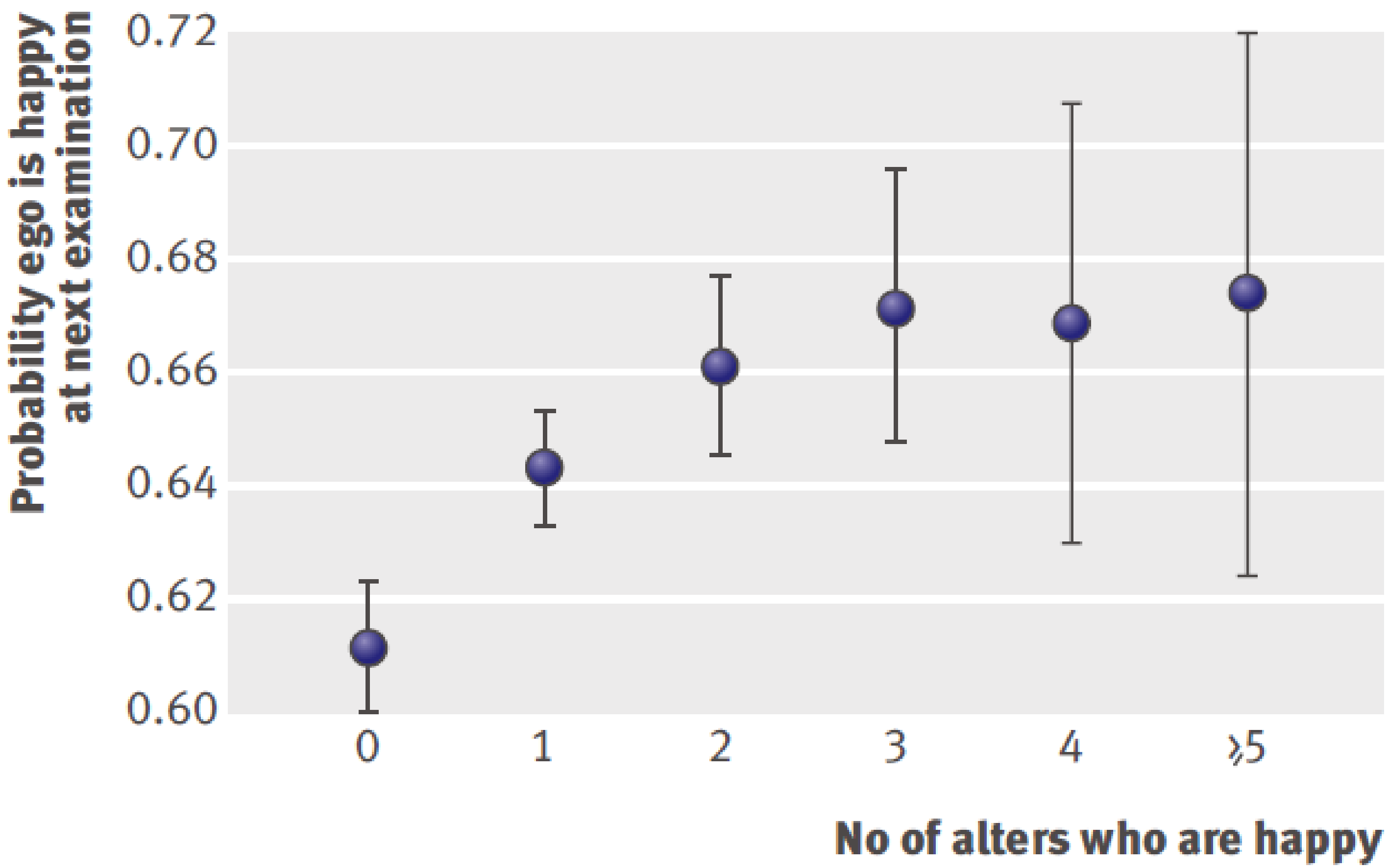
Influence and Correlation in Social Networks

Social Correlation

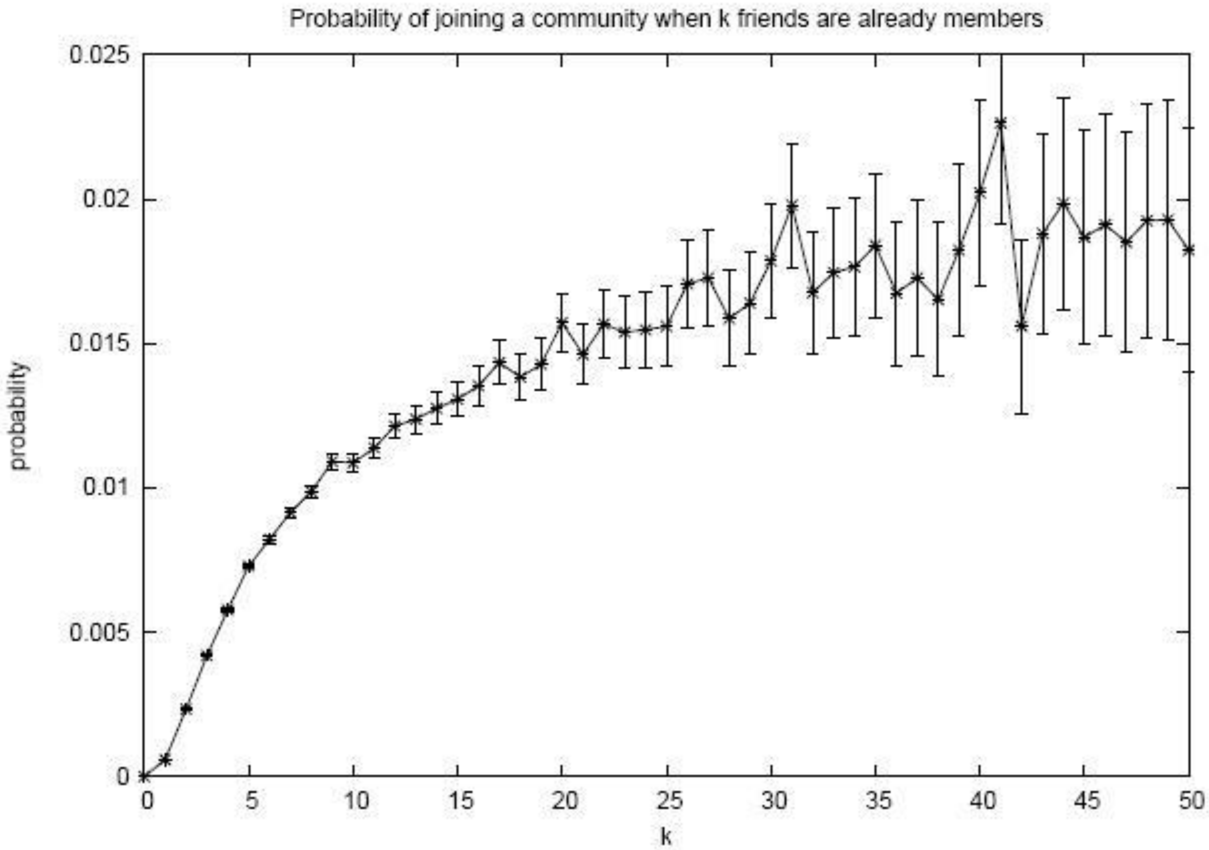
- How similar is the behavior of connected users.

- Previous studies:
  - Offline behavior
    - Fashion
    - Happiness
    - Publishing in conferences [Backstrom et al.]
  - Online behavior
    - Joining online communities [Backstrom et al.]
    - Tagging vocabulary on Flickr [Marlow et al.]
    - Using a VoIP service

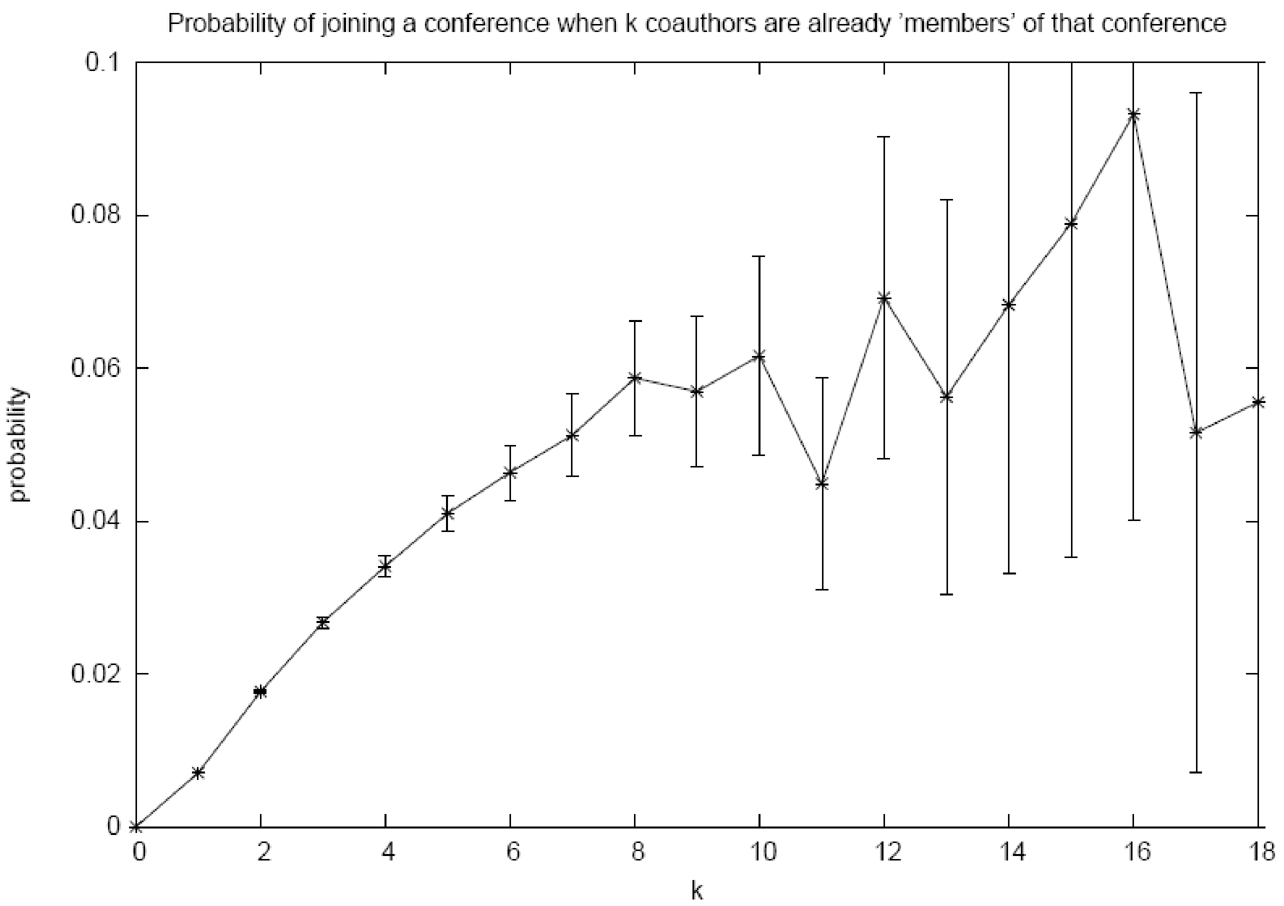
Happiness [Fowler and Christakis]



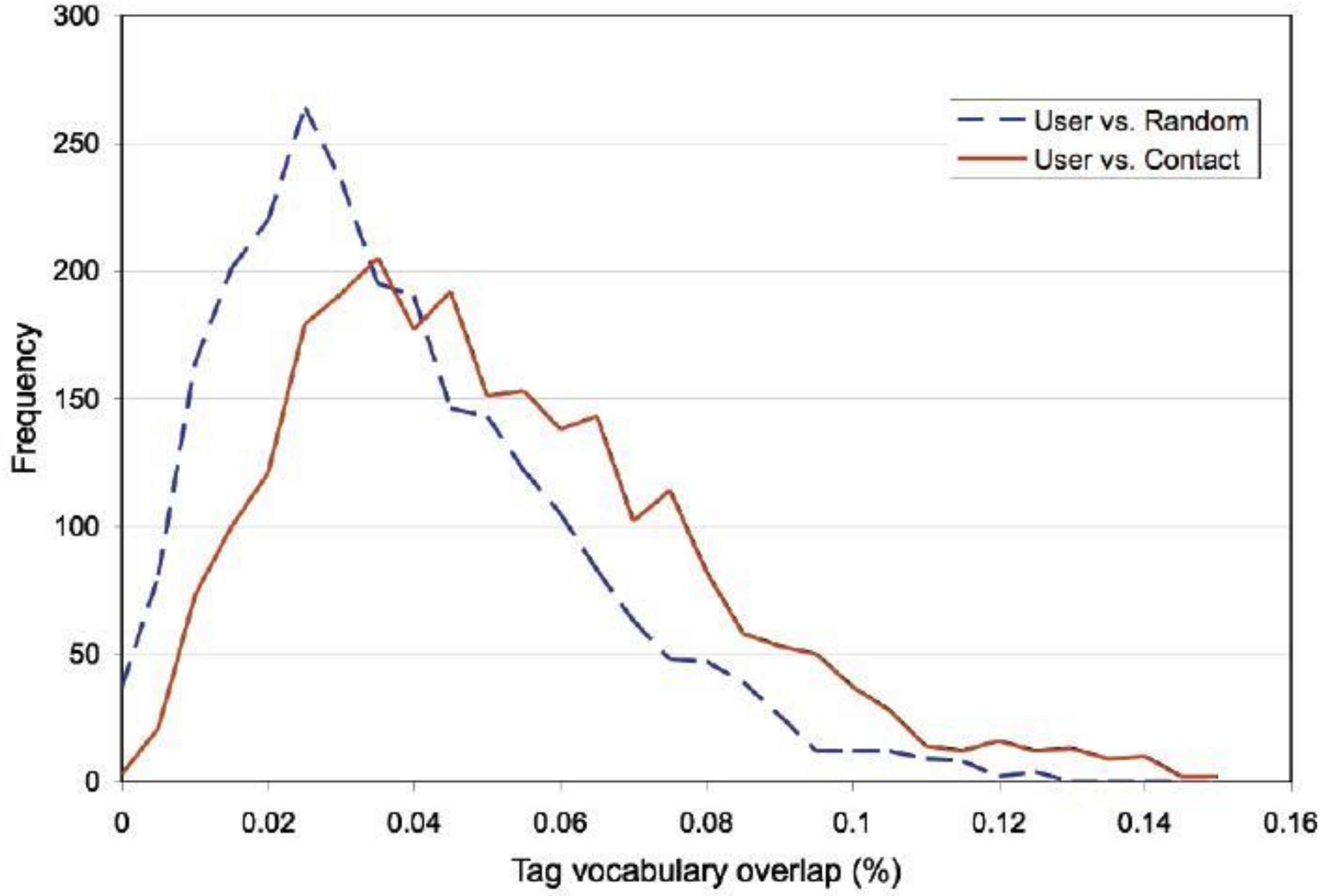
Joining communities [Backstrom et al]

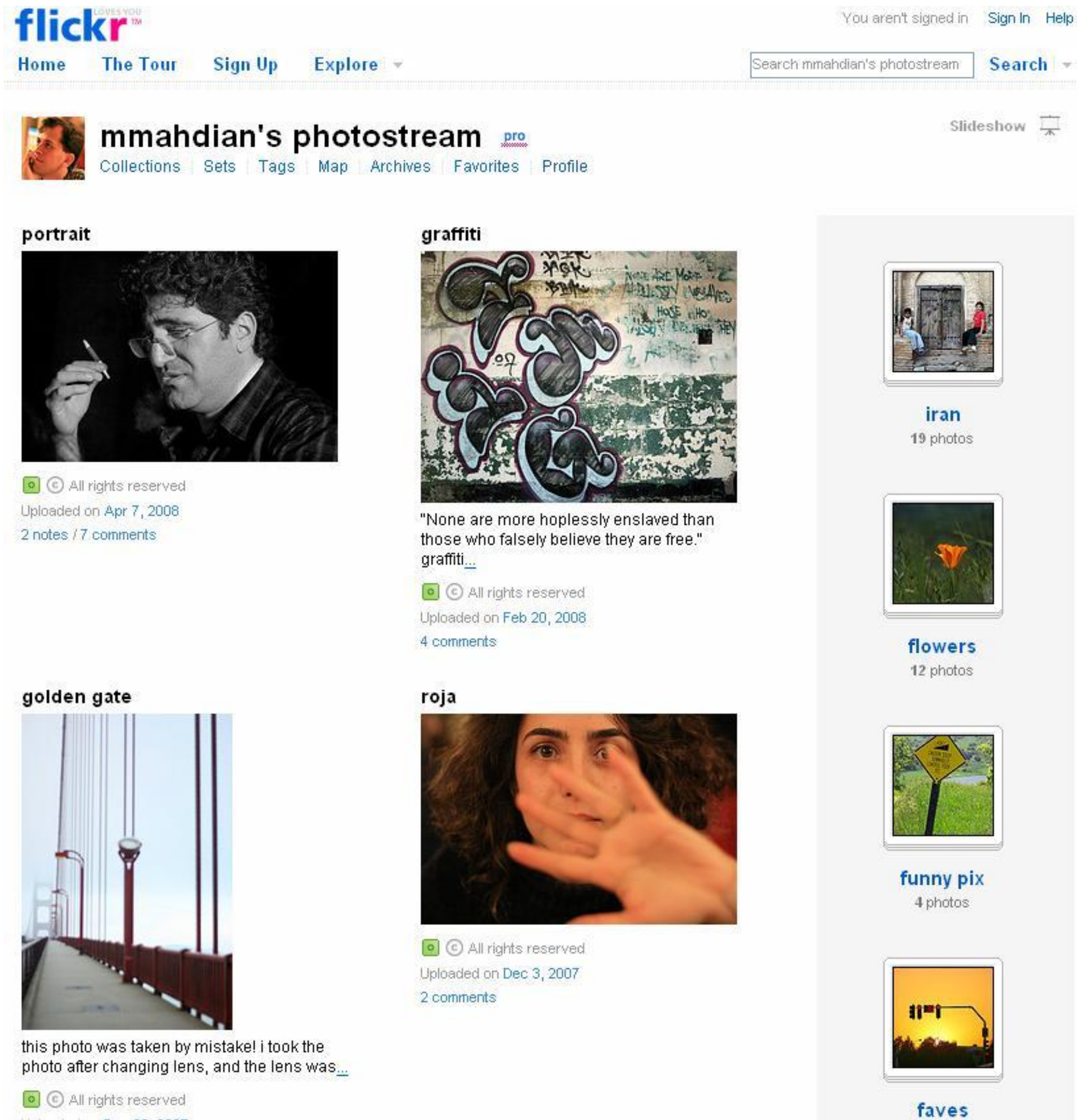


Publishing in conferences



Flickr tag vocabulary [Marlow et al.]

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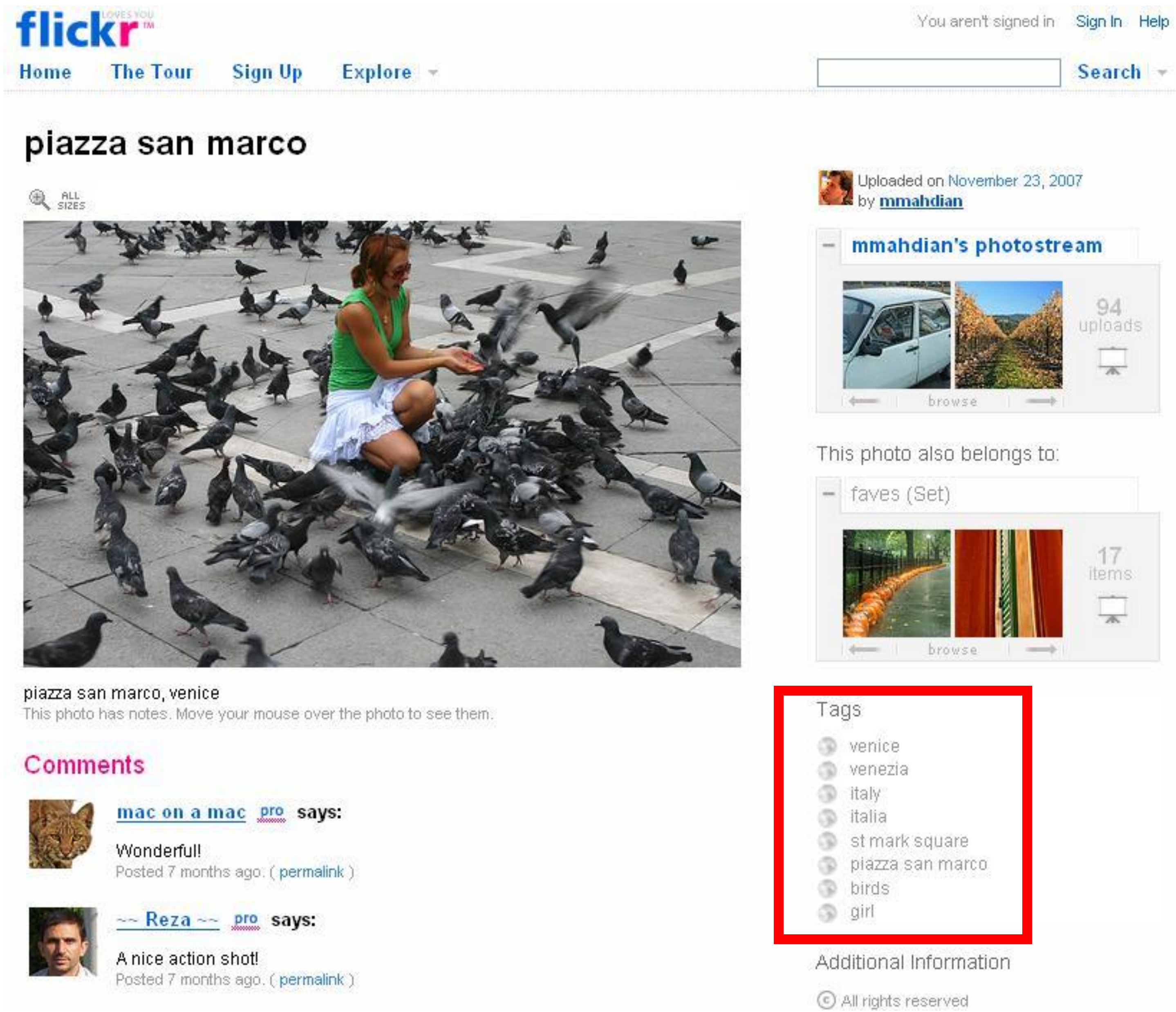
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Posted 7 months ago. (permalink)
~~ Reza ~~ pro says:
A nice action shot!
Posted 7 months ago. (permalink)
Additional Information
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Sources of Correlation

- Social influence (induction):
  One person performing an action can cause her contacts to do the same.
  - by providing information
  - by increasing the value of the action to them
- Homophily (selection):
  Similar individuals are more likely to become friends.
  - Example: two mathematicians are more likely to become friends.
- Confounding factors
  External influence from elements in the environment.
  - Example: friends are more likely to live in the same area, thus attend and take pictures of similar events, and tag them with similar tags

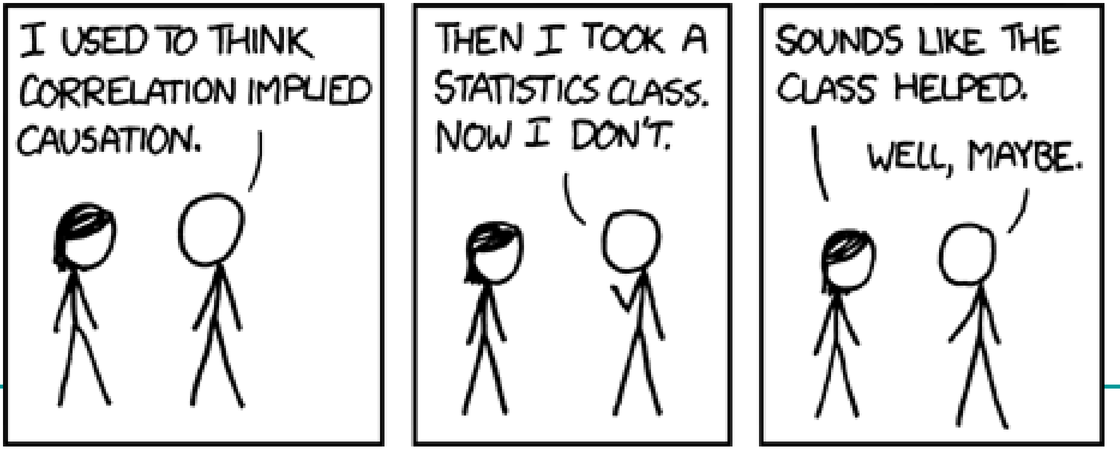
Social Influence

- Focus on a particular "action" A.
  - E.g.: buying a product, joining a community, publishing in a conference, using a particular tag, using the VoIP service, …
- An agent who performs A is called "active".
- x has influence over y if x performing A increases the likelihood that y performs A.

- Distinguishing factor: causality relationship

Causation vs. Correlation

- What we try to do is essentially distinguish causation from correlation.
- Common mistake, especially by journalists:
  - People who drink more coffee live longer
  - People who drive red cars create more accidents
  - Eating pizza "cuts cancer risk“
  - Ice cream sales and drowning



Identifying social influence

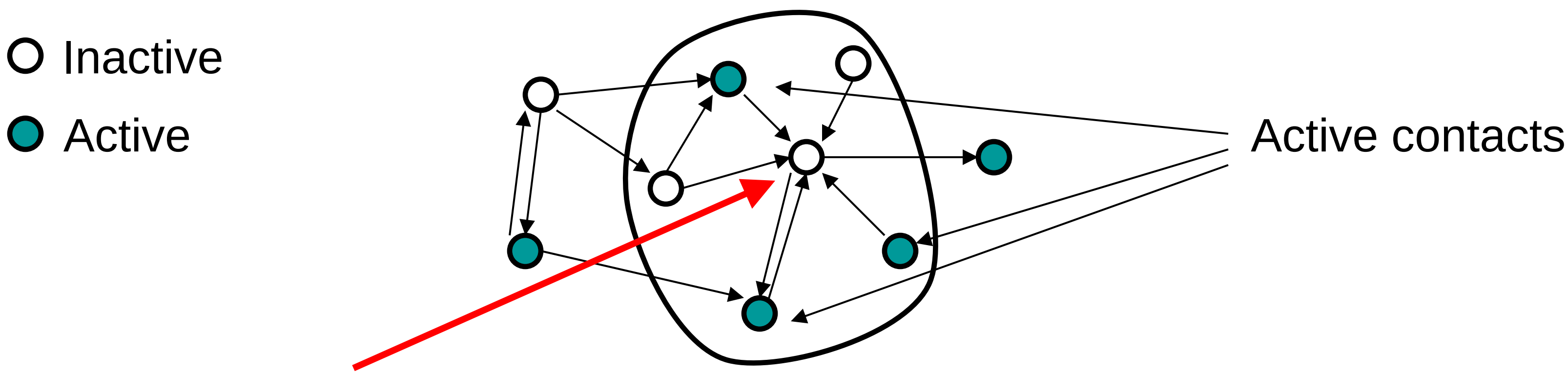
- Why is it important?
- Analysis: predicting the dynamics of the system. Whether a new norm of behavior, technology, or idea can diffuse like an epidemic
- Design: designing a system to induce a particular behavior, e.g.:
  - vaccination strategies (random, targeting a demographic group, random acquaintances, etc.)
  - viral marketing campaigns

Approach

- Measure correlation
- Models for influence and correlation
- Tests for distinguishing influence from correlation
- Theoretical results
- Apply tests on synthetic data
- Apply tests on real data (Flickr)

Influence Model

- Graph (static or dynamic)
- Edge (u,v): Node u can influence node v
- Discrete time: t = 0, 1, 2, …,T
- For each t, every inactive node becomes active with probability p(x), where x is the # active contacts



Model – Influence Probability

- Natural choice for $p(x)$: logistic regression function:

$$\ln\left(\frac{p(x)}{1-p(x)}\right) = \alpha \cdot x + \beta$$

with x (# active contacts) is the explanatory variable. I.e.,

$$p(x) = \frac{e^{\alpha \cdot x+\beta}}{1+e^{\alpha \cdot x+\beta}}$$

- Given data, can estimate α with Maximum Likelihood
- Coefficient α measures social correlation.

Measuring social correlation

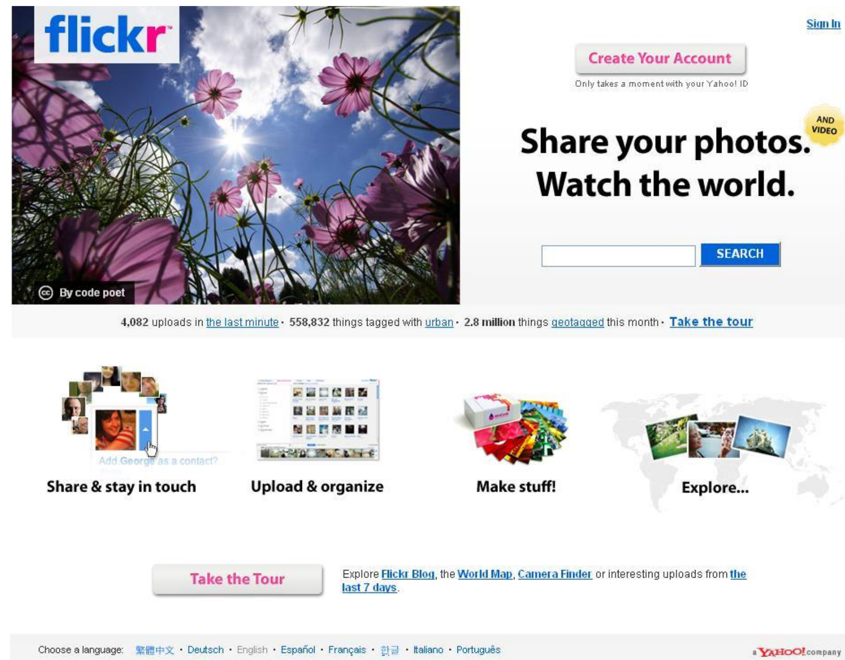
- Given data, we compute the maximum likelihood estimate for parameters α and β.
- Compute values Y_0, N_0, Y_1, N_1, Y_2, N_2, …
  - Y_x = # pairs (user u, time t) where at beginning of time step t, user u is not active and has x active friends and becomes active in this step.
  - N_x = …… does not become active in this step.
- Find α, β to maximize the likelihood function:

$$f(\alpha, \beta, \mathbf{Y_x}, \mathbf{N_x}) = \prod_x p(x)^{Y_x}(1-p(x))^{N_x}$$

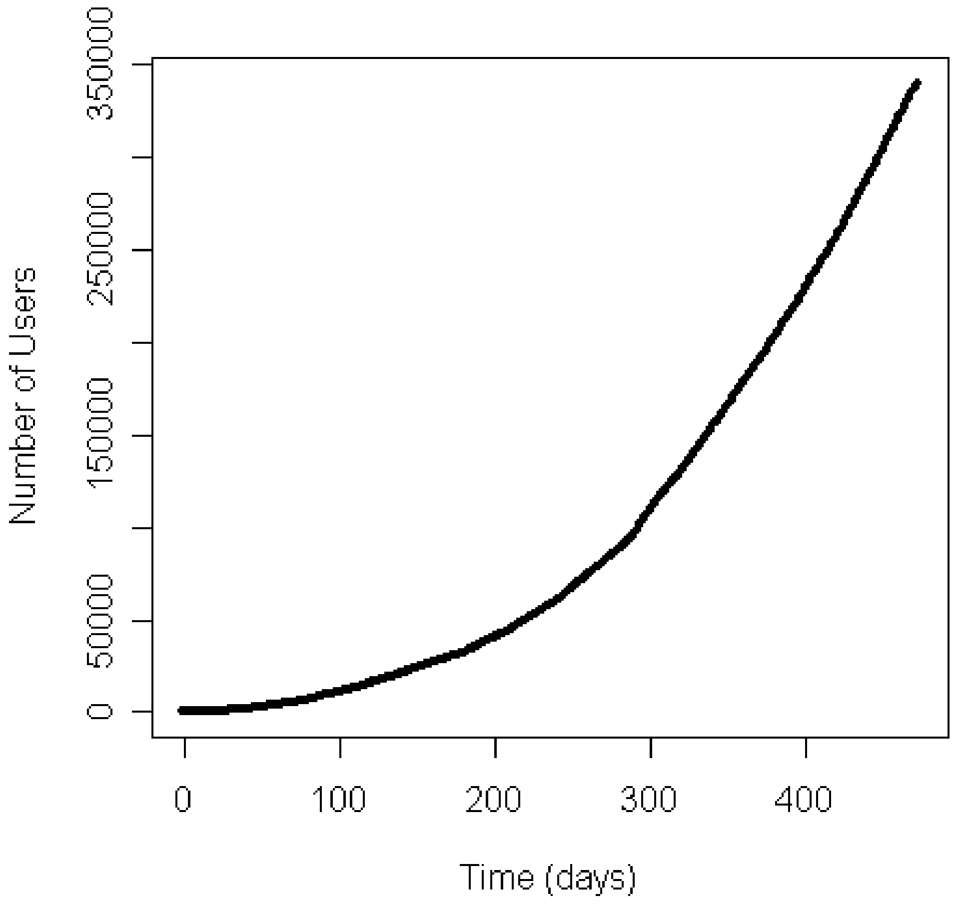
- For convenience, we cap x at a value R.

Flickr data set

- Photo sharing website
- 16 month period
- Growing # of users, final number ~800K
- ~340K users who have used the tagging feature
- Social network:
  - Users can specify “contacts”.
  - 2.8M directed edges, 28.5% of edges not mutual.



Flickr data set, growth

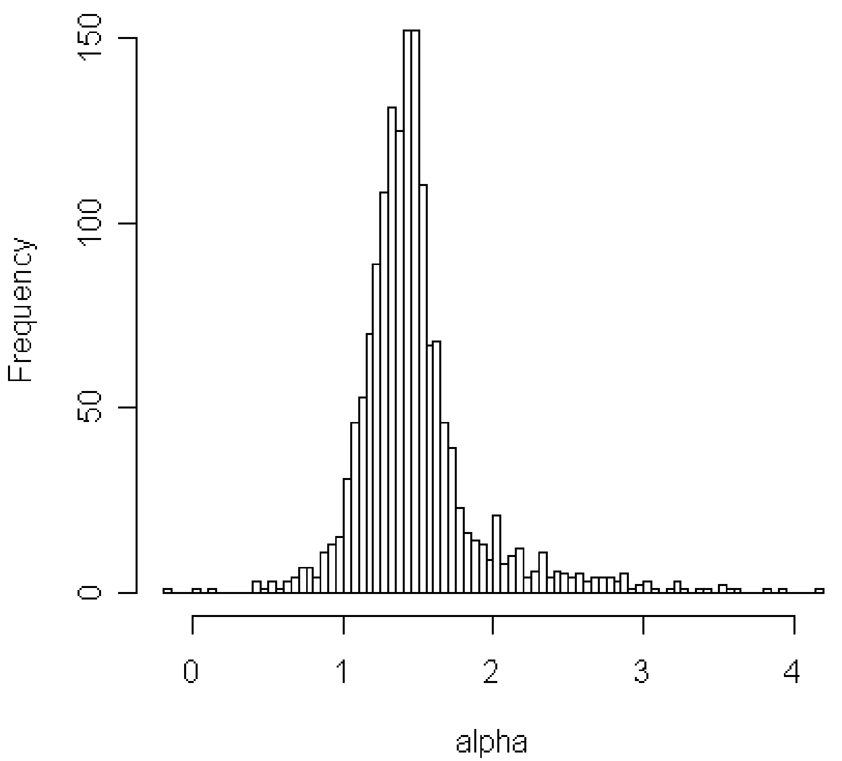


Flickr tags

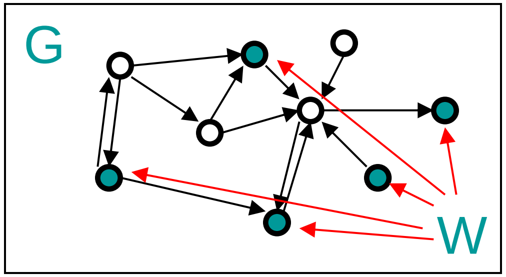
- ~10K tags
- We focus on a set of 1700
- Different growth patterns:
    - bursty (“halloween” or “katrina”)
    - smooth (“landscape” or “bw”)
    - periodic (“moon”)
- For each tag, define an action corresponding to using the tag for the first time.

Social correlation in flickr

- Distribution of α values estimated using maximum likelihood:

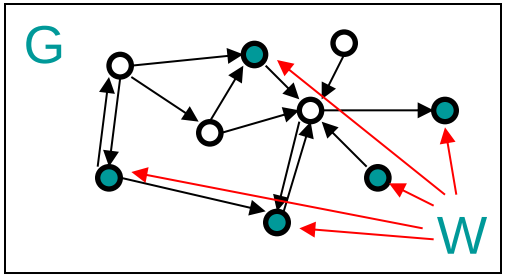


Distinguishing influence



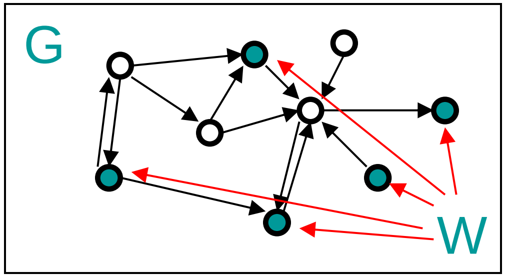
- Recall: graph G, set W of active nodes
- Influence model
  - First G is selected
  - Then W is picked from a distribution depending on G

Correlation Models



- Noninfluence models
  - Homophily (Similar individuals are more likely to become friends):
    - First W is picked, then G is picked from a distribution that depends on W
  - Confounding factors (External influence from elements in the environment):
    - Both G and W are picked from distributions that depend on another var X

Correlation Model



- Generally, we consider this correlation model:
  - (G,W) are selected from a joint distribution
  - Each agent in W picks an activation time i.i.d. from a distribution on [0,T]

Testing for Influence

- Shuffle Test:
  - **Simple Idea:** In non-influence model, even though an agent's probability of activation can depend on friends, her timing of activation is independent
  - Compute coefficient α
  - Shuffle time-stamp of all actions, and re-estimate coefficient α'
  - If $\alpha \approx \alpha'$, social influence is ruled out.
  - If $\alpha \neq \alpha'$, social influence can't be ruled out.
- Edge-Reversal Test:
  - Reverse direction of all edges, and re-estimate α.

Testing for Influence

Edge-Reversal Test:

- **Simple Idea:**
  - Main idea: assume edge (u → v), where u, v become active
  - If we have influence u is expected to become active before v
  - If there is no influence, each is equally likely to become active first
- **Test:**
  - Reverse direction of all edges, and re-estimate α.

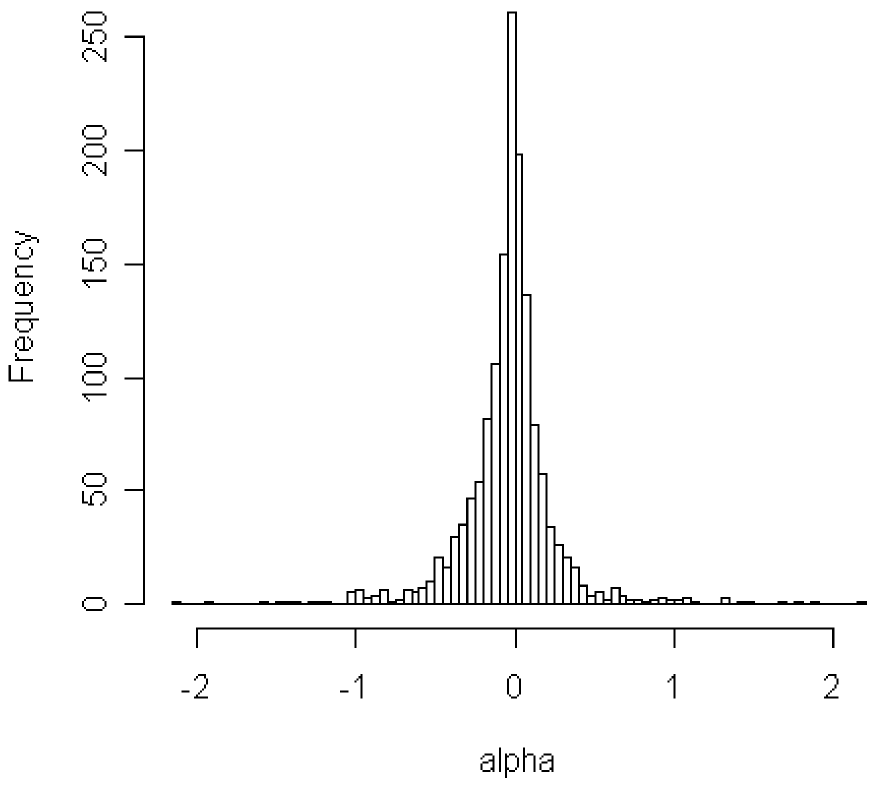
Shuffle test, theoretical justification

- Theorem. If the graph is large enough, the shuffle test rules out the general model of correlation.

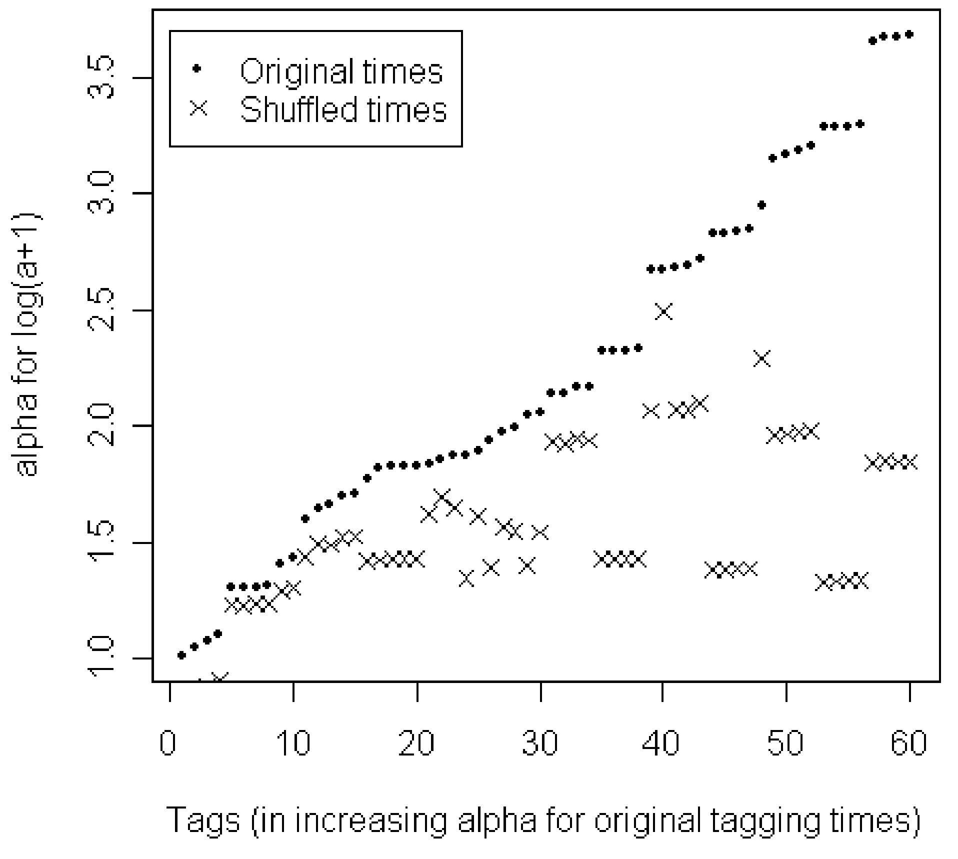
Simulations

- Run the tests on randomly generated action data on Flickr network.
- Baseline: no-correlation model, actions generated randomly to follow the pattern of one of the real tags, but ignoring network
- Influence model: same as described, with a variety of (α, β) values
- Correlation model: pick a # of random centers, let W be the union of balls of radius 2 around these centers.

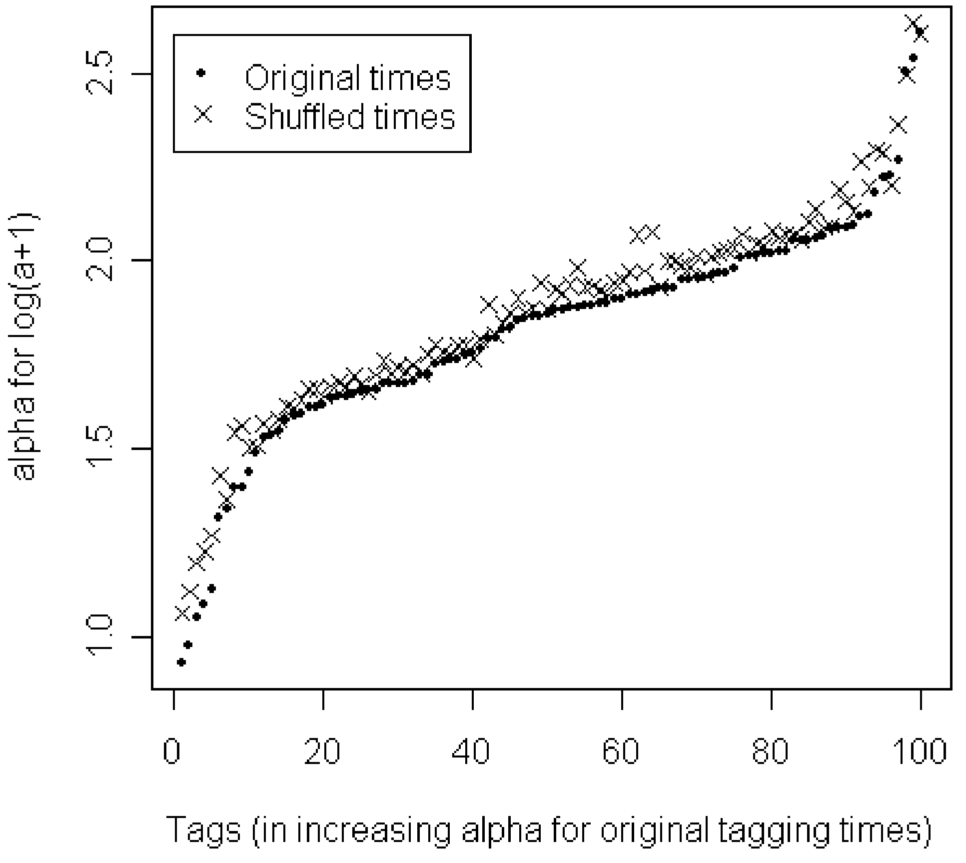
Simulation Results, Baseline



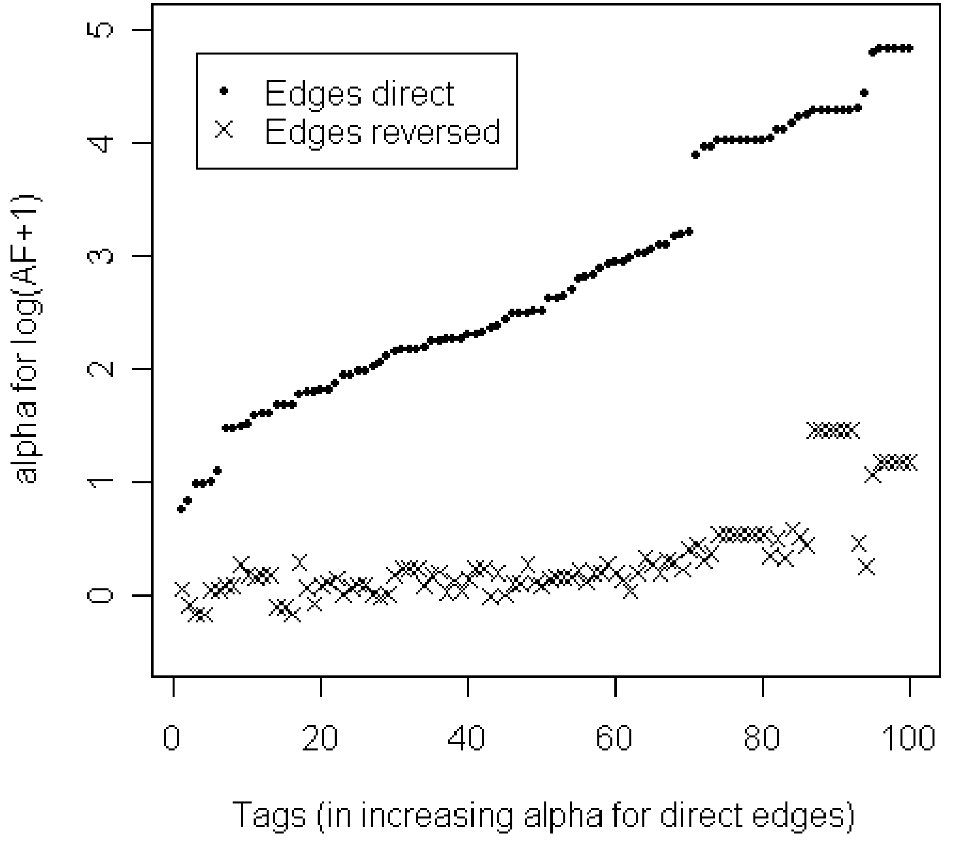
Shuffle Test, Influence Model



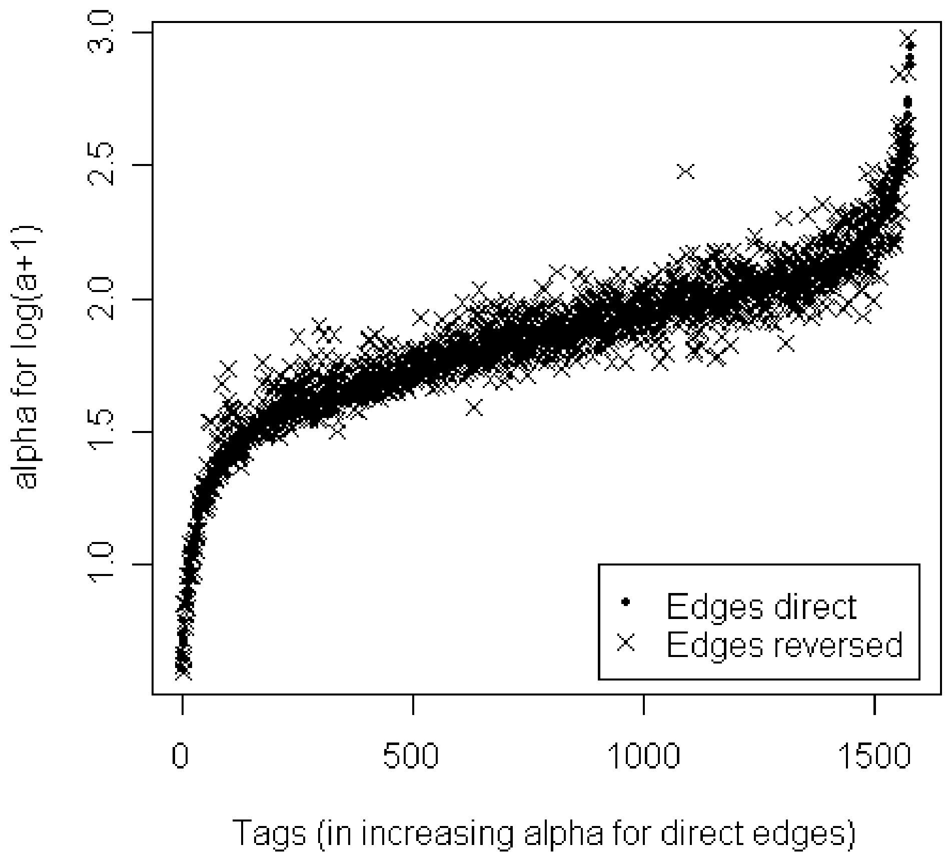
Shuffle Test, Correlation Model



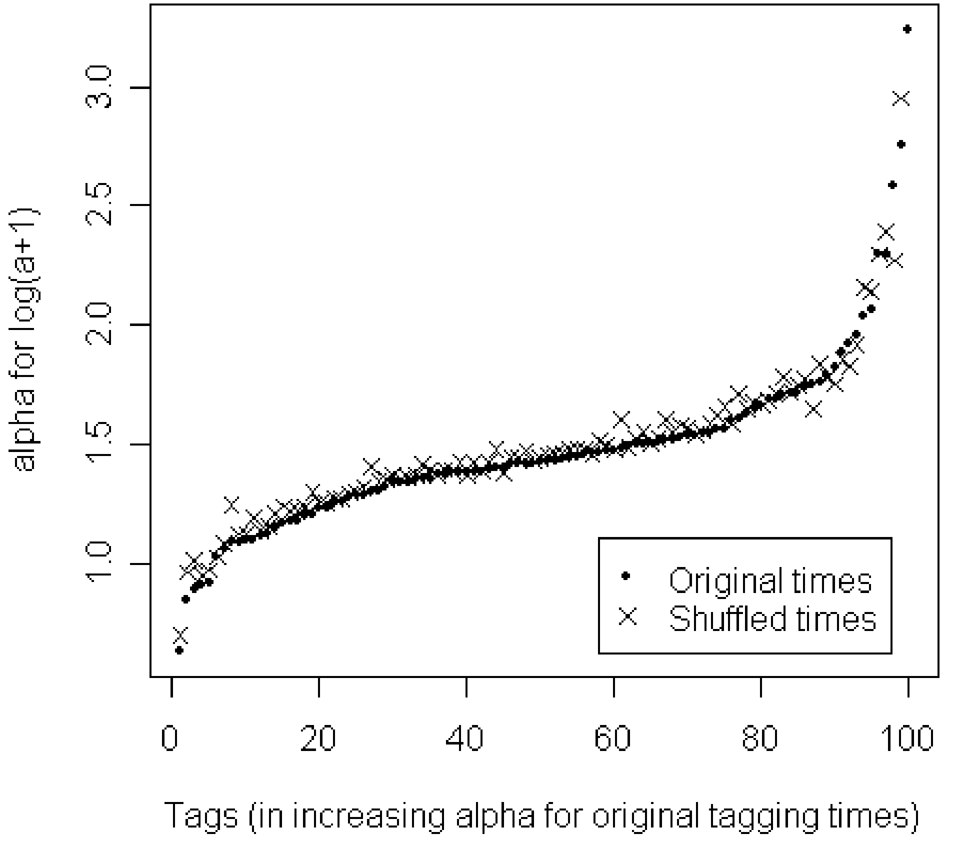
Edge-Reversal Test, Influence Model



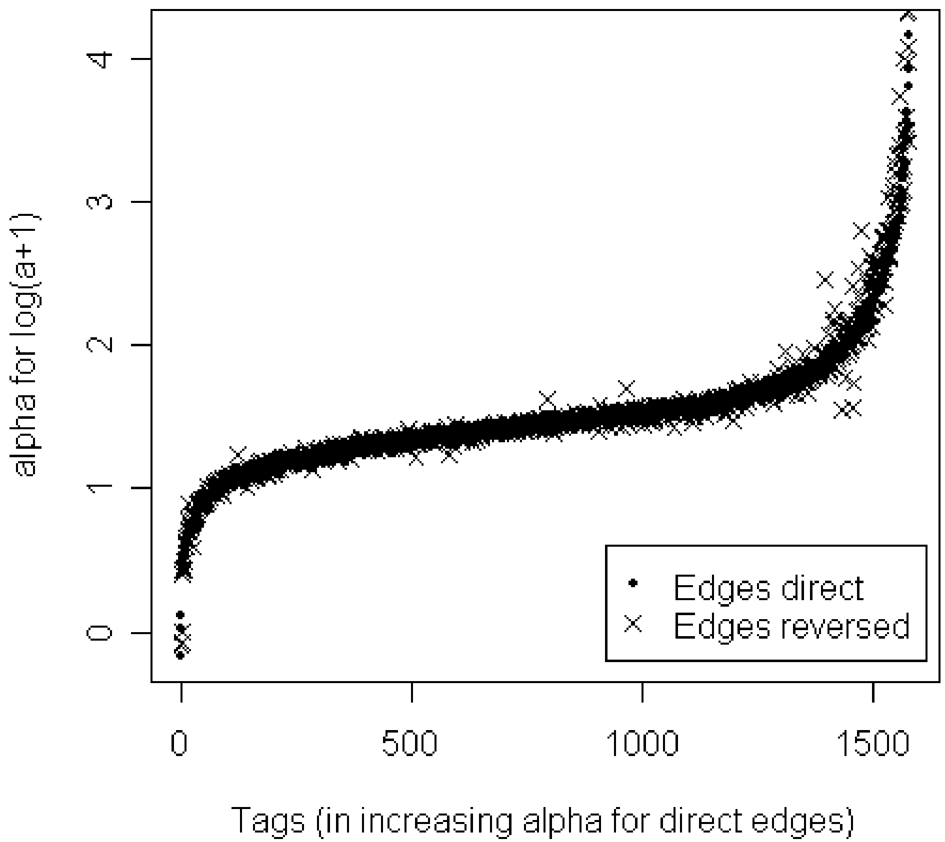
Edge-Reversal Test, Correlation Model



Shuffle Test on Flickr Data



Edge-Reversal Test on Flickr Data



Conclusions

- Our contributions
  - Defined two models that exhibit correlation, one with and the other without social influence
  - Developed statistical tests to distinguish the two
  - Theoretical justification for one of the tests
  - Simulations suggest that the tests “work” in practice
  - On Flickr, we conclude that despite considerable correlation, no social influence can be detected
- Discussion
  - cannot conclusively say there is influence without controlled experiments (example: flu treatment)
  - still can rule out potential candidates
  - Open: develop algorithms to find “influential” nodes/communities given a pattern of spread