Social and Information Network Analysis
Positive and Negative Relationships

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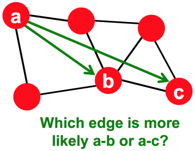
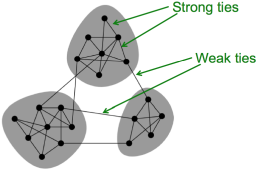
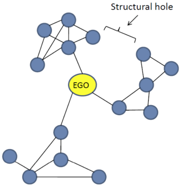
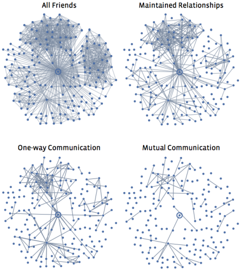
To Recap







- Triadic Closure
- The Strength of Weak Ties
- Tie Strength in Social Media
- Closure and Structural Holes
- Community Detection



Positive and Negative Relationships

- Relationships in the networks thus far have positive connotations:
  - friendship, collaboration, sharing of information
- However, there exist also negative (or antagonistic) relationships:
  - controversy, disagreement, and sometimes outright conflict

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How should we reason about the mix of positive and negative relationships that take place within a network?

Positive and Negative Relationships

- Given a network and annotated links as positive and negative
  - Goal: understand the tension between these two forces
- Underlying framework for such an analysis is the notion of structural balance

Positive and Negative Relationships

- We focus on basic models of positive and negative relationships where the graph is complete:
  - A social network on a set of people:
    - Everyone knows everyone else
    - Edges are labeled with either $+$ or $-$, where $+$ indicates friends, and $-$ indicates enemies
    - Examples?
    - Generally, small groups of people who all know each other, e.g., a classroom, a small company, a sports team, a fraternity or sorority, international relationships

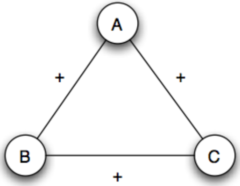
Positive and Negative Relationships

- The models can be extended to settings where
  - The graph is not complete
  - The graph structure is only “approximately balanced"
  - The dynamic aspects of the structural balance theory are captured by modeling how the set of friendships and antagonisms in a complete graph might evolve over time, as the social network implicitly seeks out structural balance.

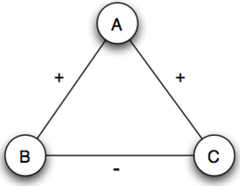
Structural Balance for Triangles

- Key idea - based on theories in social psychology:
  - Any two people in the group seen in isolation are either friends or enemies
  - For any three people in the group, certain configurations of $+$'s and $-$'s are socially and psychologically more plausible than others
  - Four distinct ways to label the three edges among three people with $+$'s and $-$'s

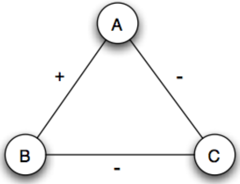
Balanced vs. Not Balanced Triangles



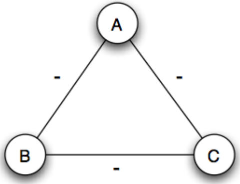
(a) *A, B, and C are mutual friends: balanced.*



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



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

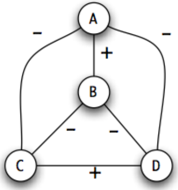


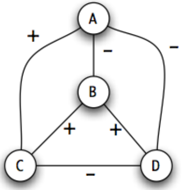
(d) *A, B, and C are mutual enemies: not balanced.*

Structural Balance for Arbitrary Networks

- How to extend structural balanced to networks of arbitrary number of nodes (i.e., $N > 3$)?
  - A labeled complete graph is balanced if every triangle in the graph is balanced

Structural Balance Property: For every set of three nodes, if we consider the three edges connecting them, either all three of these edges are labeled $+$, or else exactly one of them is labeled $+$





Characterizing the Structure of Balanced Networks

- What can we say about the structure of a balanced network?
  - More precisely, how does a balanced network look like?
  - Note that the balanced labeled network is complete
- When is a network balanced?
  - Everyone likes each other $\rightarrow$ all triangles have three + labels.
  - There are two groups of friends with negative relations between people in different groups

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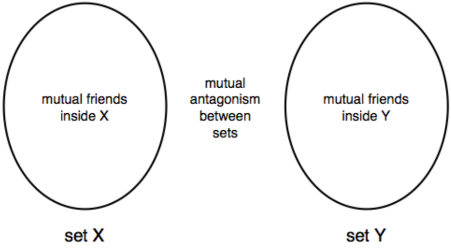

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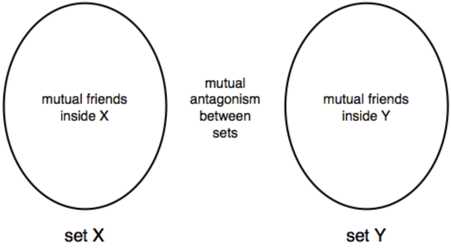

- These are the *only* ways to have a balanced network

The Balance Theorem

- *If a labeled complete graph is balanced, then either all pairs of nodes are friends, or else the nodes can be divided into two groups, X and Y, such that every pair of nodes in X like each other, every pair of nodes in Y like each other, and everyone in X is the enemy of everyone in Y.*

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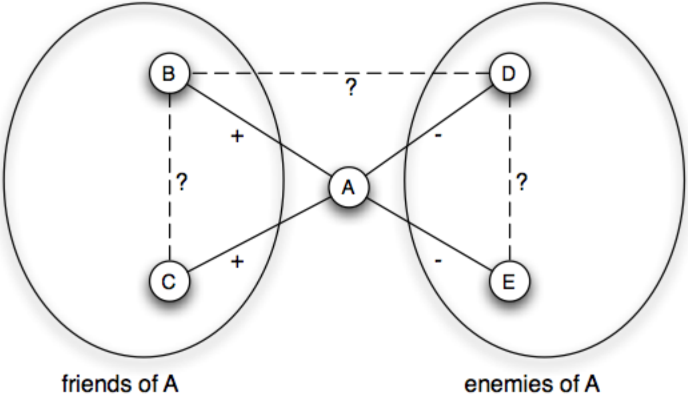
  - Implication: Structural Balanced Property (a purely *local* property) implies a strong *global* property (either everyone gets along, or the world is divided into two battling factions)

Proving the Balance Theorem

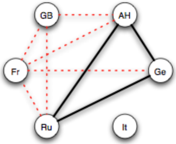
- Given a labeled balanced complete graph
- Conclude that either everyone is friends, or that there are sets X and Y as described in the claim
  Proof:
- If no negative edges, done
- Assume there is at least one negative edge
  - Want to show that:
    - Every two nodes in X are friends
    - Every two nodes in Y are friends
    - Every node in X is an enemy of every node in Y

Proving the Balance Theorem

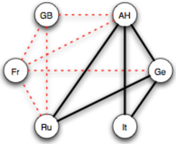


Applications of Structural Balance - International Relations

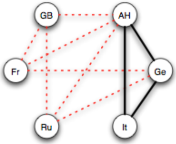
- Nodes are nations, and $+$ and $-$ are edge labels indicating alliances or animosity.
- Structural balance can sometimes provide an effective explanation for the behavior of nations during various international crises.



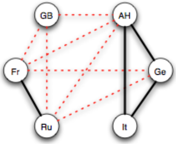
(a) *Three Emperors' League 1872–81*



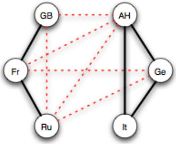
(b) *Triple Alliance 1882*



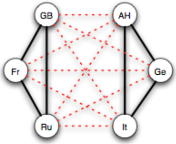
(c) *German-Russian Lapse 1890*



(d) *French-Russian Alliance 1891–94*



(e) *Entente Cordiale 1904*



(f) *British Russian Alliance 1907*

International Relations

Conclusion on International Relations:

- Structural balance is not necessarily a good thing:
    - Since its global outcome is often two implacably opposed alliances, the search for balance in a system can sometimes be seen as a slide into a hard-to-resolve opposition between two sides

Trust, Distrust, and On-Line Ratings

- User communities on the Web where people can express positive or negative sentiments about each other:
  - The technology news site Slashdot, where users can designate each other as a "friend" or a "foe";
  - On-line product-rating sites such as Epinions, where a user can express evaluations of different products, and also express trust or distrust of other users.
    - Epinions seen as a directed graph;
    - Some patterns - easy to reason about:
    - For example, if user A trusts user B, and user B trusts user C, then it is natural to expect that A will trust C.
    - But what if A distrusts B and B distrusts C: should we expect A to trust or to distrust C?
      Appealing arguments in both directions!

A Weaker Form of Structural Balance

To recap:

- There are two kinds of structures on a group of three people that are inherently unbalanced:
  - A triangle with $2+$ edges and $1-$ edge.
  - A triangle with $3-$ edges.
  - Source of stress that the network might try to resolve.
  - First case stronger than the second.

Question:

- What structural properties arise when we rule out only triangles with exactly two positive edges, while allowing triangles with three negative edges to be present in the network.

Characterizing Weakly Balanced Networks

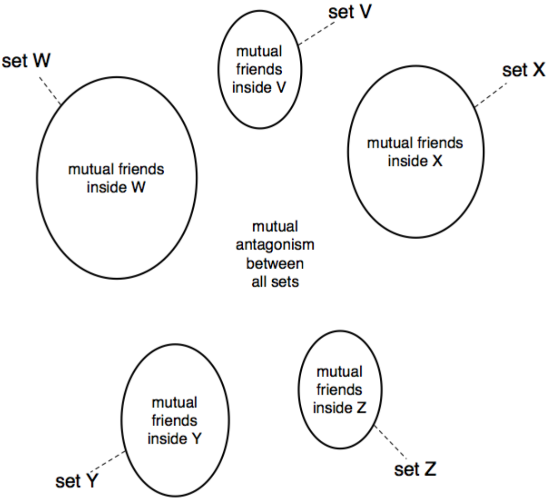
- A complete labeled graph is *weakly balanced* if the following property holds:
  - *Weak Structural Balance Property: There is no set of three nodes such that the edges among them consist of exactly two positive edges and one negative edge.*
- How do they look like?

Characterization of Weakly Balanced Networks

If a labeled complete graph is weakly balanced, then its nodes can be divided into groups in such a way that every two nodes belonging to the same group are friends, and every two nodes belonging to different groups are enemies.

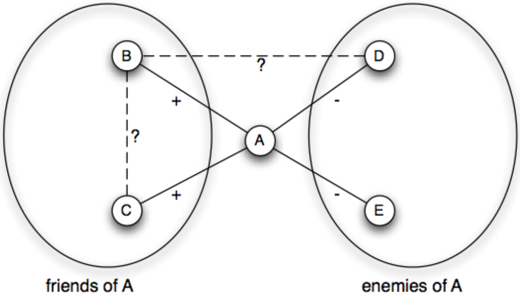
- In other words,
  - Given a weakly balanced complete graph
  - Produce a division of its nodes into groups of mutual friends, such that all relations between nodes in different groups are negative.

Weakly Balanced Networks



Proving the Characterization

- Pick any node A at random
- Show:
  - All of A's friends are friends with each other.
  - A and all his friends are enemies with everyone else in the graph.



- Repeat until all nodes are assigned to a set.

In Summary

- We looked at the structure of a network with positive and negative relationships
  - Implication: a purely local property (such as the structural balanced property) implies a strong global property (either everyone gets along, or the world is divided into groups of battling factions)