646	0.840	0.464	926.5
T_1	$+--$	109,303	0.072	0.119	-175.2
T_2	$++-$	115,884	0.077	0.406	-823.5
T_0	$---$	16,272	0.011	0.012	-8.7
Wikipedia					
T_3	$+++$	555,300	0.702	0.489	379.6
T_1	$+--$	163,328	0.207	0.106	289.1
T_2	$++-$	63,425	0.080	0.395	-572.6
T_0	$---$	8,479	0.011	0.010	10.8

Table 3. Number of balanced and unbalanced undirected triads.

Prediction (Epinions)



t_i	count	$P(+)$	s_g	s_r	B_g	B_r	S_g	S_r
t_1	178,051	0.97	95.9	197.8	✓	✓	✓	✓
t_2	45,797	0.54	-151.3	-229.9	✓	✓	✓	o
t_3	246,371	0.94	89.9	195.9	✓	✓	o	✓
t_4	25,384	0.89	1.8	44.9	o	o	✓	✓
t_5	45,925	0.30	18.1	-333.7	o	✓	✓	✓
t_6	11,215	0.23	-15.5	-193.6	o	o	✓	✓
t_7	36,184	0.14	-53.1	-357.3	✓	✓	✓	✓
t_8	61,519	0.63	124.1	-225.6	✓	o	✓	✓
t_9	338,238	0.82	207.0	-239.5	✓	o	✓	✓
t_{10}	27,089	0.20	-110.7	-449.6	✓	✓	✓	✓
t_{11}	35,093	0.53	-7.4	-260.1	o	o	✓	✓
t_{12}	20,933	0.71	17.2	-113.4	o	✓	✓	✓
t_{13}	14,305	0.79	23.5	24.0	o	o	✓	✓
t_{14}	30,235	0.69	-12.8	-53.6	o	o	✓	o
t_{15}	17,189	0.76	6.4	24.0	o	o	o	✓
t_{16}	4,133	0.77	11.9	-2.6	✓	o	✓	o
				Number of correct predictions	8	7	14	13

Paper: Predicting Positive and Negative Links in Online Social Networks

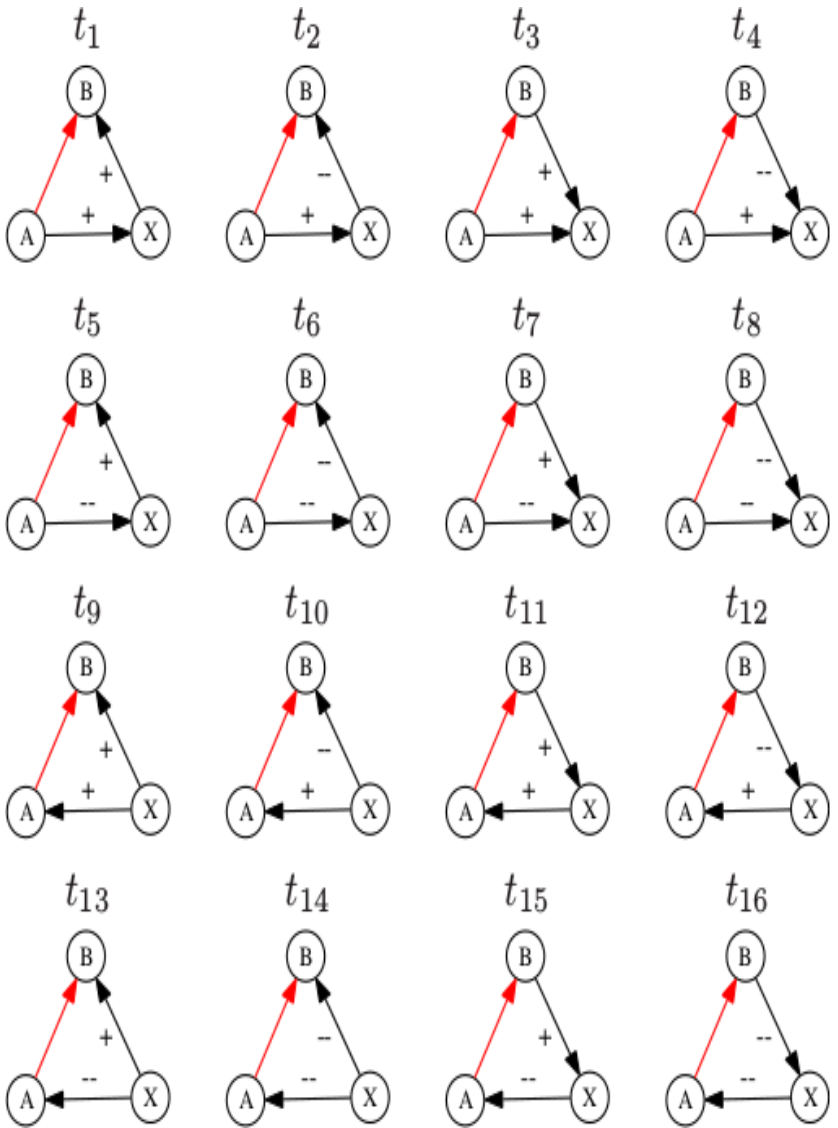
Predicting Signed Edge using Machine Learning Approach

Features

- predicting the sign of the edge from *u* to *v*
  - outgoing edge from *u* : $d^{+}_{out}(u)$, $d^{-}_{out}(u)$
  - incoming edge to *v* : $d^{+}_{in}(v)$, $d^{-}_{in}(v)$
  - embeddedness : *C(u, v)*
  - total out-degree of *u* : $d^{+}_{out}(u) + d^{-}_{out}(u)$
  - total in-degree of *v* : $d^{+}_{in}(v) + d^{-}_{in}(v)$

Features

- Triads involving (*u,v)*



Result

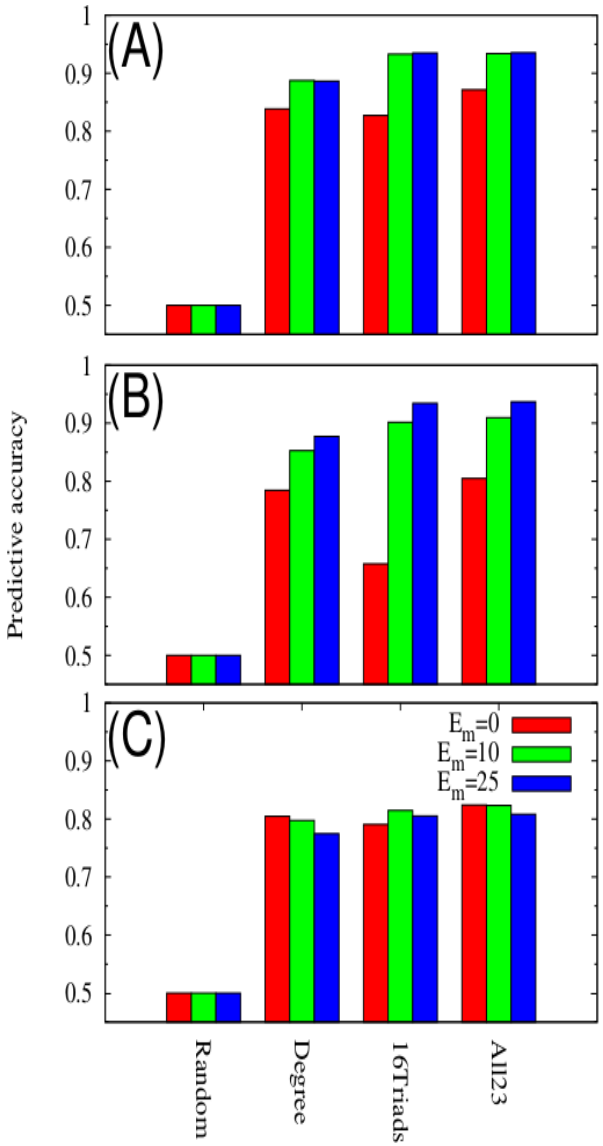


Figure 1: Accuracy of predicting a sign of edge (u, v) given signs of all other edges in the network. (a) Epinions, (b) Slashdot, (c) Wikipedia.

Generalization

All23	Epinions	Slashdot	Wikipedia
Epinions	0.9342	0.9289	0.7722
Slashdot	0.9249	0.9351	0.7717
Wikipedia	0.9272	0.9260	0.8021

Table 6: Predictive accuracy when training on the "row" dataset and evaluating the prediction on the "column" dataset.