Networks with Signed Edges
Some example datasets:

- Author Citation/Collaboration Networks
  - ANetMiner and Microsoft Academic Graph
- Pinterest (to be released):
  - Users: age, gender, boards they own
  - Boards: title, creation time, pins that belong to a board
  - Pins: title, description, link, image, creation time
- Datasets on Reddit: [https://www.reddit.com/r/datasets/](https://www.reddit.com/r/datasets/)
  - Presidential candidate endorsements by newspaper
  - 25M presidential debate tweets
  - Vehicle mobility data in Cologne, Germany

More at: [http://cs224w.stanford.edu/resources.html](http://cs224w.stanford.edu/resources.html)
Each link $A \rightarrow B$ is explicitly tagged with a sign:

- **Epinions**: Trust/Distrust
  - Does A trust B’s product reviews?
    (only positive links are visible to users)

- **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

<table>
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<tr>
<th></th>
<th>Epinions</th>
<th>Slashdot</th>
<th>Wikipedia</th>
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Does structural balance hold?

- Compare frequencies of signed triads in real and “shuffled” signs

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<th>Wikipedia</th>
<th>Consistent with Balance?</th>
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<td>- - -</td>
<td>0.007</td>
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</table>

P(T) … fraction of a triads
P₀(T)… triad fraction if the signs would appear at random
Evolving Directed Networks

- **New setting:** Links are directed, created over time
  - Node A links to B
  - Directions and signs of links from/to X provide context

- **How many \( \triangle \) are now explained by balance?**
  - **Only half** (8 out of 16)

16 signed directed triads

(in directed networks people traditionally applied balance by ignoring edge directions)

Edge sign according to the balance theory
Do people close such triads with the “balanced” edge?

New setting: Links are directed, created over time

Directions and signs of links from/to X provide context
### Alternate Theory: Status

- **Status in a network** [Davis-Leinhardt ’68]
  - $A \rightarrow^+ B :: B$ has higher status than $A$
  - $A \rightarrow^- B :: B$ has lower status than $A$
    - Note the notion of status is now implicit and governed by the network (rather than the number of edits)

- **Apply this principle transitively over paths**
  - Can replace each $A \rightarrow B$ with $A \leftarrow^+ B$
  - Obtain an all-positive network with same status interpretation
Status vs. Balance

Status and balance give different predictions!
At a global level (in the ideal case):

- **Status ⇒ Hierarchy**
  - All-positive directed network should be approximately **acyclic**

- **Balance ⇒ Coalitions**
  - Balance ignores directions and implies that subgraph of negative edges should be approximately **bipartite**
Theory of Status

- **Edges are directed:**
  - X has links to A and B
  - Now, A links to B (triad A-B-X)
  - How does sign of $A \rightarrow B$ depend signs from/to X?
    - $P(A \rightarrow B \mid X)$ vs. $P(A \rightarrow B)$

- We need to formalize:
  - 1) Links are embedded in triads: Triads provide **context for signs**
  - 2) Users are **heterogeneous** in their linking behavior
1) Context: 16 Types

- Link A → B appears in context X: A → B | X

- 16 possible contexts:

Note: Context of a link is uniquely determined by the directions and signs of links from/to X
2) Heterogeneity in linking behavior

- Users differ in frac. of + links they give/receive
- For a user U:
  - Generative baseline: Frac. of + given by U
  - Receptive baseline: Frac. of + received by U

Basic question:
- How do different link contexts cause users to deviate from their baselines?
  - Link contexts as modifiers on a person’s predicted behavior
  - **Def: Surprise**: How much behavior of A/B deviates from his/her baseline when A/B is in context X
Intuition: How much behavior of user A in context X deviates from his/her baseline behavior

Baseline: For every user A:
\[ p_g(A_i) \]... generative baseline of \( A_i \)
- Fraction of times \( A_i \) gives a plus

Context: \((A_1, B_1 | X_1), ..., (A_n, B_n | X_n)\)
- all instances of triads in context X
  - \((A_i, B_i, X_i)\) ... an instance where when user \( A_i \) links to user \( B_i \) the triad of type X is created.
- Say k of those triads closed with a plus
  - \( k \) out of \( n \) times: \( A_i \overset{+}{\rightarrow} B_i \)
**Surprise:** How much behavior of user A in context X **deviates** from his/her **baseline** behavior

- **Generative surprise of context X:**
  
  \[ s_g(X) = \frac{k - \sum_{i=1}^{n} p_g(A_i)}{\sqrt{\sum_{i=1}^{n} p_g(A_i)(1 - p_g(A_i))}} \]

  - \( p_g(A_i) \) ... generative baseline of \( A_i \)
  - **Context X:** \( (A_1, B_1 \mid X_1), \ldots, (A_n, B_n \mid X_n) \)
  - \( k \) of instances of triad \( X \) closed with a plus edges

- **Receptive surprise is similar, just use** \( p_r(A_i) \)

*Context X:*

\[ X \]

Vs.

\[ A \rightarrow B \rightarrow A \rightarrow B \]
Example: Computing Surprise

- **Surprise**: How much behavior of user deviates from baseline when in context X
  - Generative surprise of context X =

  \[
  s_g(X) = \frac{k - \sum_{i=1}^{n} p_g(A_i)}{\sqrt{\sum_{i=1}^{n} p_g(A_i)(1 - p_g(A_i))}}
  \]

  We have 3 triads of context X: \((z,u,v), (y,v,w), (q,v,w)\)
  They all close with a plus: So \(k=3\)
  \(P_g(u)=1/2=0.5\) \(P_g(v)=2/2=1\)
  \(S_g(X)=(3-2.5)/\sqrt{(0.5*0.5 + 1*0 + 1*0)} = 1\)
Status: Two Examples

- Assume status theory is at work
- What sign does status predict for edge $A \rightarrow B$?
  - We have to look at this separately from the viewpoint of $A$ and from the viewpoint of $B$

![Diagram](diagram.png)

Gen. surprise of $A$: –
Rec. surprise of $B$: –

Gen. surprise of $A$: –
Rec. surprise of $B$: –
Joint Positive Endorsement

- X positively endorses A and B
- Now A links to B

A puzzle:
- In our data we observe:
  Fraction of positive links deviates
  - Above generative baseline of A: $S_g(X) > 0$
  - Below receptive baseline of B: $S_r(X) < 0$

- Why?
A’s viewpoint:

- Since B has a positive evaluation, B is likely of high status
- Thus, evaluation A gives is more likely to be positive than A’s baseline behavior
B’s viewpoint:

- Since A has positive evaluation, A is likely to be high status
- Thus, evaluation B receives is less likely to be positive than the baseline evaluation B usually receives

Surprise of A→B deviates in different directions depending on the viewpoint!
Consistency with Status

- **Determine node status:**
  - Assign $X$ status 0
  - Based on signs and directions of edges set status of $A$ and $B$

- **Surprise is status-consistent, if:**
  - Gen. surprise is status-consistent if it has same sign as status of $B$
  - Rec. surprise is status-consistent if it has the opposite sign from the status of $A$

- **Surprise is balance-consistent, if:**
  - If it completes a balanced triad
# Status vs. Balance (Epinions)

- **Predictions by status and balance:**

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<th>count</th>
<th>$P(+)$</th>
<th>$S_g(t_i)$</th>
<th>$S_r(t_i)$</th>
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</table>

Number of correct predictions: 8, 7, 14, 13.
Edge sign prediction problem

- Given a network and signs on all but one edge, predict the missing sign

Friend recommendation:

- Predicting whether you know someone vs. Predicting what you think of them

Setting:

- Given edge \((A, B)\), predict its sign:
- Let’s look at signed triads \((A, B)\) belongs to:
For the edge (A,B) we examine its network context:

- In what types of triads does our red-edge participate in?

- Each triad then “votes” and we determine the sign
## Balance and Status: Complete Model

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## Balance and Status: Complete Model

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### Balance and Status: Complete Model

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**Prediction accuracy:**

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<td>84%</td>
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<tr>
<td>Wikipedia</td>
<td>64%</td>
<td>70%</td>
<td>81%</td>
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**Observations:**

- Signs can be modeled from local network structure alone!
  - Status works better on Epinions and Wikipedia
  - Wikipedia is harder to model:
    - Votes are publicly visible
Do people use these very different linking systems by obeying the same principles?

- How generalizable are the results across the datasets?

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<th>Slashdot</th>
<th>Wikipedia</th>
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Nearly **perfect generalization** of the models even though networks come from very different applications!
Signed networks provide insight into how social computing systems are used:

- Status vs. Balance
- Role of embeddedness and public display
- More evidence that networks are globally organized based on status

Sign of relationship can be reliably predicted from the local network context:

- ~90% accuracy sign of the edge
- People use signed edges consistently regardless of particular application
  - Near perfect generalization of models across datasets
What about the effect of evaluations on the target T?
Facebook privacy now defaults to friends only

By Doug Gross, CNN
updated 3:39 PM EDT, Thu May 22, 2014 | Filed under: Social Media
Join the discussion...

**Tom** · 7 hours ago
If you're posting something to facebook, it shouldn't be anything you wouldn't print and tape to the front door of a local grocery store.

21 up · Reply · Share

**ccw101 → Tom** · 7 hours ago
I hate Facebook for the fact the only person you have control over is yourself. I have seen full grown adults get angry at their own children and rip them a new one on their Facebook home page!
If adults can be so ST***id then what do kids do?
Facebook is scary. And has given people the opportunity to use it to cause home break in's, ruined reputations, fights, suicides etc.

8 up · Reply · Share

**IAmNotATroll → ccw101** · 7 hours ago
Come now, I thoroughly enjoy watching my in-laws publicly argue and shred each other to pieces over Facebook.

8 up · Reply · Share

**Furby → IAmNotATroll** · 6 hours ago
I had a distant cousin try to blackmail my mom on FB publically.
Me and her became real close after that - and not in the way you want to get close to someone. Some people are just plain dumb.
How do people react to evaluations they receive?

How does positive/negative feedback influence subsequent user behavior?
Positively Evaluated

Negatively Evaluated
Evaluations can affect

Post quality (How well you write)

Community bias (How people perceive you)

Posting frequency (How regularly you post)

Voting behavior (How you vote on others)
Four large comment-based news communities with

1.2M articles, 1.8M registered users, 42M posts, 140M votes, 1 year
How do we measure community feedback?

Number of up-votes

Up-votes minus Down-votes

Fraction of up-votes
User ratings were independent of the total number of votes

Crowdsourcing exercise:
On a scale 1-7 how would you feel about getting X positive and Y negative votes?

Fraction of up-votes: \( R^2 = 0.92 \)
What happens after you give a user a positive, or a negative evaluation?
Compare similar pairs of users who were evaluated differently on similar content

Rosenbaum, P. R., & Rubin, D. B. (1983). The central role of the propensity score in observational studies for causal effects.
Matching pairs of users

Match pairs of users where one got positive and one got negatively evaluated.
Match based on similar history text quality, number of posts, overall proportion of up-votes, etc.

Text quality determined by training a machine learning model using text features, validated using crowd workers.
Evaluations can affect

Post quality (How well you write)

Community bias (How people perceive you)

Posting frequency (How regularly you post)

Voting behavior (How you vote on others)
How much of a future evaluation can be explained by textual effects?

Text quality drops significantly after a negative evaluation, but does not change after a positive evaluation. 

$p < 0.05$ in all communities

To learn more about these types of effects, see Kanouse, D. E., & Hanson Jr, L. R. (1987). Negativity in evaluations.
Evaluations can affect Community bias (How people perceive you)

How does community perception of a user change after an evaluation?
Community Bias?

Actual Evaluation $P/(P+N)$

<table>
<thead>
<tr>
<th>Up-votes</th>
<th>Text Quality</th>
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<th>Down-votes</th>
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Judged Text Quality

| $0.9$ | $0.8$ |

$0.9-0.8$
Community Effects

Posts made after a negative evaluation were perceived worse than those made after a positive evaluation

\[ p < 0.05 \text{ in all communities} \]
Does feedback regulate post *quantity*?

Evaluations can affect Posting frequency (How regularly you post)
Users who receive negative feedback post more frequently

Don’t feed the trolls!

Times more frequent after vs. before
Evaluations can affect Voting Behavior (How you vote on others)

Does feedback result in subsequent backlash?
Users who receive negative feedback are more likely to down-vote others.
Negatively-evaluated users write worse (and more!), are themselves evaluated worse by the community, and evaluate other community members worse. Positively-evaluated users, on the other hand, don’t do any better.
Is there a downward spiral in online communities?
The proportion of down-votes is increasing over time

- 0.8m down-votes
- 1.7m down-votes
CNN

0.23

0.18

Jan Mar May Jul

IGN

0.20

0.10

Jan Mar May Jul

Breitbart

0.12

0.05

Jan Mar May Jul

allkpop

0.11

0.05

Nov Jan Mar May