On the Precision of Social and Information Networks

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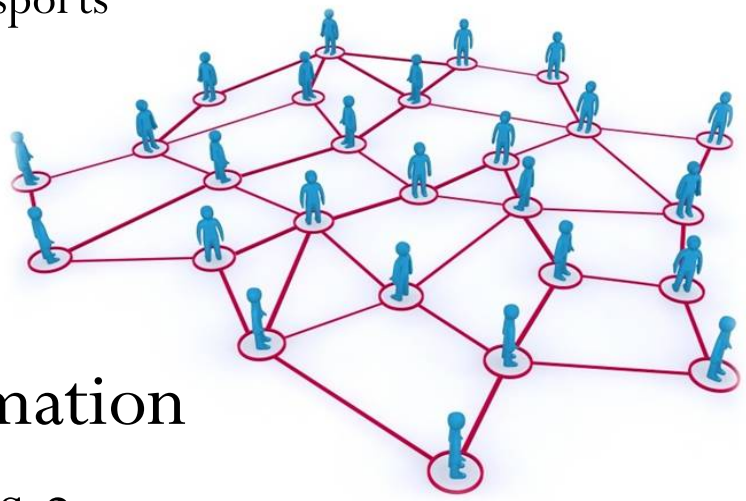
Information Networks

- Social Networks play an important role in information dissemination
  - Emergency events, product launches, sports updates, celebrity news,…



- Their effectiveness as information dissemination mechanisms is a source of their popularity

A Fundamental Tension

Two conflicting characteristics in social networks:

- **Diversity:** Users are interested in diverse content
- **Broadcast:** Users disseminate information via posts/tweets – these are blunt broadcast mechanisms!

Running Example

Bob tweets about:

- Christianity
- DC Politics
- Bulls

Charlie tweets about:

- Jay-Z
- Lady Gaga
- Kobe

Adam interested in

- Apple
- Rap music
- Lakers

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Bob tweets about:

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Follow

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A Fundamental Tension

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- **Diversity:** Users are interested in diverse content
- **Broadcast:** Users disseminate information via posts/ tweets – these are blunt broadcast mechanisms!

Precision: Do users receive a lot of un-interesting content?

Recall: Do users miss a lot of potentially interesting content?

Question we study

Can information networks have high precision and recall?

Case Study: Twitter

- A random tweet is uninteresting to a random user…
- … but users have interests and follow others based on these

Information networks like Twitter are constructed according to users' interests!

Revisiting our example…

Bob tweets about:

- Christianity
- DC Politics
- Bulls

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Follow

Adam interested in

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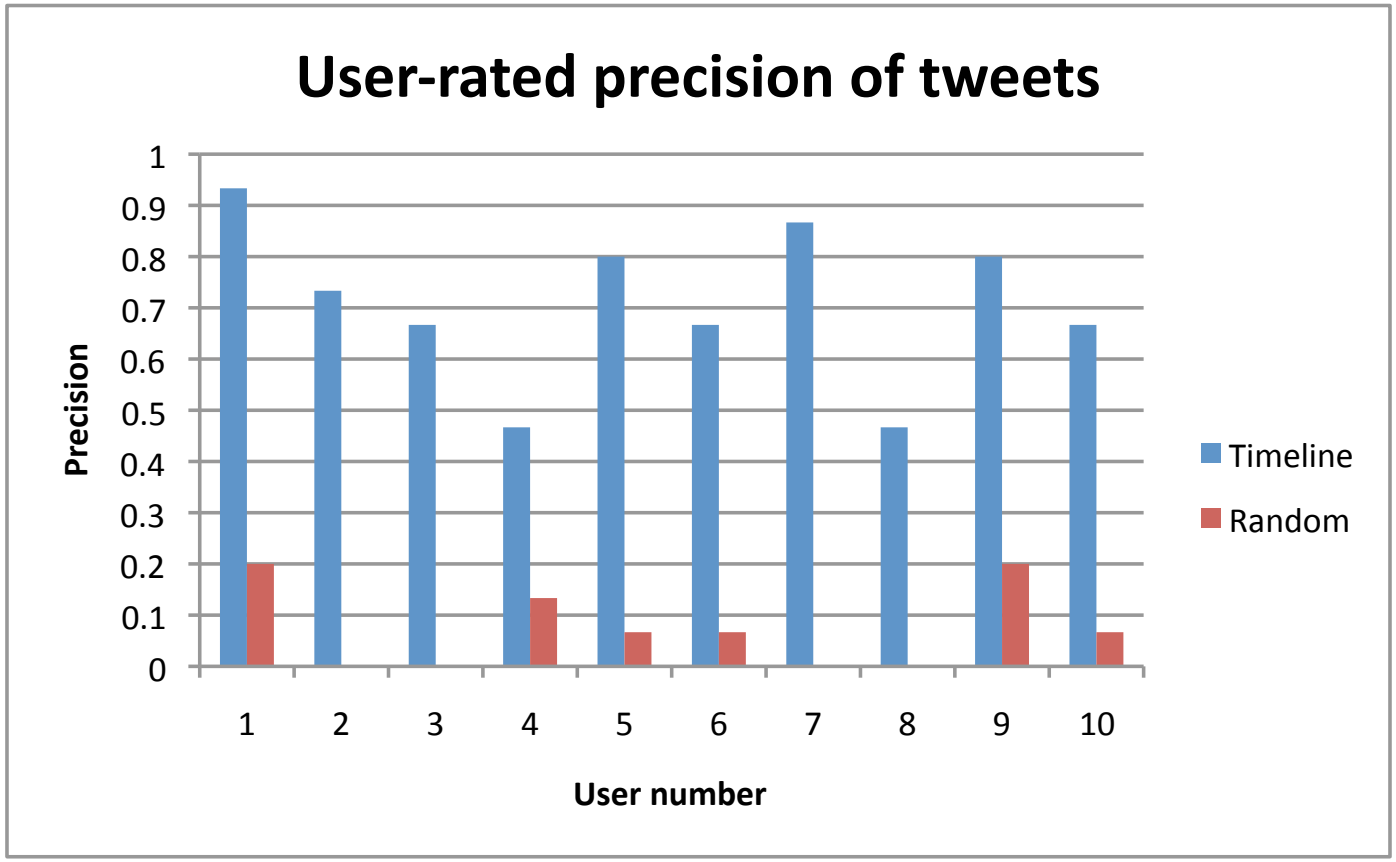
Small User Study on Twitter



Roadmap

- Assumptions:
  1. Users have immutable interests (independent of the network)
  2. Choose to connect to other users based on their interests
  3. Step (2) is optimized for precision and recall

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- **Question 1:** What conditions on the structure of user interests are necessary for high precision and recall, and small dissemination time?

- **Question 2:** Can we empirically validate these conditions as well as the conclusion on Twitter?

User-Interest Model

- Set of interests I; Set of users U
- Each interest *i* is associated with two sets of users:
  - **Producers** *P(i)* = Users who tweet about *i*
  - **Consumers** *C(i)* = Users who are interested in *i*
- Denote the mapping from users to interests as *Q(I, U)*
- Assume: $P(i) \subseteq C(i)$ for all interests *i*

Example Revisited

User b 

P(b) = {s}
C(b) = {r, s, t}

User c 

P(c) = {q, t}
C(c) = {q, r, s, t}

User a 

P(a) = {q}
C(a) = {q, r, s}

Social (user-user) Graph *G(U,E)*

User b

P(b) = {s}
C(b) = {r, s, t}

User c

P(c) = {q, t}
C(c) = {q, r, s, t}

User a receives interests
R(a) = {q, t}

Social graph

User a

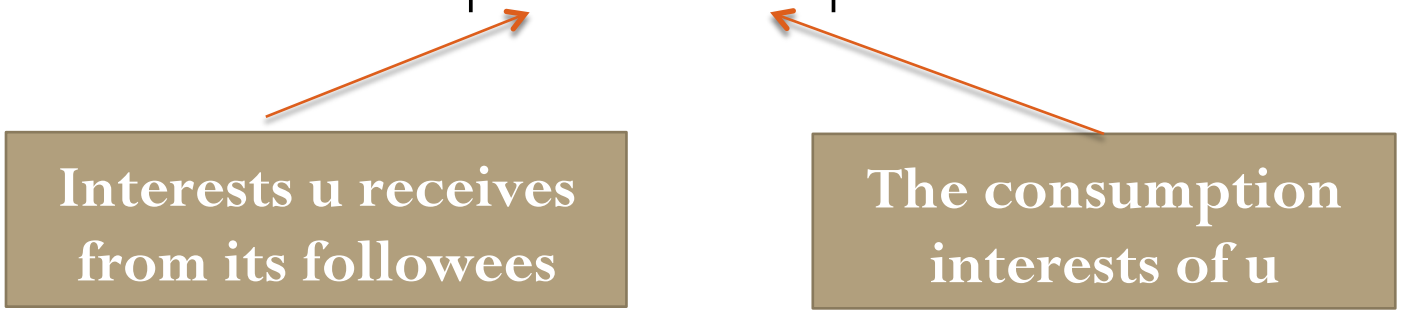
P(a) = {q}
C(a) = {q, r, s}

PR Score

$PR(u)$ = Precision and recall score for user u

- Function of user-interest map $Q(I,U)$ and social graph $G(U,E)$

$$PR(u) = \frac{|R(u) \cap C(u)|}{|R(u) \cup C(u)|}$$



Example

User b 

P(b) = {s, t}
C(b) = {r, s, t}

User c 

P(c) = {q, t}
C(c) = {q, s, t}

Social graph

R(a) = {q, t}
C(a) = {q, r, s}

PR(a) = ¼ = 0.25

User a 

P(a) = {q}
C(a) = {q, r, s}

Improved Score

User b

P(b) = {s, t}
C(b) = {r, s, t}

User c

P(c) = {q, t}
C(c) = {q, s, t}

Social graph

R(a) = {q, s, t}
C(a) = {q, r, s}

PR(a) = 2/4 = 0.5

User a

P(a) = {q}
C(a) = {q, r, s}

α-PR User-Interest Maps *Q(I,U)*

A user-interest map Q(I,U) is α-PR if: There exists a social graph G(U,E) s.t. all users u have PR-Score $\geq \alpha$

Special case: 1-PR means that R(u) = C(u) for all users u

Necessary Conditions for 1-PR

- **Condition 1:**

  If *Q(I, U) is* "non-trivial" and *G(U,E)* is (strongly) connected:

  Then P(i) ⊂ C(i)* for some interest *i

- **Informal implication:**

  Users have broader consumption interests and narrower production interests

Experimental Setup

- Classify text of tweets using 48 topics
  - Yields "topic distribution" for each user
  - Entropy of distribution lies between 0 and $\log_2(48) = 3.87$

- $P(u)$= Interest distribution in tweets produced by u
- $C(u)$ = Interest distribution in URL clicks made by u

Verifying Condition 1

TYPE OF INTEREST DISTRIBUTION	AVERAGE SUPPORT	AVERAGE ENTROPY
Consumption	7.78	2.00
Production	3.96	1.24

Can Interests be chosen at Random?

Different interests can have different "participation levels"

Theorem: If users choose P production and C consumption interests **at random** preserving participation levels of the interests then:

With high probability the interest structure is not α-PR for any constant α

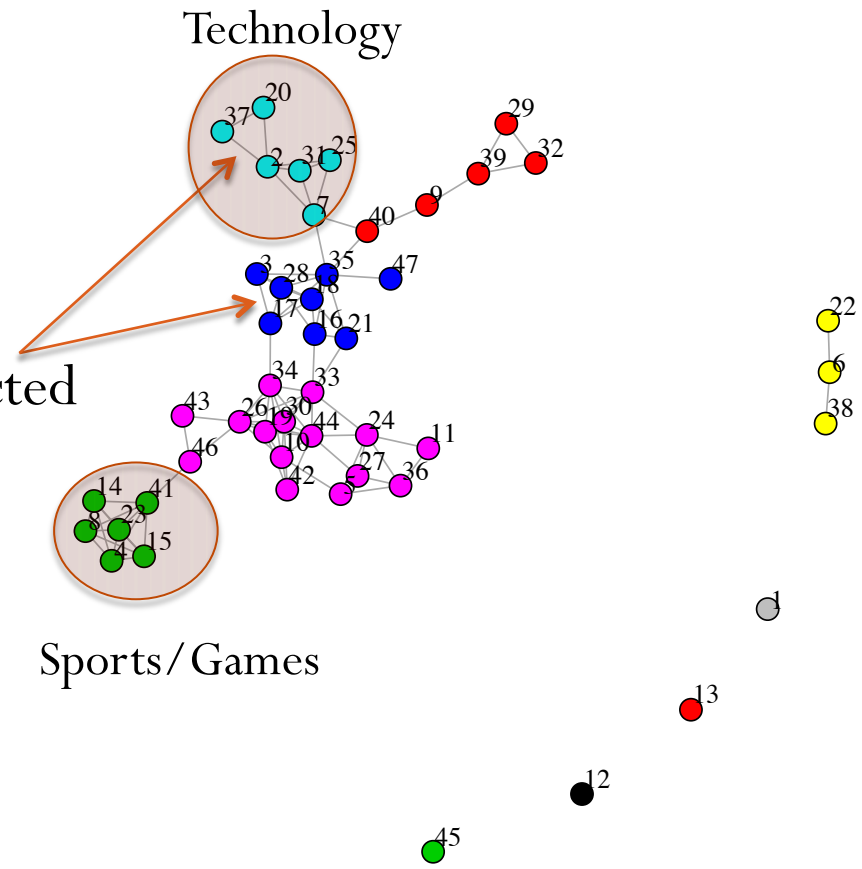
Technically needs:

- $n = |U|$ and $|I| = m > n^{1/2}$
- $P = log^{\delta} n$ for $\delta > 2$ *and* $C < n^{1/3}$
- *Bounded second moment of participation level distribution*

Key proof idea: Q(I,U) behaves like an expander graph

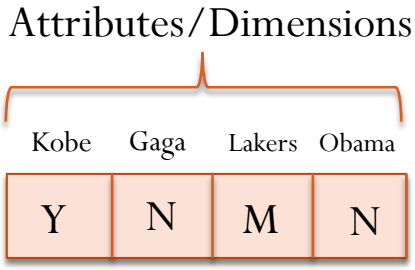
Condition 2:
Interests have Clustered Structure

Share more users than is predicted by a random assortment



Interest Structure achieving 1-PR

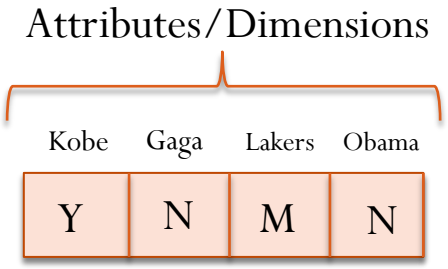
Kronecker graph model



d = O(log n) dimensions
K = O(log n) values

Interest Structure achieving 1-PR

Kronecker graph model



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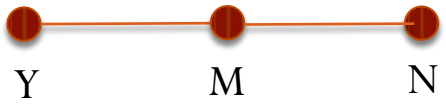
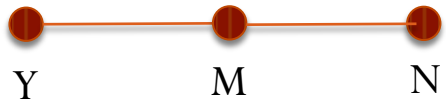
Similarity graph on values



	Y	**M**	**N**
Y	1	1	0
M	1	1	1
N	0	1	1

Interest Structure

Similarity graph on values

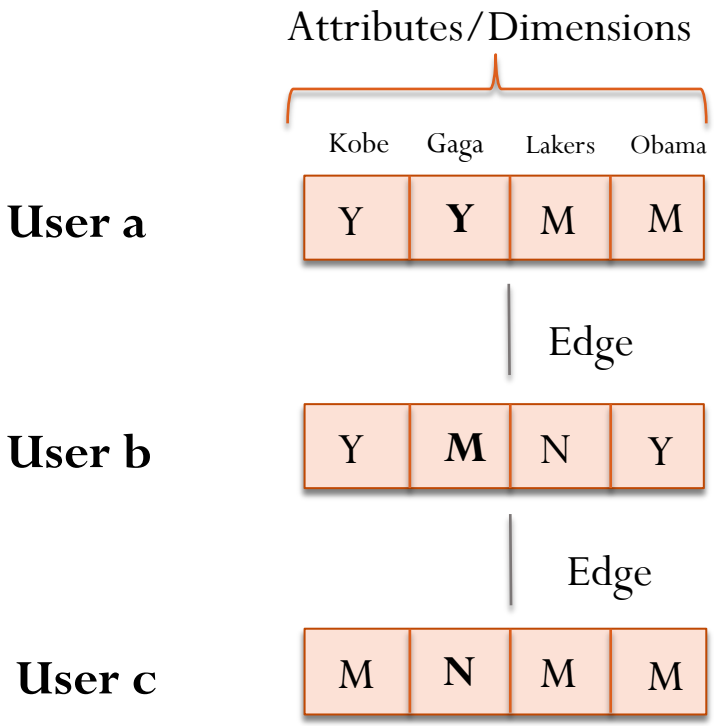


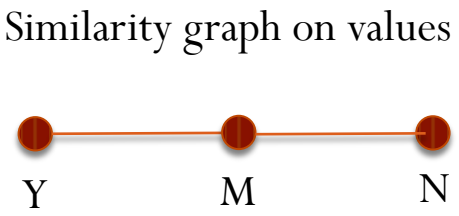
Attributes/Dimensions

	Kobe	Gaga	Lakers	Obama	
Interest i	Y		M		Set of relevant dimensions + their values
Producer	Y	*	M	*	Agrees *exactly* on all relevant dimensions
Consumer	M	*	N	*	*Similar* on all relevant dimensions
Not interested	N	*	M	*	

User-user Graph

[Leskovec, Chakrabarti, Kleinberg, Faloutsos, Ghahramani '10]





Undirected Edge between two users iff ALL dimensions are similar

Such graphs can have:

- Super-constant average degree
- Heavy tailed degree distributions
- Constant diameter

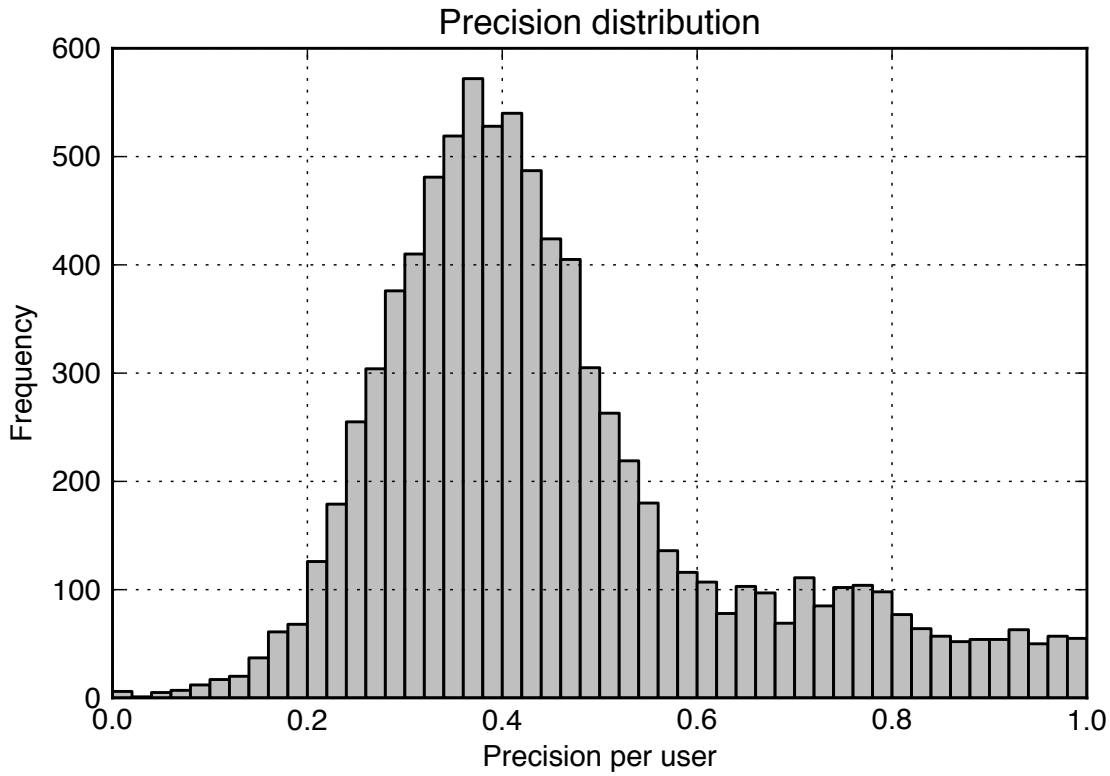
Main Positive Result

- **The Kronecker interest structure has 100% PR!**
- Users only receive interesting information
- Users receive all information they are interested in
- The dissemination time is constant.

Empirical Study of Precision

$$\text{Precision}(u) = \frac{\sum_{(u,v)\in E} \left|C(u) \cap P(v)\right|}{\sum_{(u,v)\in E} \left|P(v)\right|}$$

Median precision = 40%
Baseline precision = 17%



Interpretation: *One in 2.5 interests received on any follow edge are interesting*

Caveat: This is only a first step!

- Measuring interests
  - Use URL clicks as a measure of consumption/relevance
  - Use 48 topics as proxy for interests
  - Not considered quality of tweets in measuring interest
  - Not explored structure of interests in great detail
- Empirical validation
  - User studies are more reliable, but our study is small
  - We have not measured recall or dissemination time

Open Questions

- Better empirical measures of interests and PR?
  - In-depth analysis of structure of interests
  - How can recall be measured?

- Can high PR information networks arise in a decentralized fashion?
  - How can users discover high PR links?

Thank You!