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]

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Joining communities [Backstrom et al]

Probability of joining a community when k friends are already members

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Publishing in conferences

Probability of joining a conference when \( k \) coauthors are already "members" of that conference

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Flickr tag vocabulary [Marlow et al.]
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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

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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"
  - Black people six times more likely to be jailed than whites

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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: \(t = 0, 1, 2, \ldots, T\)
- 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 $\alpha$ with Maximum Likelihood
- Coefficient $\alpha$ measures social correlation.
Measuring social correlation

- Given data, we compute the maximum likelihood estimate for parameters $\alpha$ and $\beta$.

- Compute values $Y_0, N_0, Y_1, N_1, Y_2, N_2, \ldots$
  
  - $Y_x = \# \text{ pairs (user u, time t)}$ where at beginning of time step t, user u is not active and has $x$ active friends and becomes active in this step.
  
  - $N_x = \ldots$ does not become active in this step.

- Find $\alpha, \beta$ to maximize the likelihood function:

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

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

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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.

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Flickr data set, growth

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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 $\alpha$ 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 $X$

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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 $\alpha$.
  - Shuffle time-stamp of all actions, and re-estimate coefficient $\alpha'$.
  - 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 $\alpha$. 

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Testing for Influence

Edge-Reversal Test:

- **Simple Idea:**
  - Main idea: assume edge \((u \rightarrow v)\), 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 \(\hat{\text{R}}\).
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 $(\alpha, \beta)$ values.

- **Correlation model:** pick a # of random centers, let $W$ be the union of balls of radius 2 around these centers.
Simulation Results, Baseline

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Shuffle Test, Influence Model

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Shuffle Test, Correlation Model

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Edge-Reversal Test, Influence Model

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Edge-Reversal Test, Correlation Model

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Shuffle Test on Flickr Data

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Edge-Reversal Test on Flickr Data

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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