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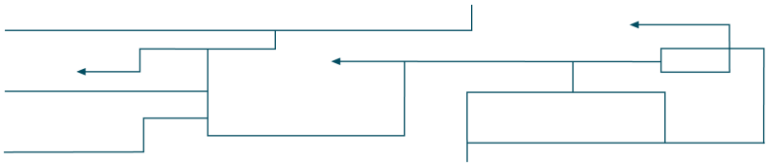

The Slashdot Zoo

Mining a Social Network with Negative Edges

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18th Int. World Wide Web Conference, Madrid 2009



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Outline

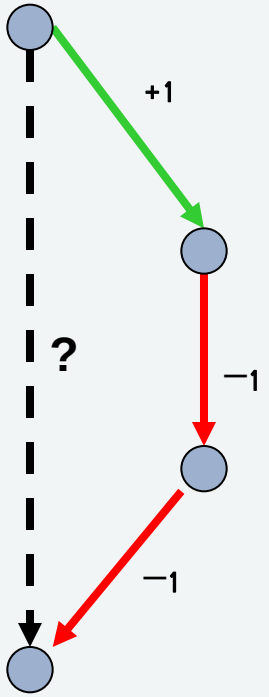
- Signed networks and the multiplication rule
- The Slashdot Zoo

- Analysis at global level: Signed clustering coefficient
- Analysis at node level: Trust and troll detection
- Analysis at edge level: Link sign prediction

- Conclusion

Signed Networks and the Multiplication Rule

- Signed social networks have **enemy** relations in addition to **friend** relations
- Assumption: *The enemy of my enemy is my friend*
  - See e.g. (Hage&Harary 1983)
  - Assumption of structural balance (Harary 1953)
- Mathematical formulation: if edges are weighted by ±1, relationships between unconnected nodes may be predicted by multiplying the weights along a path
- Study a social network with negative edges
  - At the global level
  - At the node level
  - At the edge level

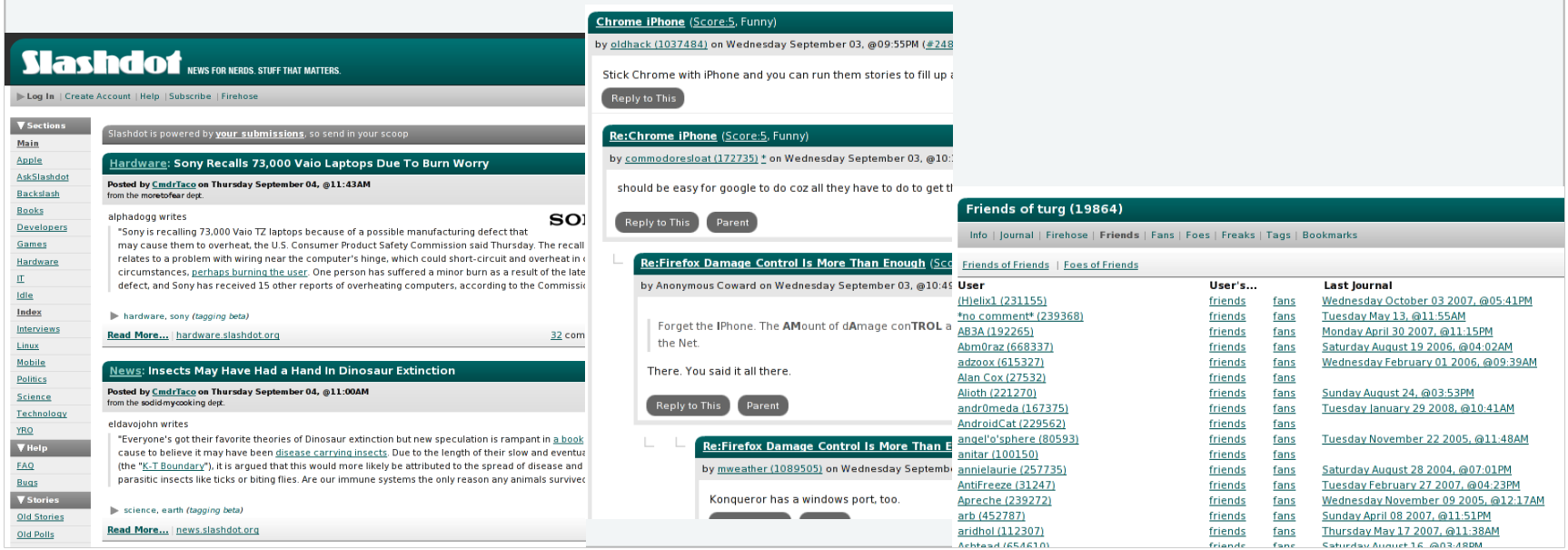


Slashdot

News for Nerds. Stuff that matters.

http://slashdot.org/

- Technology news website founded in 1997 by Rob Malda (a.k.a. CmdrTaco)
- Powered by Slash (http://slashcode.org/)
- Features: user accounts, threads, moderation, tags, journals and the ***zoo*** (and more)

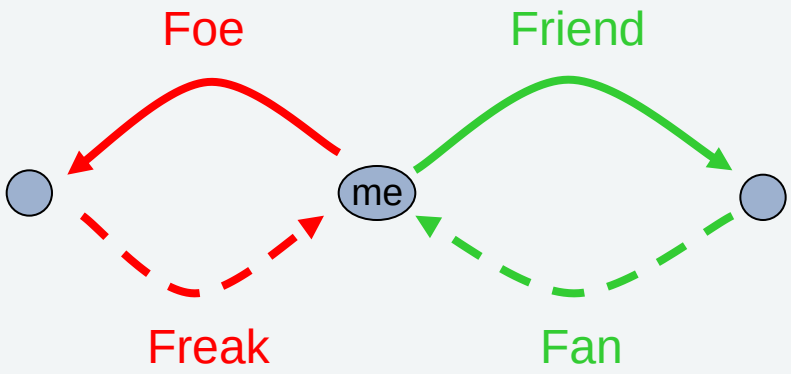


The Slashdot Zoo

Slashdot Zoo: Tag users as ***friends*** and ***foes***

You are the fan of your friends and the freak of your foes.

Graph has ***two*** types of edges: friendship and enmity

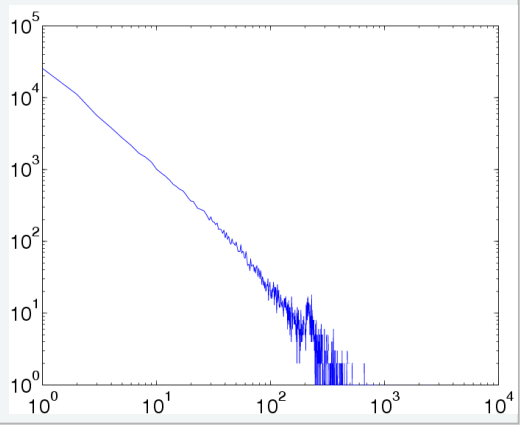


The resulting graph is sparse, square, asymmetric and has signed edge weights.

Statistics about the Slashdot Zoo

Statistics about the **giant connected component**:

- 77,985 users
- 510,157 endorsements (388,190 friends / 122,967 foes)
- 75.9% of all endorsements are positive
- Sparsity: 0.00839% of all possible edges exist
- Mean links per user: 6.54 (4.98 friends / 1.56 foes)
- Median number of links: 3
- Diameter = 6, Radius = 3
- Degree distribution: power law



Famous (and Popular?) Slashdotters

From left to right:

- CmdrTaco (Rob Malda, founder/editor)
- John Carmack (Quake, Doom, etc.)
- Bruce Perens (Debian, Open Source Definition)
- CleverNickName (Wil Wheaton, Star Trek)

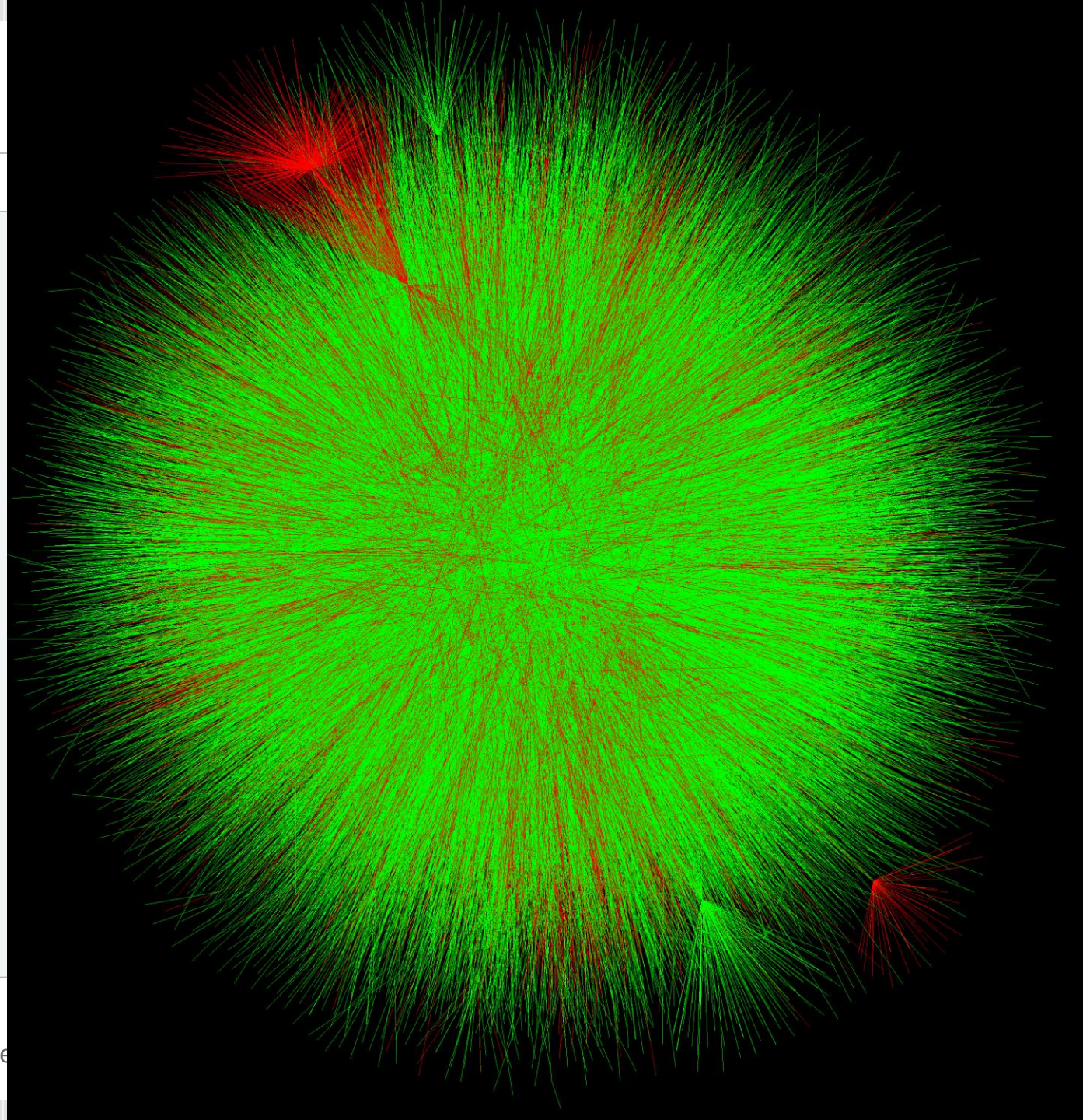



The Slashdot Zoo

GREEN: friend link

RED: foe link

Centered at CmdrTaco



Analysis at the Global Level: The Clustering Coefficient

Characteristic number of a network, $0 \leq C \leq 1$ (Watts & Strogatz, 1998)

Def.: Percentage of incident edge pairs completed by an edge to form a triangle.

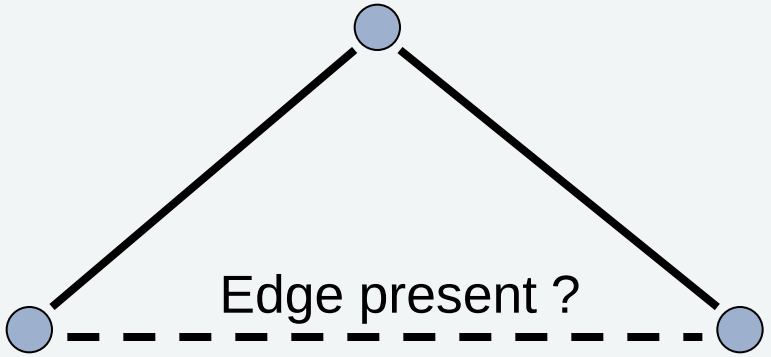
$$C = |\hat{A} \circ \hat{A}^2|_+ / |\hat{A}^2|_+ \qquad \hat{A} = abs(a)$$

High clustering coefficient: clustered graph with many cliques. (Graph is clustered when the value higher than that predicted by random graph models.)

Slashdot Zoo has C = 3.22%

(vs. 0.0095% random)

Also works for directed graphs.



Signed Clustering Coefficient

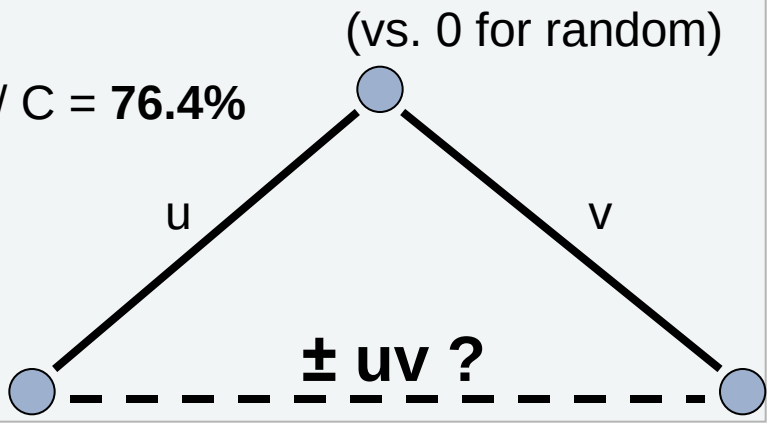
"The enemy of my enemy is my friend"

→ multiplication rule

- Denote the amount to which the network is balanced by counting "wrongly" signed edges negatively

$$C_S = |A \circ A^2|_+ / |\hat{A}^2|_+$$

- Range: $-1 \leq C_S \leq +1$
- Slashdot Zoo has $C_S = +2.46\%$
- Relative signed clustering coefficient: $C_S / C = \mathbf{76.4\%}$



Analysis at the Node Level: Centrality

Measures that apply to single nodes: centrality, trust, reputation, etc.

Simple functions:

- Fan count minus freak count

Algebraic function:

- PageRank, ignoring edge sign (Page&Brin 1998)
- Signed variants of PageRank, e.g. (Kamvar 2003)

PageRank and the Multiplication Rule

- Let A be the network‘s adjacency matrix
- Compute PageRank by iterated multiplication of a vector with normalized, A (+ extra node for teleportation)
- Result: Dominant eigenvector of matrix A given by repeated multiplication with A
- Implicit assumption: powers of A denote relations in the network

Matrix multiplication:

$$(AA)_{ij} = \sum_k A_{ik} A_{kj}$$

Observation: Matrix multiplication relies on edge weight products

Thus: **Methods based on matrix multiplication assume the validity of the multiplication rule.**

Top Users

- For each user score, show the top 6

	#1	#2	#3	#4	#5	#6
Fans minus Freaks	CleverNickName	Bruce Perens	CmdrTaco	John Carmack	NewYorkCountryLawyer	$$$$$exyGal
PageRank	FortKnox	SamTheButcher	Ethelred Unraed	turg	Some Woman	gmhowell
Signed PageRank	FortKnox	SamTheButcher	turg	Some Woman	Ethelred Unraed	gmhowell

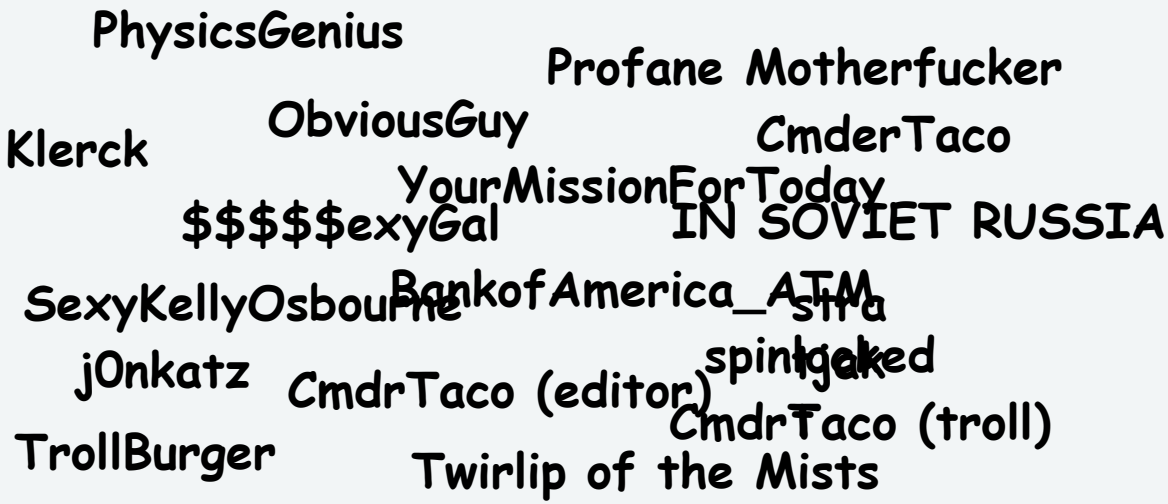
Conclusion:

Fans minus Freaks denotes prominence,
PageRank denotes community.

Detecting Trolls

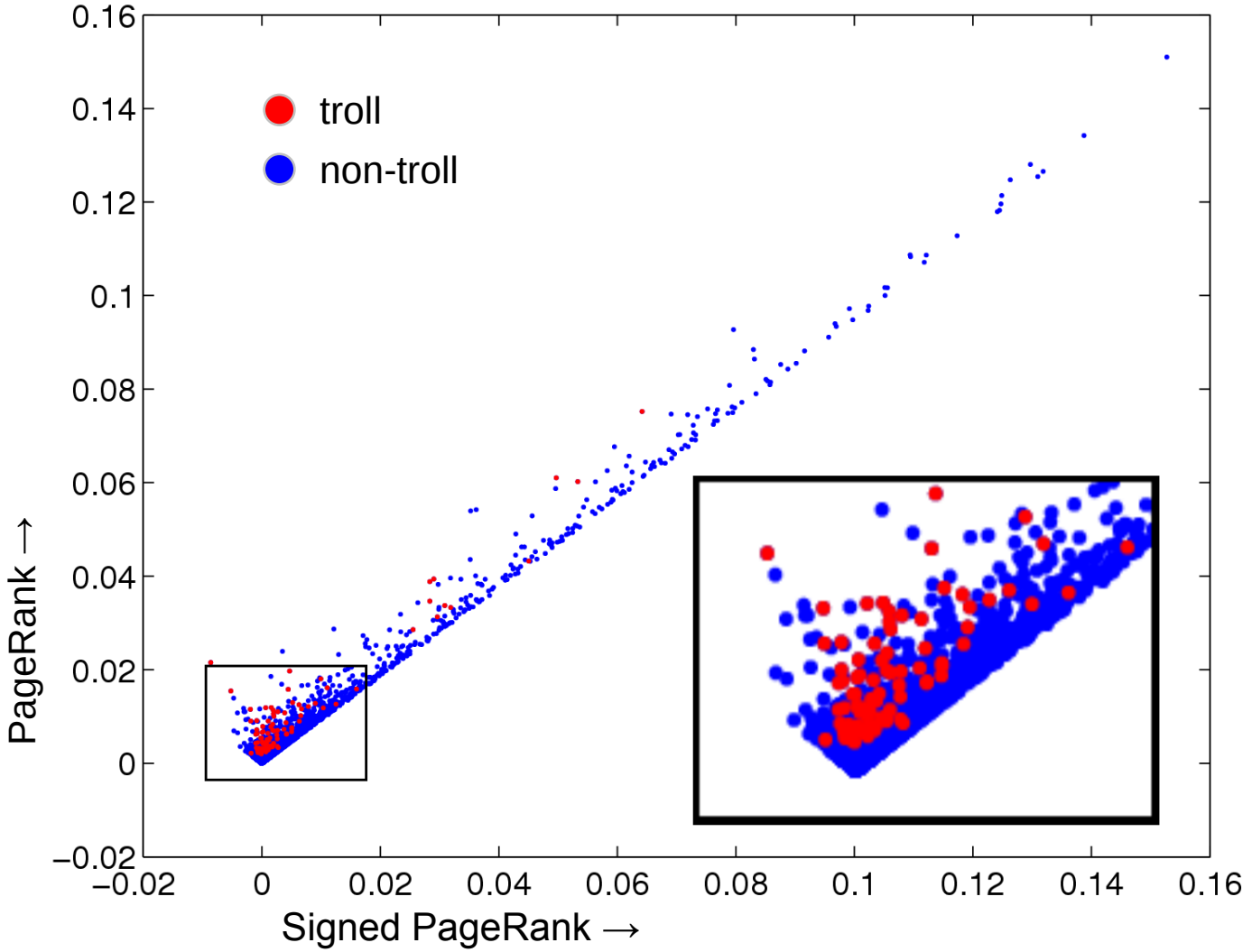
trolling, n. posting disruptive, false or offensive information to fool and provoke readers

- Slashdot is known for its ***trolls***
- Task: Predict foes of blacklist “No More Trolls” (162 names[1])



[1] See http://slashdot.org/~No+More+Trolls/foes/

PageRank for Trolls



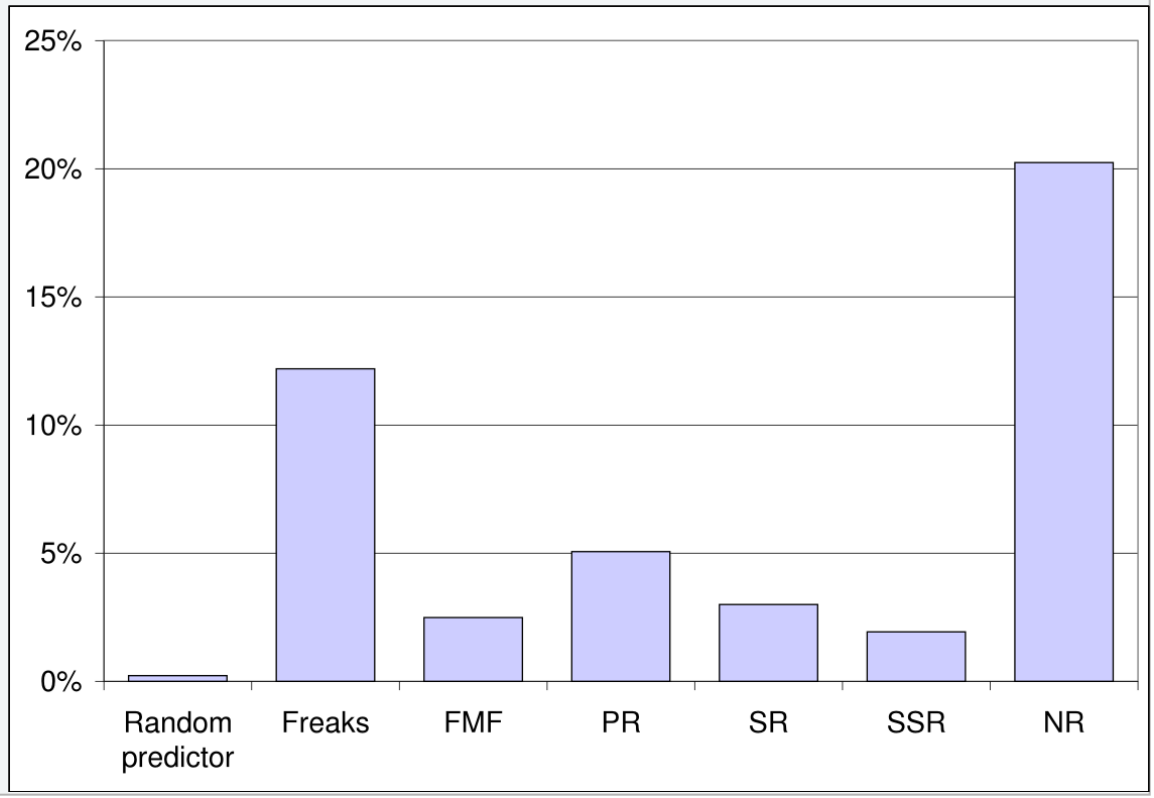
Negative Rank

- Observations:
  - PageRank and signed PageRank are almost equal for most users
  - For trolls, signed PageRank is less
- Conclusion:
  - Define NegativeRank = Signed PageRank − PageRank

How does Negative Rank peform at troll prediction?

Performance at Prediction

- Mean average precision (MAP) at troll prediction
- Negative Rank works best!



Analysis at the Edge Level: Link Sign Prediction

Task: Predict the ***sign*** of links

- Use the adjacency matrix $A \in \{-1, 0, +1\}^{n \times n}$
- Powers of A implement the multiplication rule

Simple algorithms

- Mutual friendship (A^T)
- Signed triangle completion (A^2)

Algebraic algorithms

- Rank reduction (A)
- Symmetric dimensionality reduction (A sym)
- Matrix exponential (A exp)
- Symmetric matrix exponential (A sym exp)
- Inverted signed Laplacian (Ls sym)

Algebraic Link Prediction Algorithms

Compute the rank-reduced eigenvalue decomposition:

$$A = U_k D_k U_k^T$$

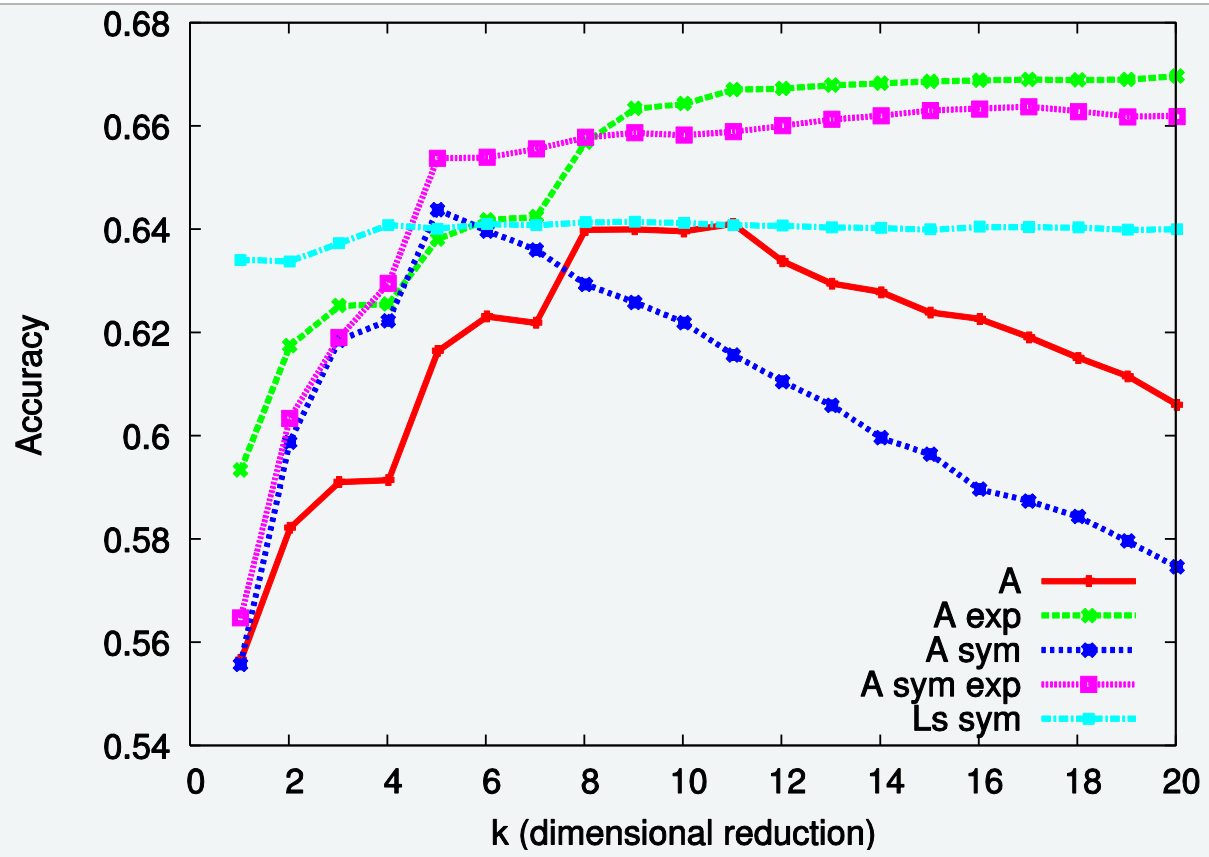
Matrix exponential: (multiplication rule)

$$\exp(A) = U_k \exp(D_k) U_k^T$$
$$= I + A + 1/2\, A^2 + 1/6\, A^3 + \ldots$$

Inverted signed Laplacian (Kunegis 2008):

$$L^+ = (D - A)^+$$

Evaluation Results



Accuracy is measured on a scale from −1 to +1.

1	0.517
A^T	0.536
A^2	0.552

Best link sign prediction: matrix exponential, confirms multiplication rule

Ongoing and Future Work

- More datasets
  - Essembly.org, Epinions.com, LibimSeTi.cz
- Study Negative Rank in detail
- Social networks with semantic relationships (more than two types)
- Other networks that can be extended to negative values
  - Folksonomies with negative tags (e.g. tags like *!funny* on Slashdot)

Conclusions

- Multiplication rule confirmed at global, nodal and relational scale
- The foe relationship can be used for trust computation and link sign prediction in social networks
- New concepts:
  - Signed clustering coefficient
  - Negative Rank
  - Link sign prediction in signed networks

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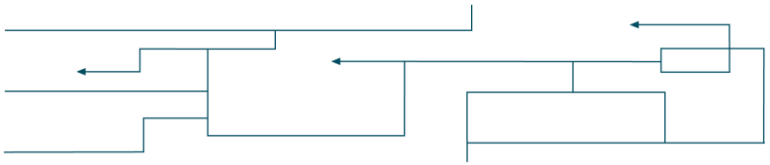

Thank You



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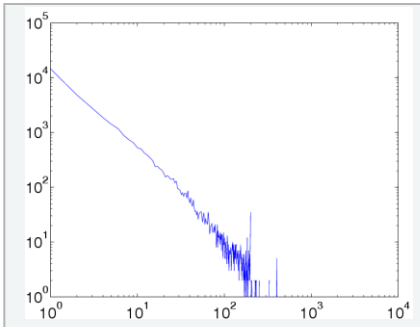
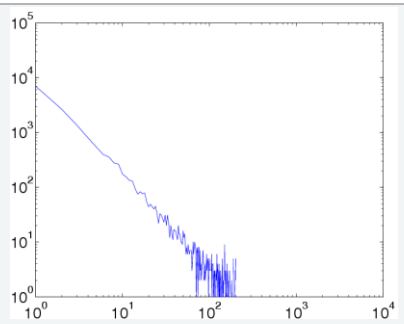
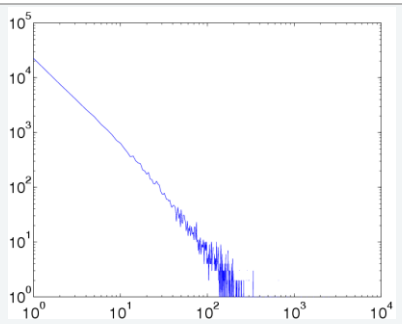
Appendix -- Degree Distributions



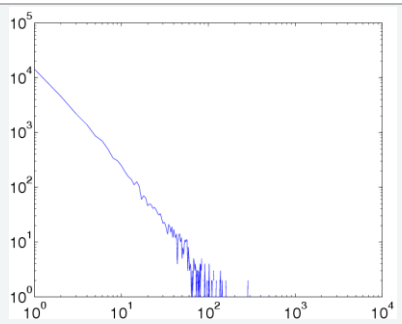
Friends



Foes

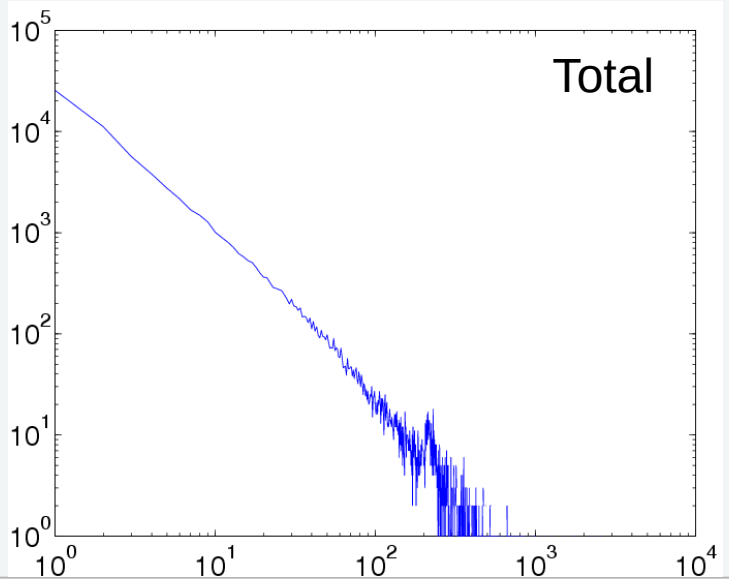


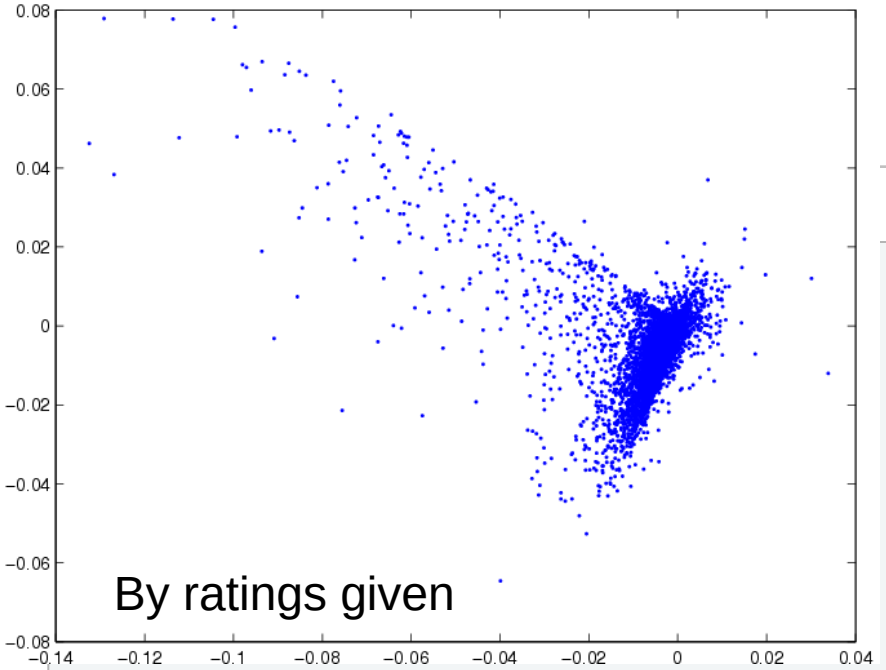
Fans

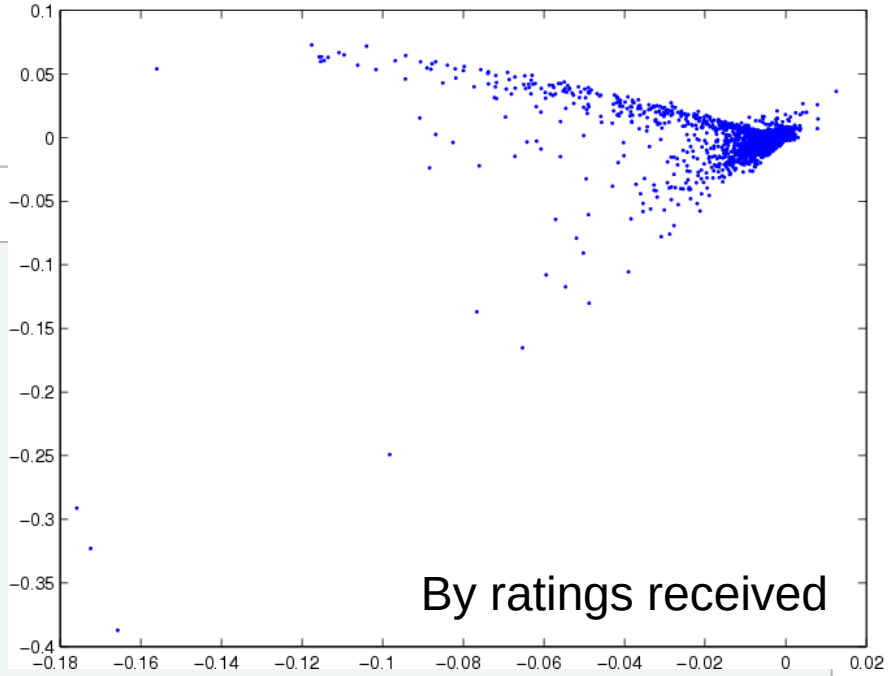


Freaks

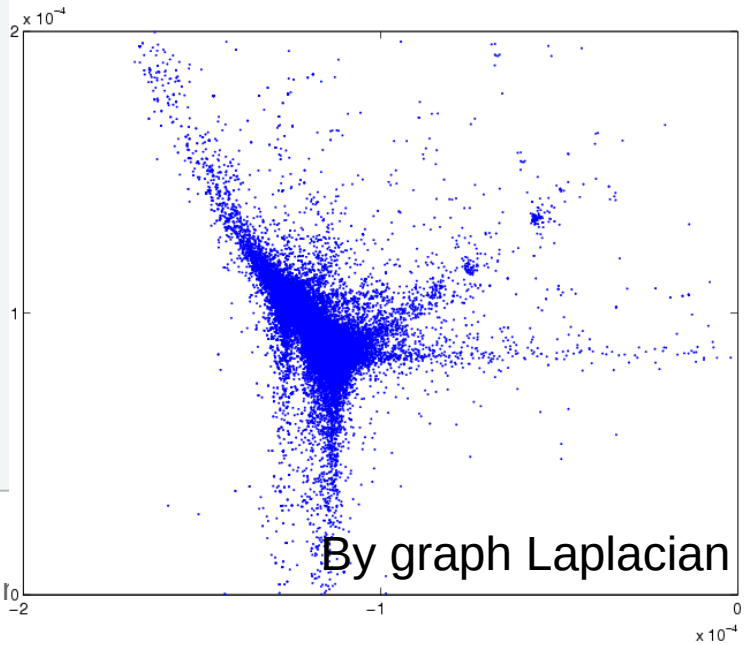
- **Observation: power laws for all four relationship types**







Appendix -- Principal Component Analysis



Appendix – Screenshots