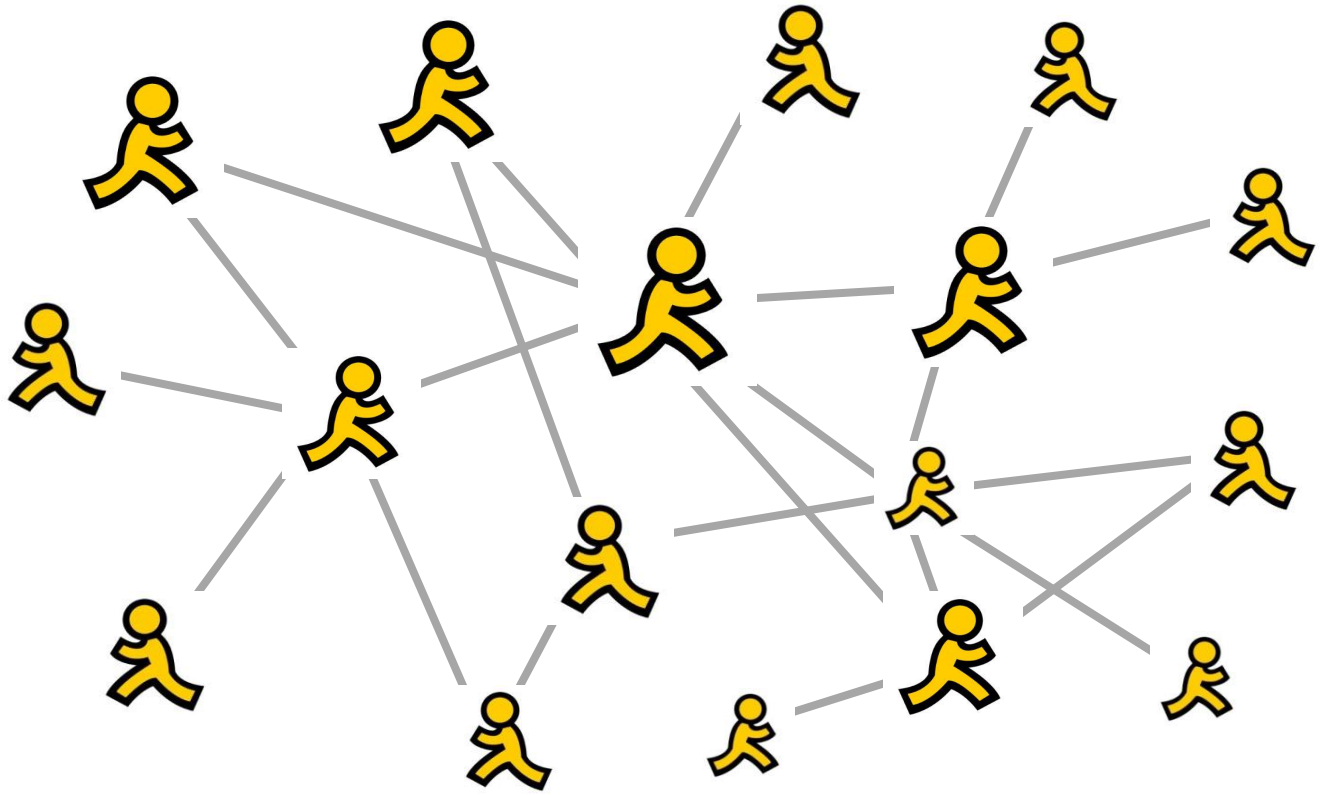
Can cascades be predicted?

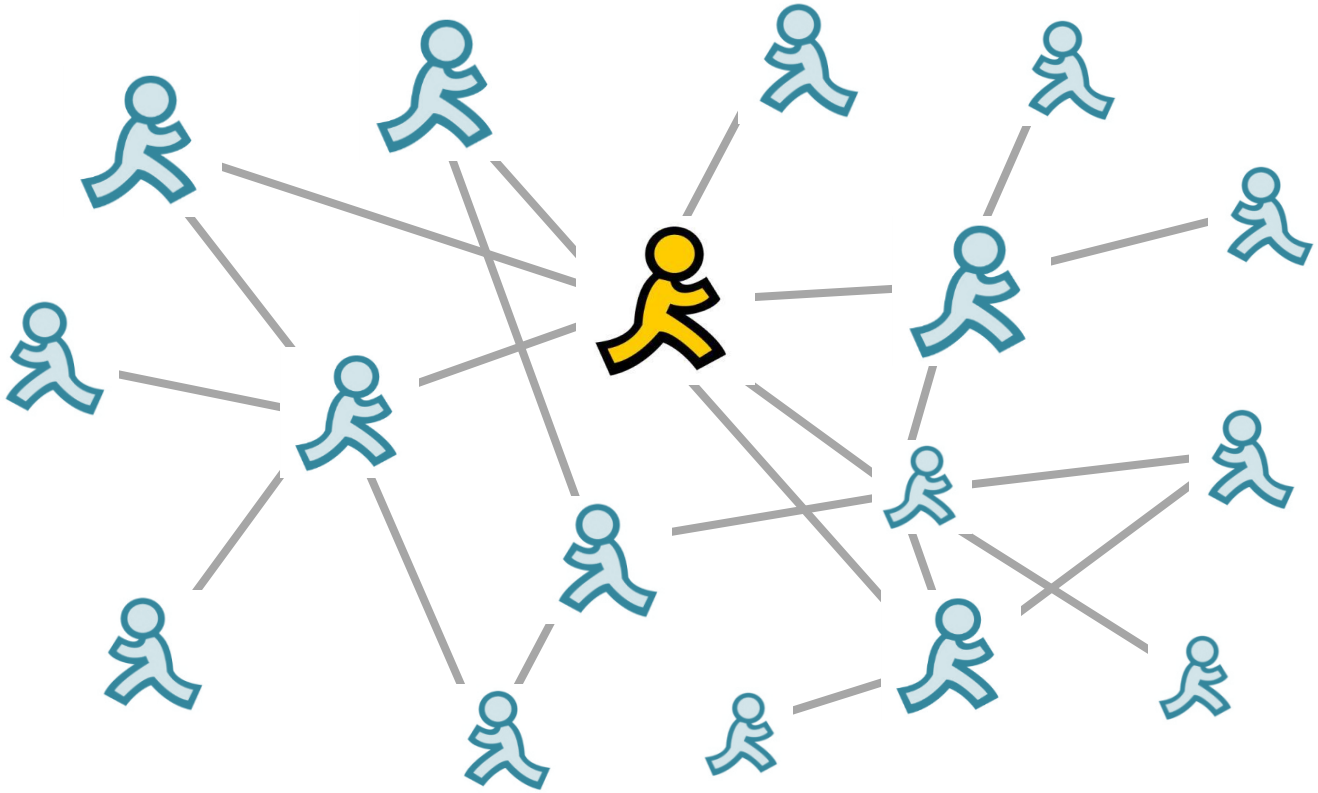
Jure Leskovec (@jure)
Joint work with **J. Cheng**, **H. Lakkaraju**, **J. McAuley**, L. Adamic, A. Dow, J. Kleinberg

Social Networks



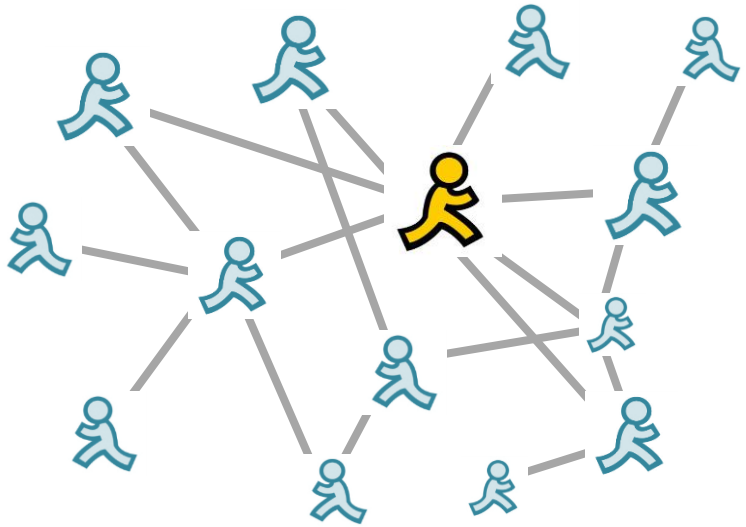
We are embedded in networks

Networks & Information



Networks provide access to information!

Networks & Information



We …

- learn
- make decisions
- gain trust and safety

… based on the influence from our neighbors in the network

- **For example:** Before purchasing electronics
  - 50% of people do research online
  - 68% of people consult friends [Burke]

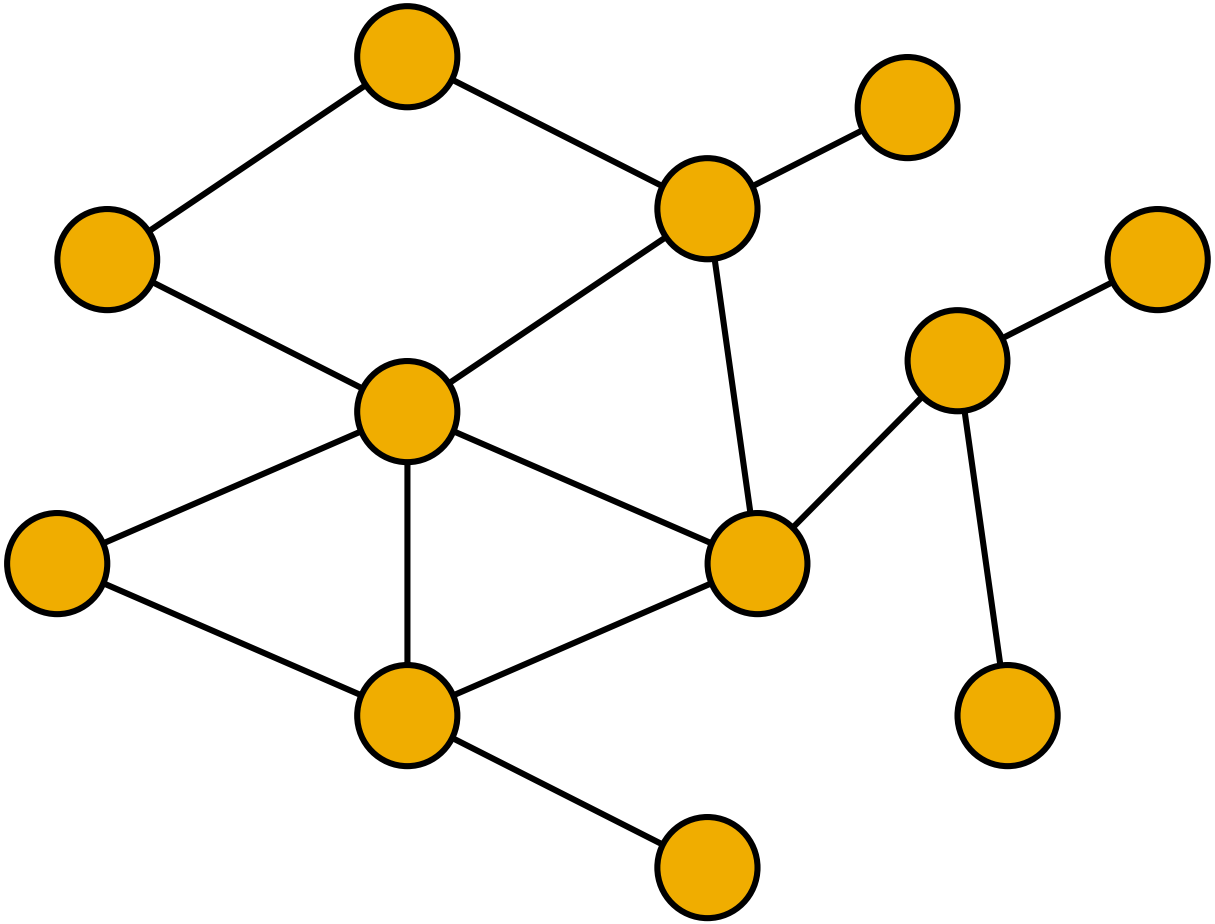
Diffusion in Networks

- **Networks provide a skeleton for the diffusion and flow of *information*!**

More generally:

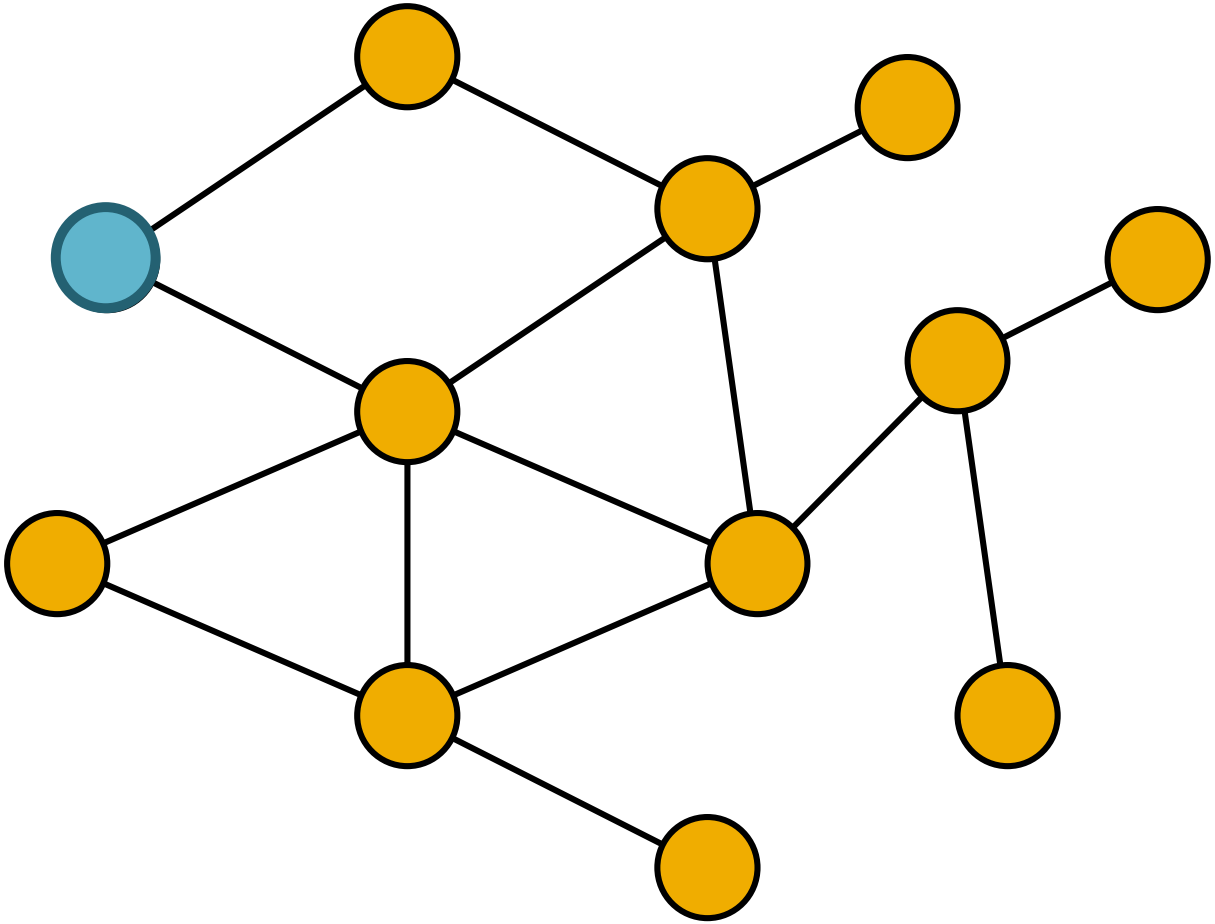
- **Contagion: Behavior that spreads from a node to node like an epidemic**
  - News, opinions, rumors
  - Word-of-mouth and product adoptions
  - Political mobilization
  - Infectious diseases

Diffusion in Networks



Contagions spread through the network like epidemics

Diffusion in Networks



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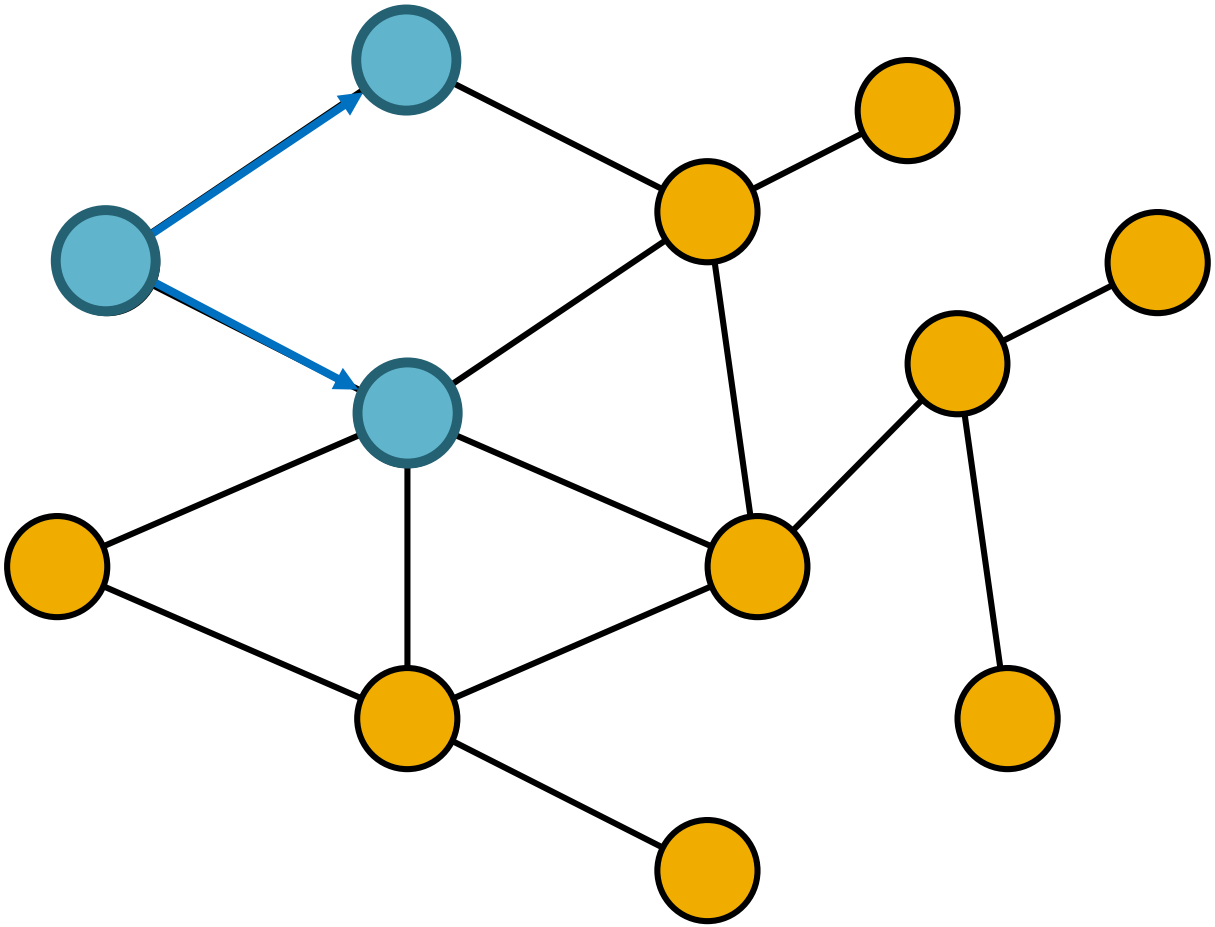

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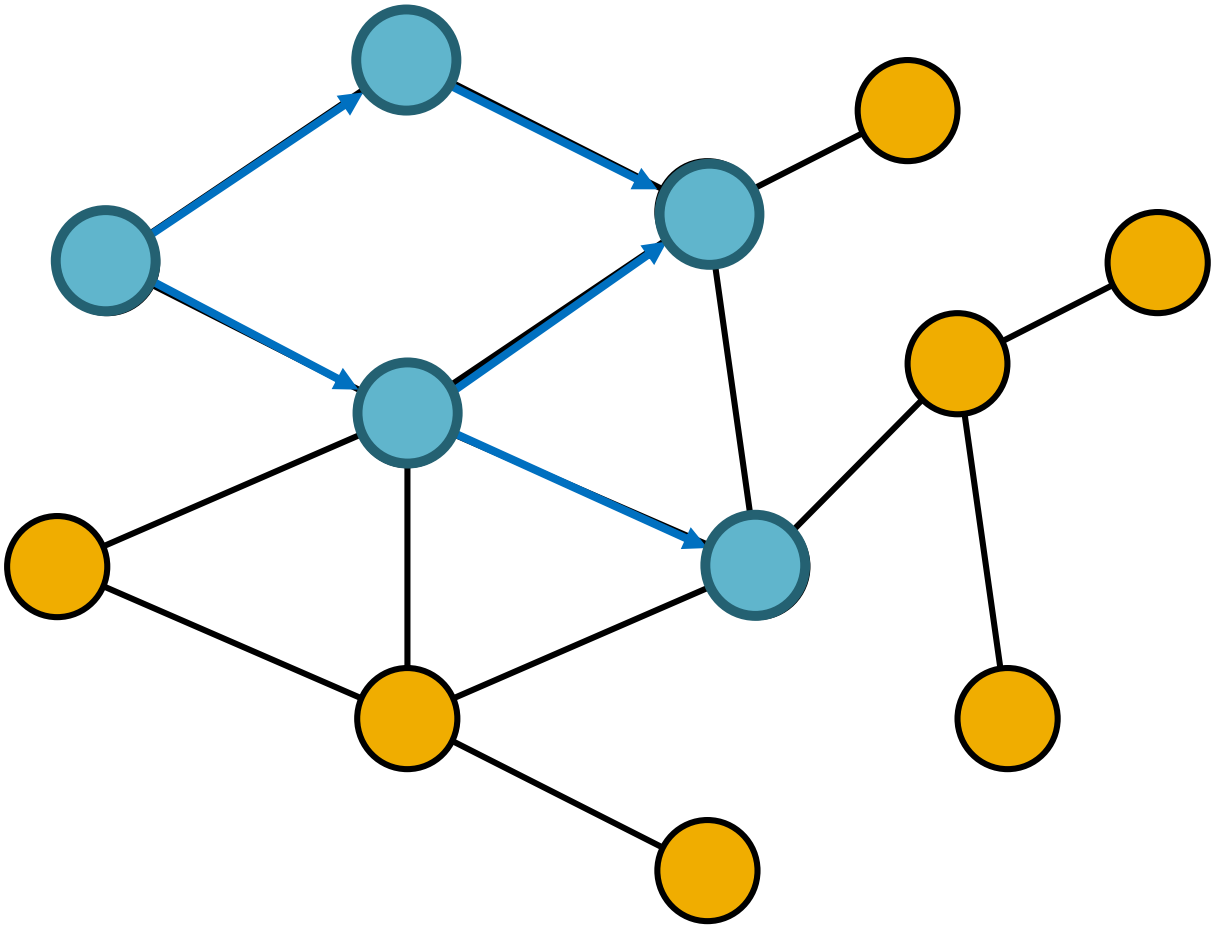

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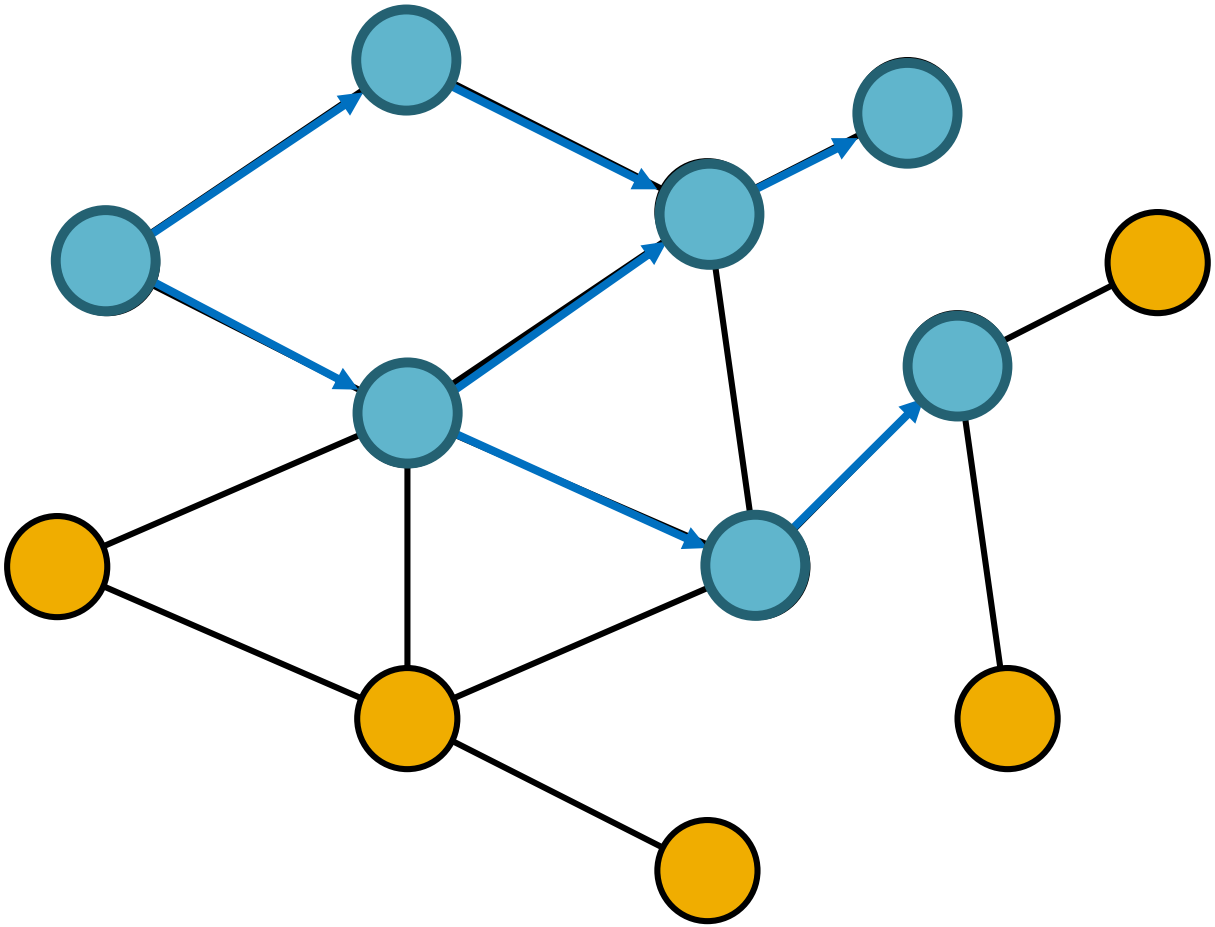
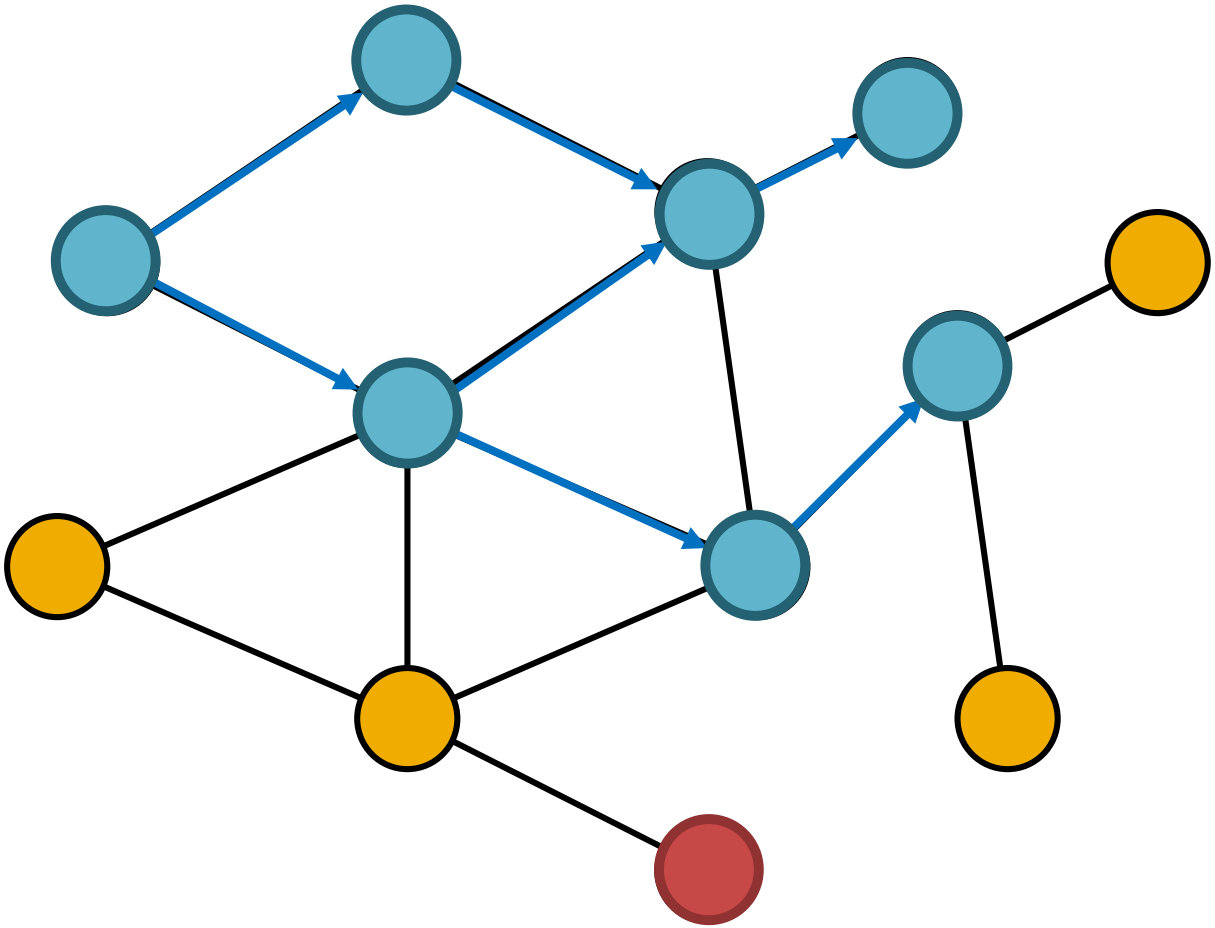
Diffusion in Networks



Contagions spread through the network like epidemics

Diffusion in Networks



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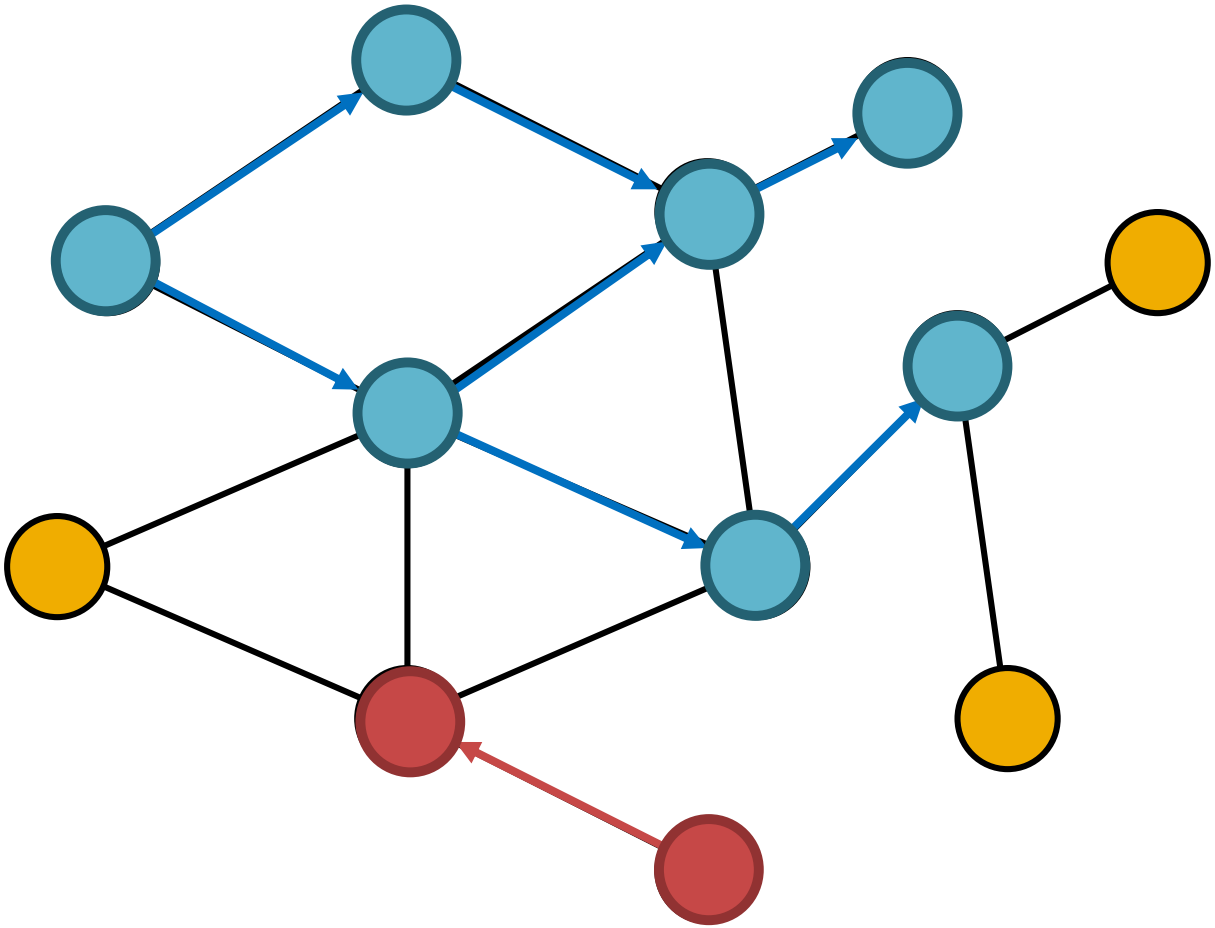

Contagions spread through the network like epidemics

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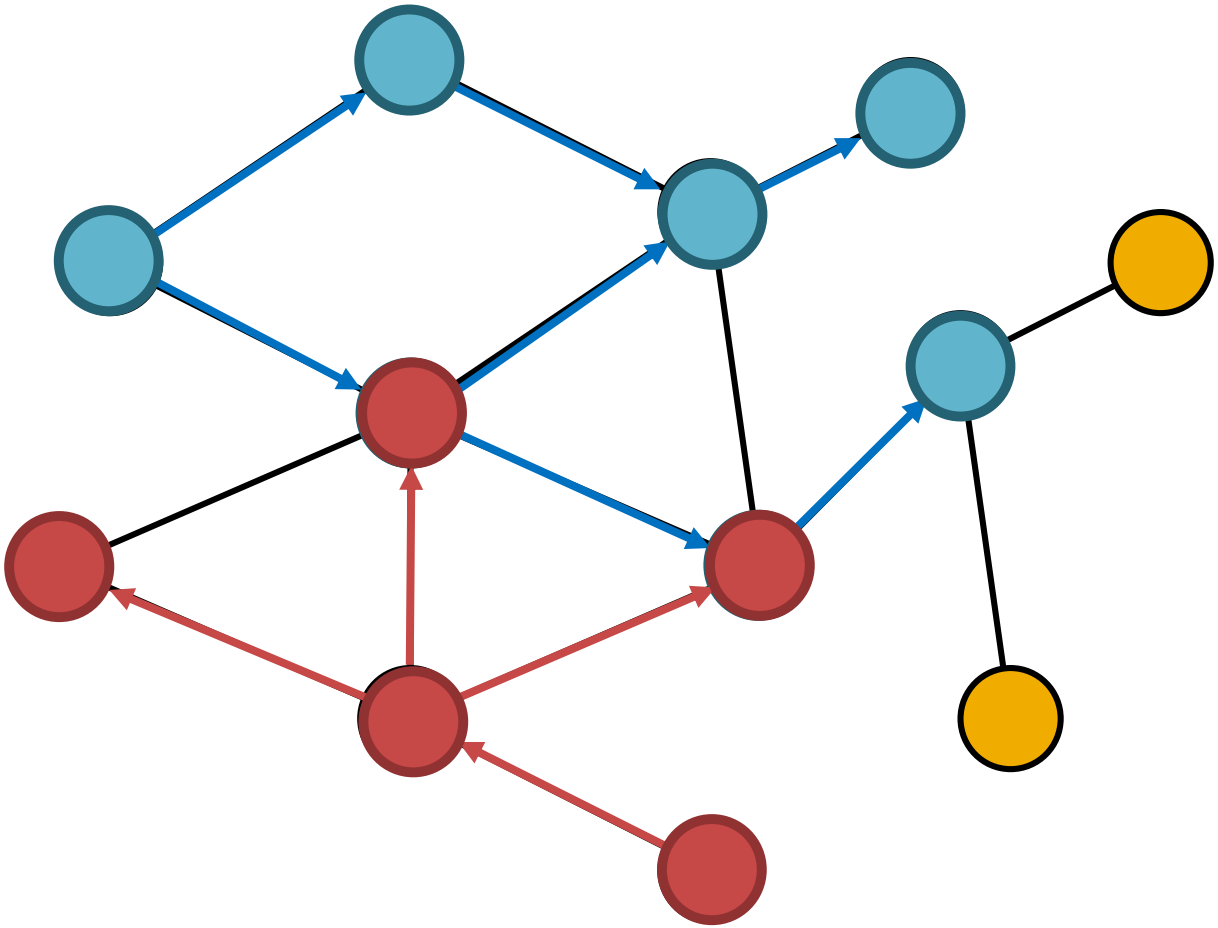
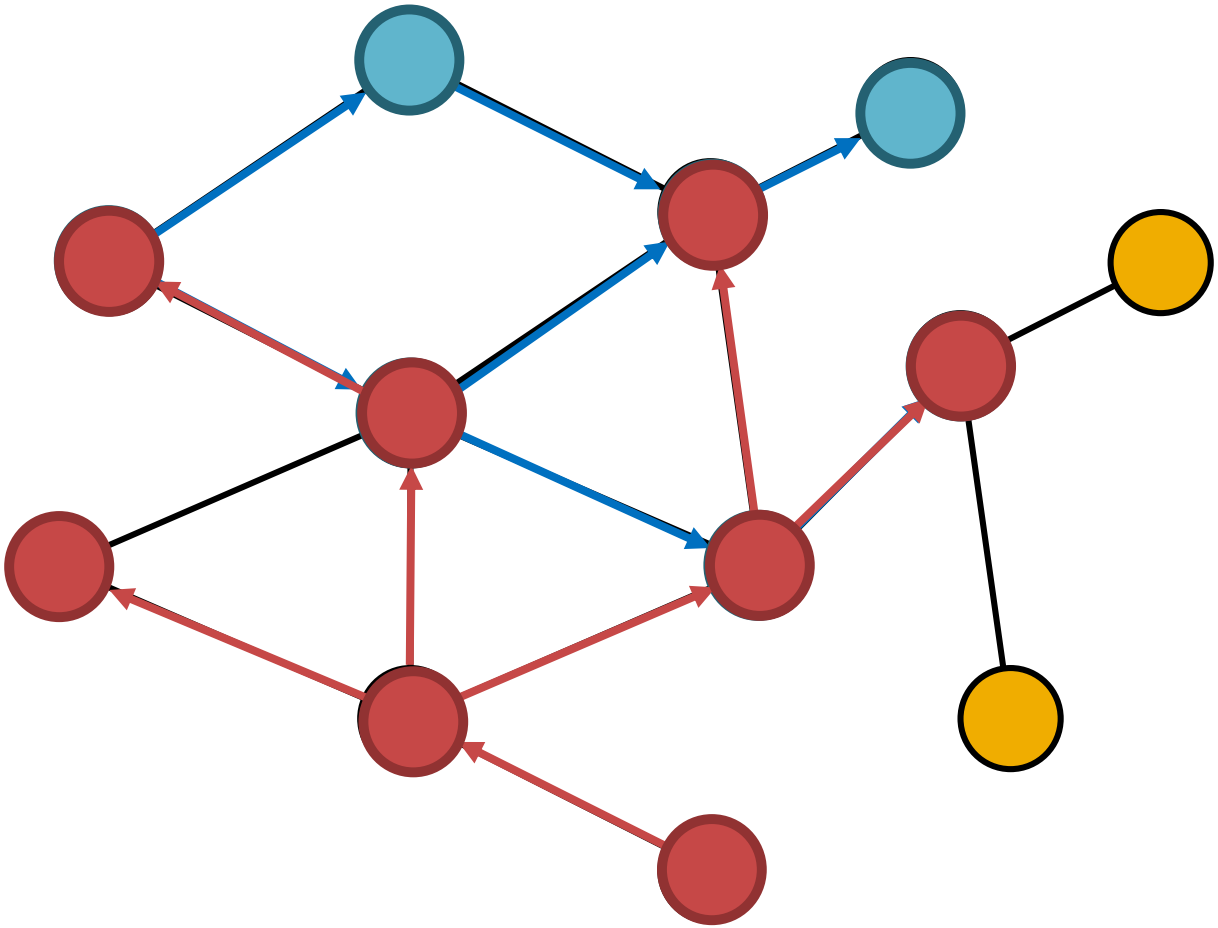


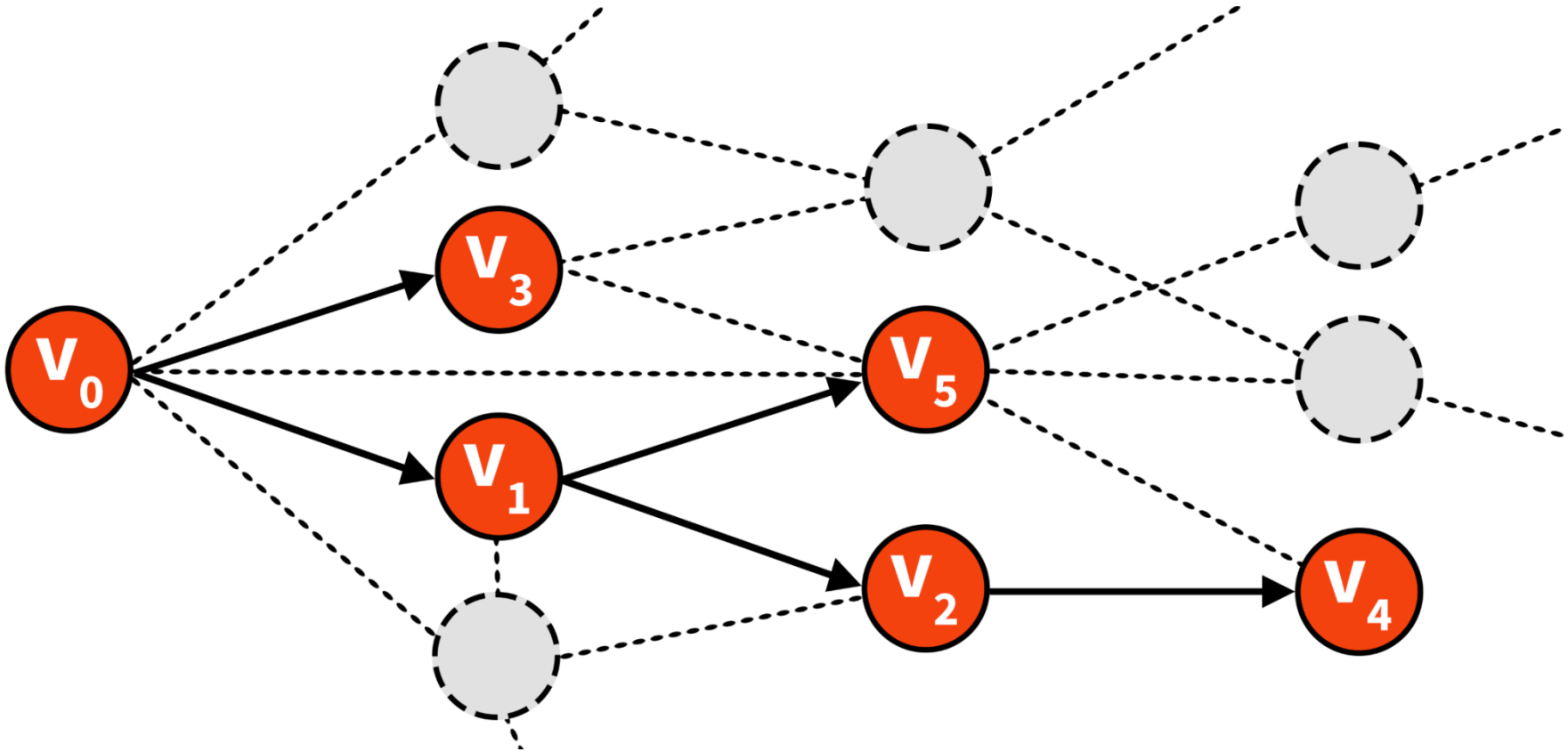
Contagions spread through the network like epidemics

Diffusion in Networks



Contagions spread through the network like epidemics

An Information Cascade



Cascades in Viral Marketing

- People send and receive product recommendations, purchase products

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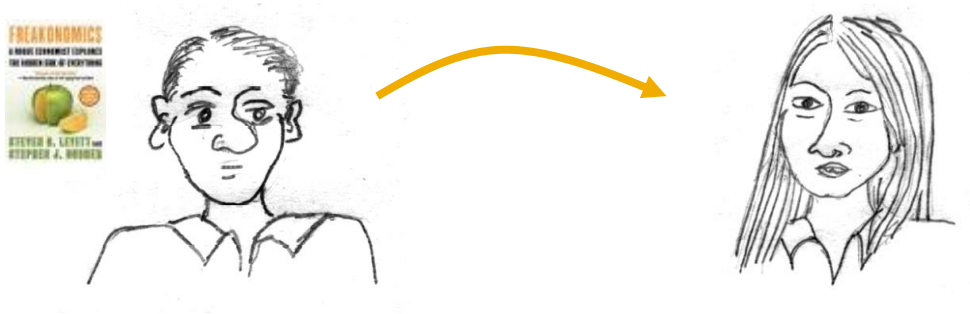

Cascades in Viral Marketing

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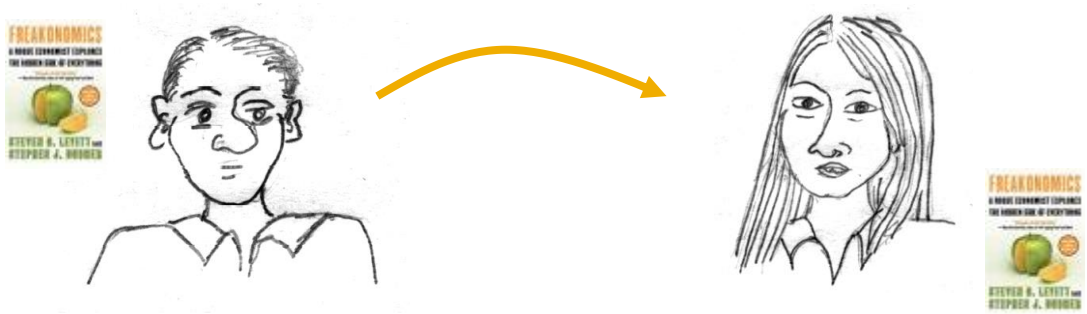

Cascades in Viral Marketing

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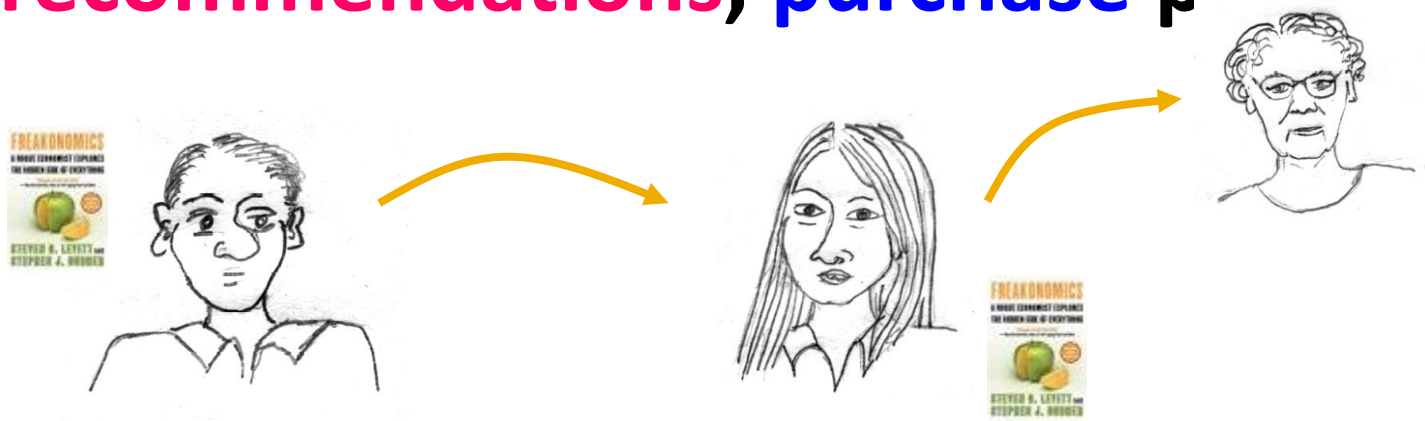

Cascades in Viral Marketing

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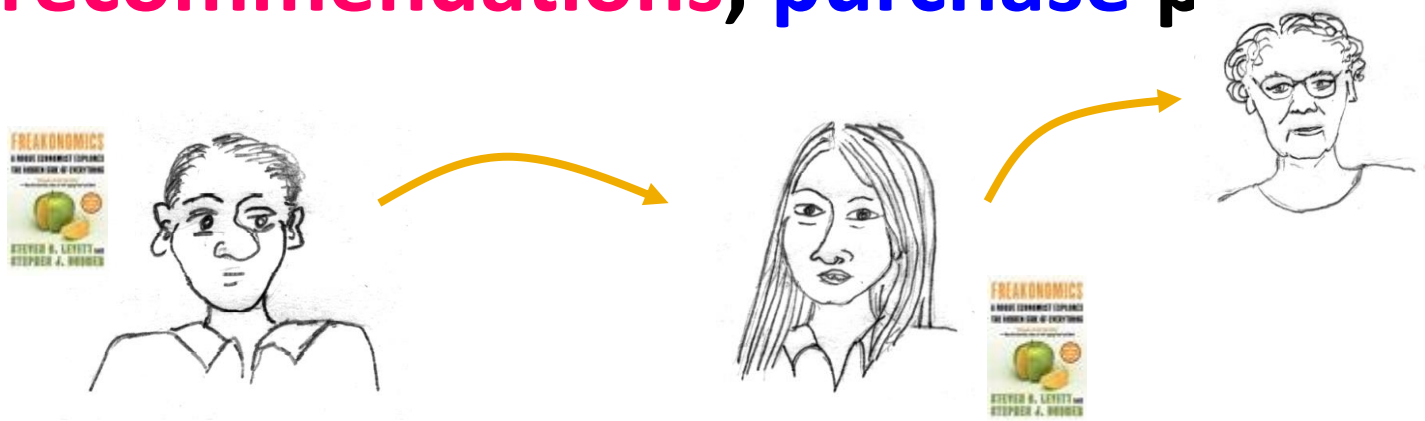
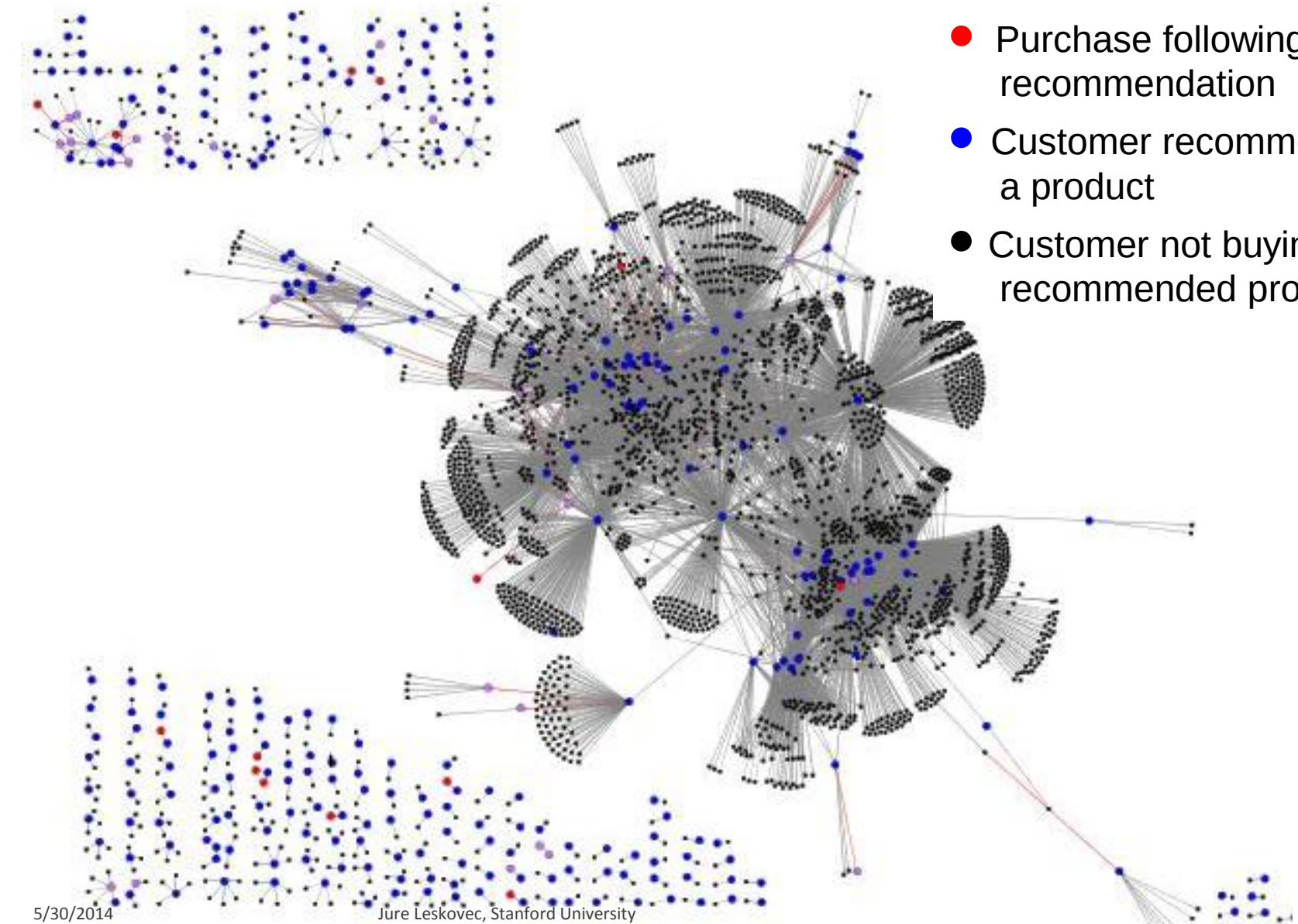


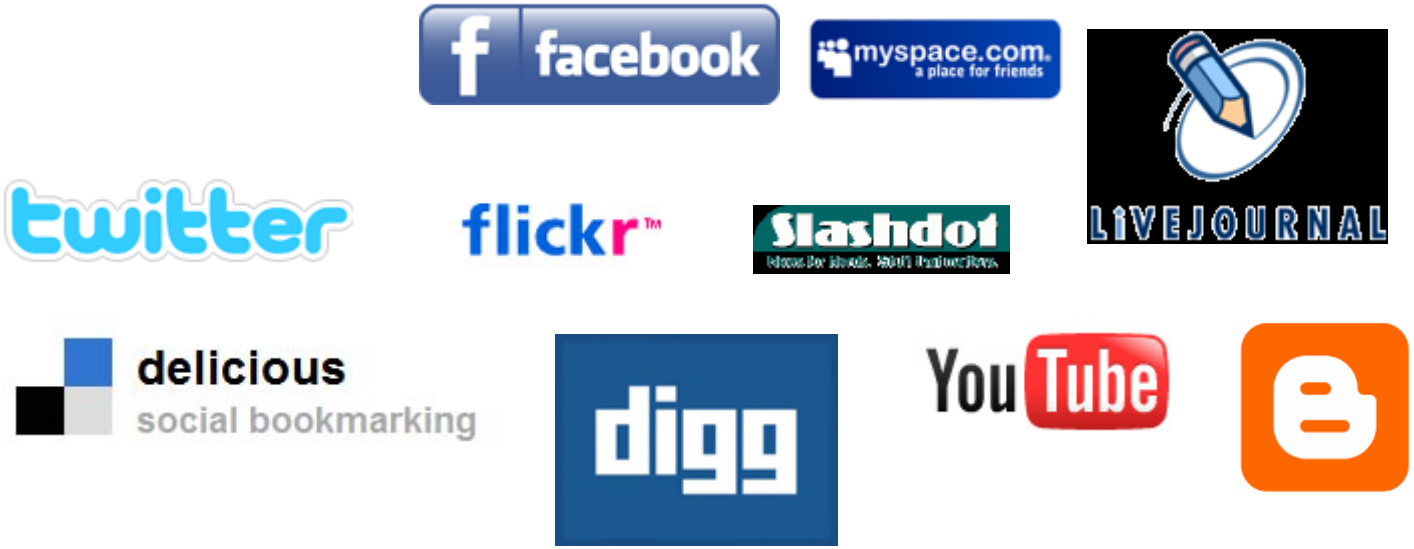
- **Large online retailer:** Jun '01 - May '03
  - 16M recommendations on 500k products
  - 4M customers

Recommendation Network



- Purchase following a recommendation
- Customer recommending a product
- Customer not buying a recommended product

Cascades in Social Media



As users of social media sites (re)share information big cascades form

Lada Adamic shared a link via Erik Johnston.
January 16, 2013

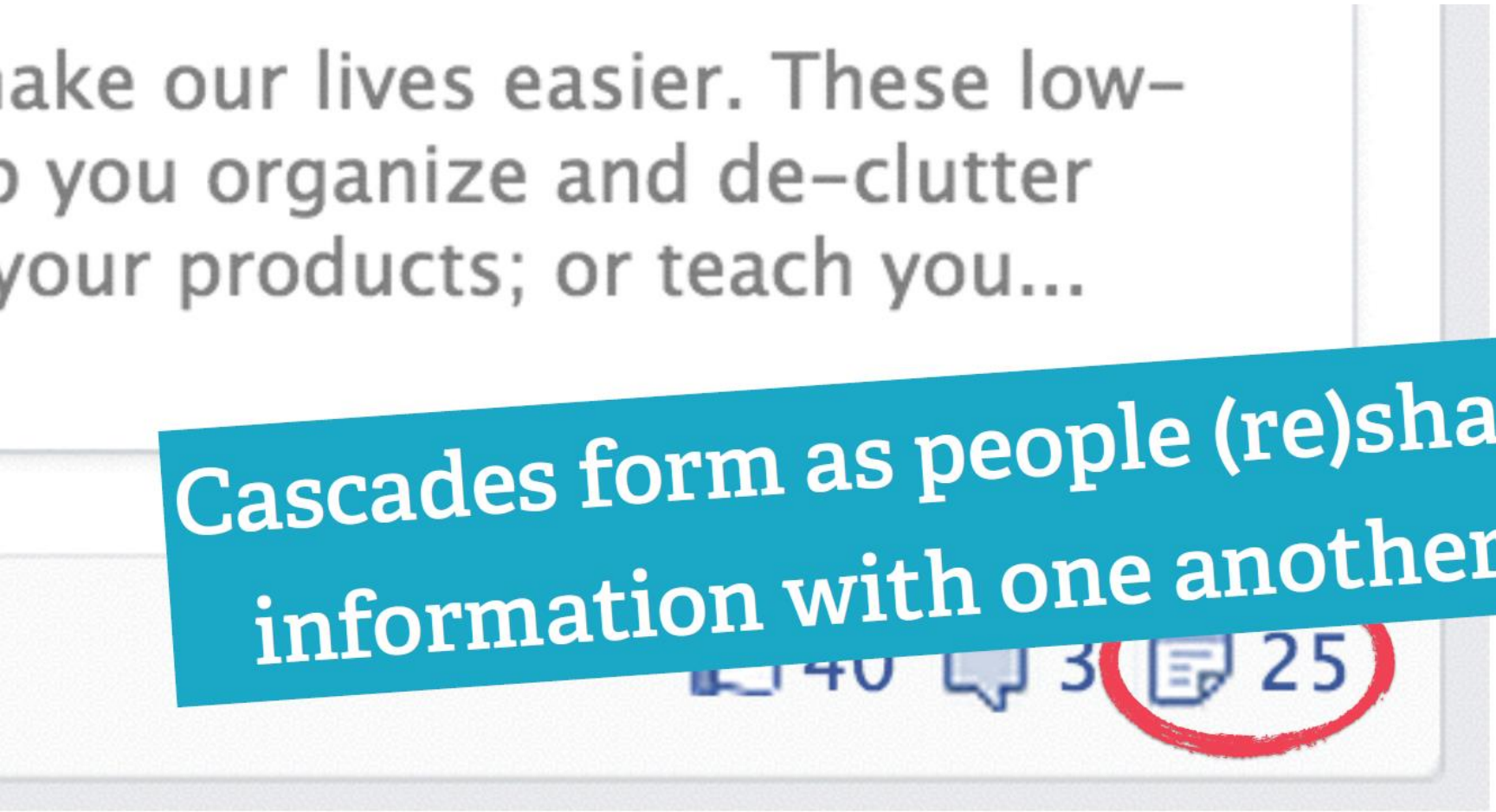
When life gives you an almost empty jar of nutella, add some ice cream... (and other useful tips)

50 Life Hacks to Simplify your World
twistedsifter.com

Life hacks are little ways to make our lives easier. These low-budget tips and trick can help you organize and de-clutter space; prolong and preserve your products; or teach you...

Like · Comment · Share

40 3 25


ake our lives easier. These low-
you organize and de-clutter
your products; or teach you...
Cascades form as people (re)share information with one another.
40
3
25

Timeline Photos

$$V = \pi z^2 a$$

$$V = Pi(z*z)a$$

antiuse

I fucking love science
Seriously. If you have a pizza with radius "z" and thickness "a", its volume is Pi(z*z)a.

Lina von DerSteig, Iman Khallaf, 周明佳 and 73,191 others like this.

27,761 shares

46 of 1,470

Album: Timeline Photos
Shared with: Public

Open Photo Viewer
Download
Embed Post

How does Information Spread?

How many people are using a particular hashtag?

Ma, Z., Sun, A., & Cong, G. (2013). On predicting the popularity of newly emerging hashtags in Twitter

Will a tweet get retweeted?

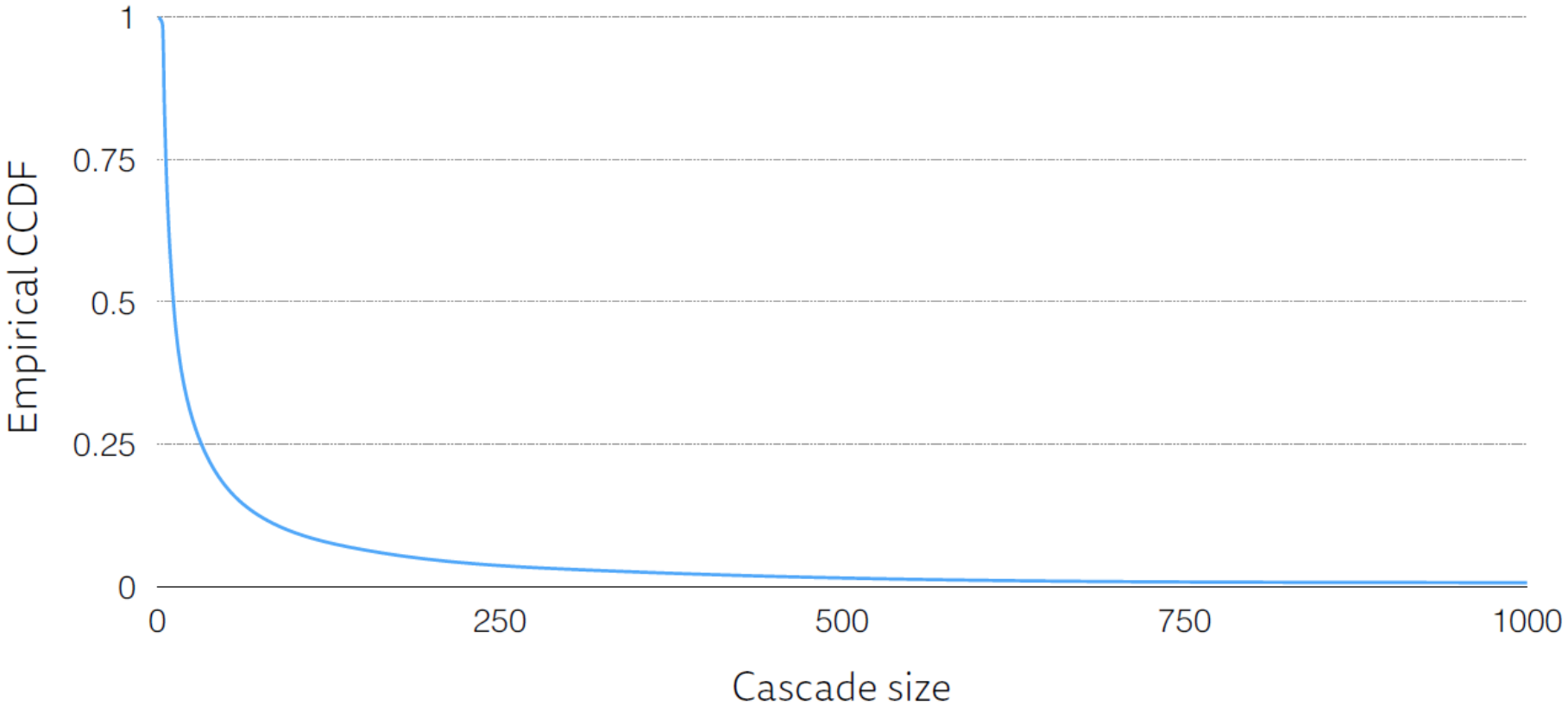
Petrovic, S., Osborne, M., & Lavrenko, V. (2011). RT to Win! Predicting Message Propagation in Twitter

How does a large photo reshare cascade spread?

Dow, P. A., Adamic, L. A., & Friggeri, A. (2013). The Anatomy of Large Facebook Cascades

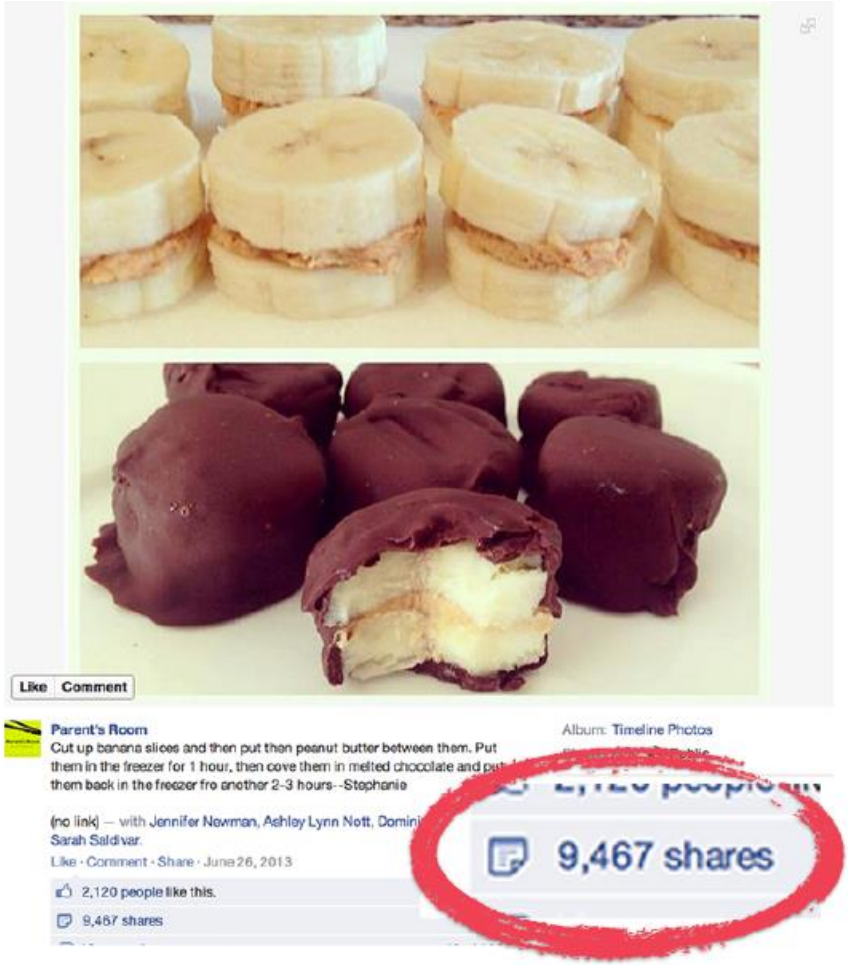
How will a cascade grow in the future?

How does Content Spread?



Large cascades are extremely rare

How does Content Spread?



Same content, very different popularity

Unpredictability of Cascades

Increasing the strength of social influence increases both inequality and unpredictability of success.

Salganik, M. J., Dodds, P. S., & Watts, D. J. (2006). Experimental study of inequality and unpredictability in an artificial cultural market.

Plan for the Talk

- **Can cascades be predicted?** [WWW '14]
  - Using complete Facebook data, can we predict which photos will get reshared a lot?
- **Can cascades be created?** [ICWSM '13]
  - Can we create machine generated submissions that get lots of activity (likes)?

Can cascades be predicted?

Cascades are predictable!

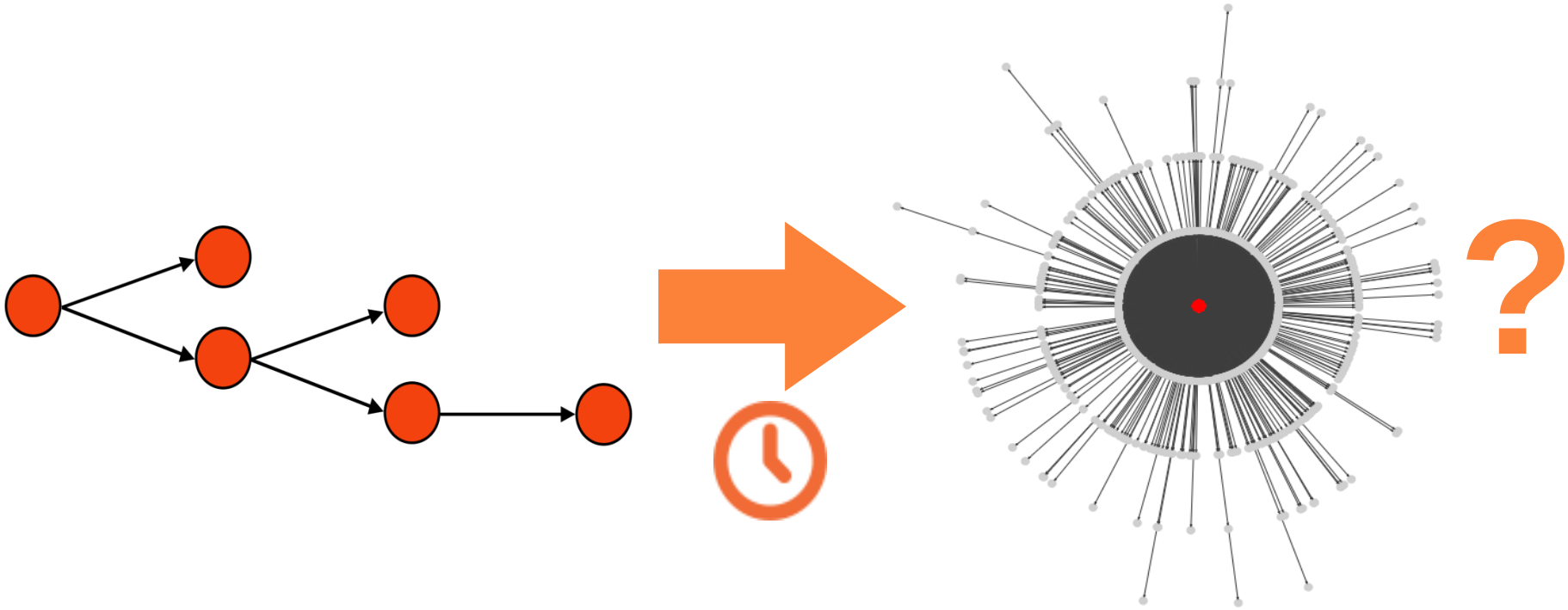
(*solution: cascade growth prediction problem)

size

structure

content

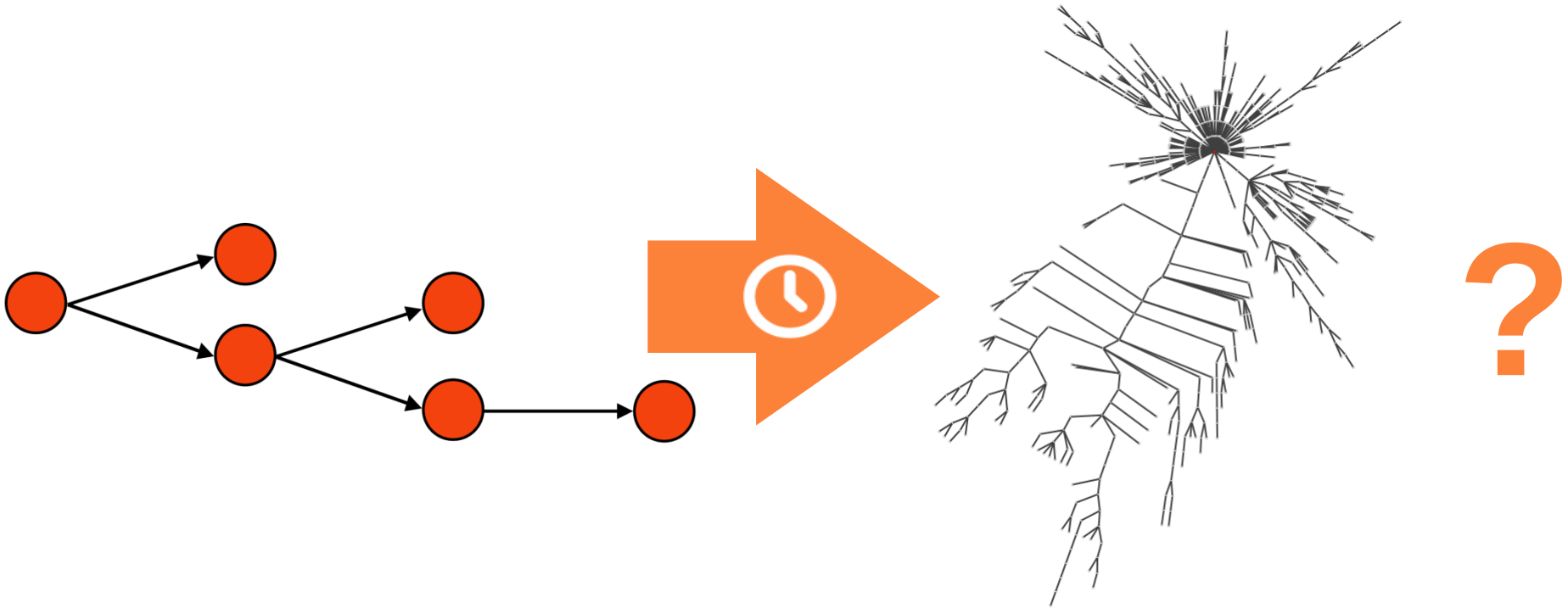
Cascade prediction problem



How to formulate the prediction problem?

Formulating the problem

- **Predict whether a cascade will get >*k* reshares?**



Formulating the problem

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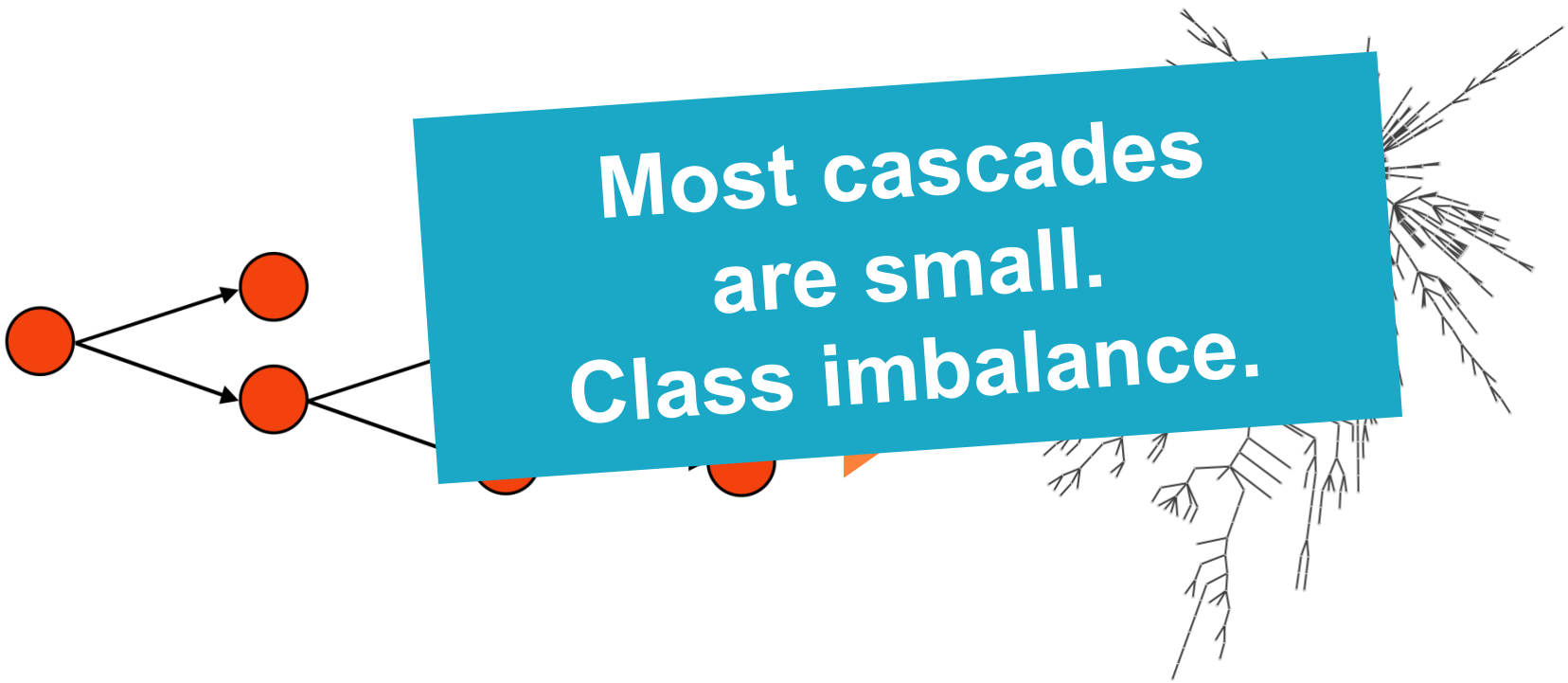
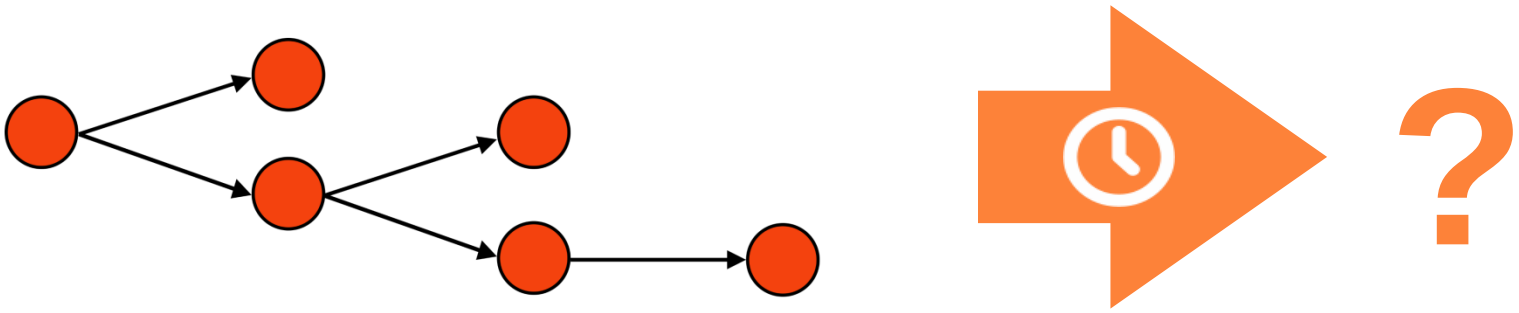


Formulating the Problem

- **Predict the exact number of nodes in a cascade**

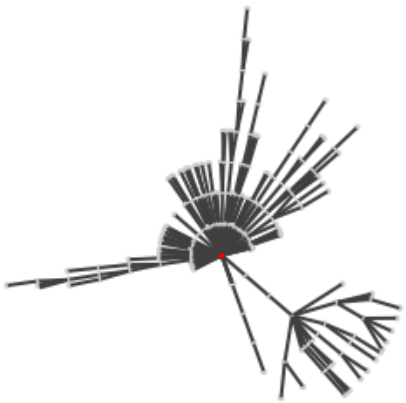


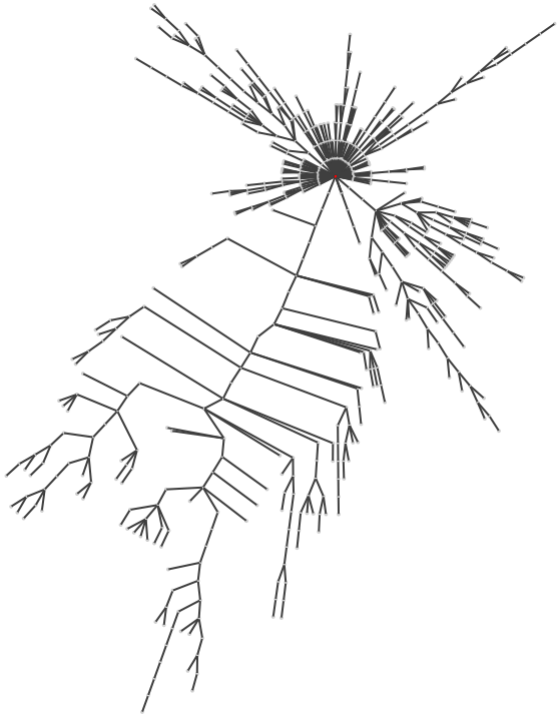
Formulating the Problem

- **Predict the exact number of nodes in a cascade**

Formulating the Problem

- **Only look at cascades with a minimum number of reshares and predict future growth**





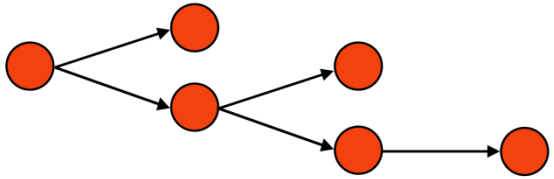
?

Formulating the Problem

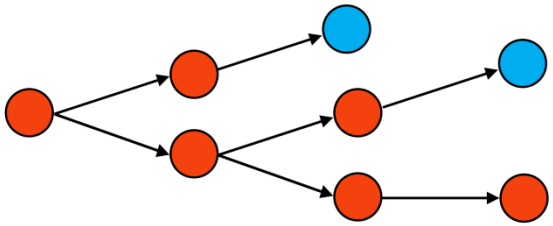
- **Only look at cascades with a minimum number of reshares and predict future growth**

Cascade Growth Prediction

- **Will a cascade reach the median size?**



k reshares



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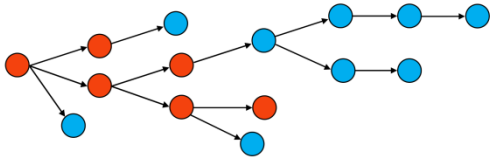
less than the median *f(k)*

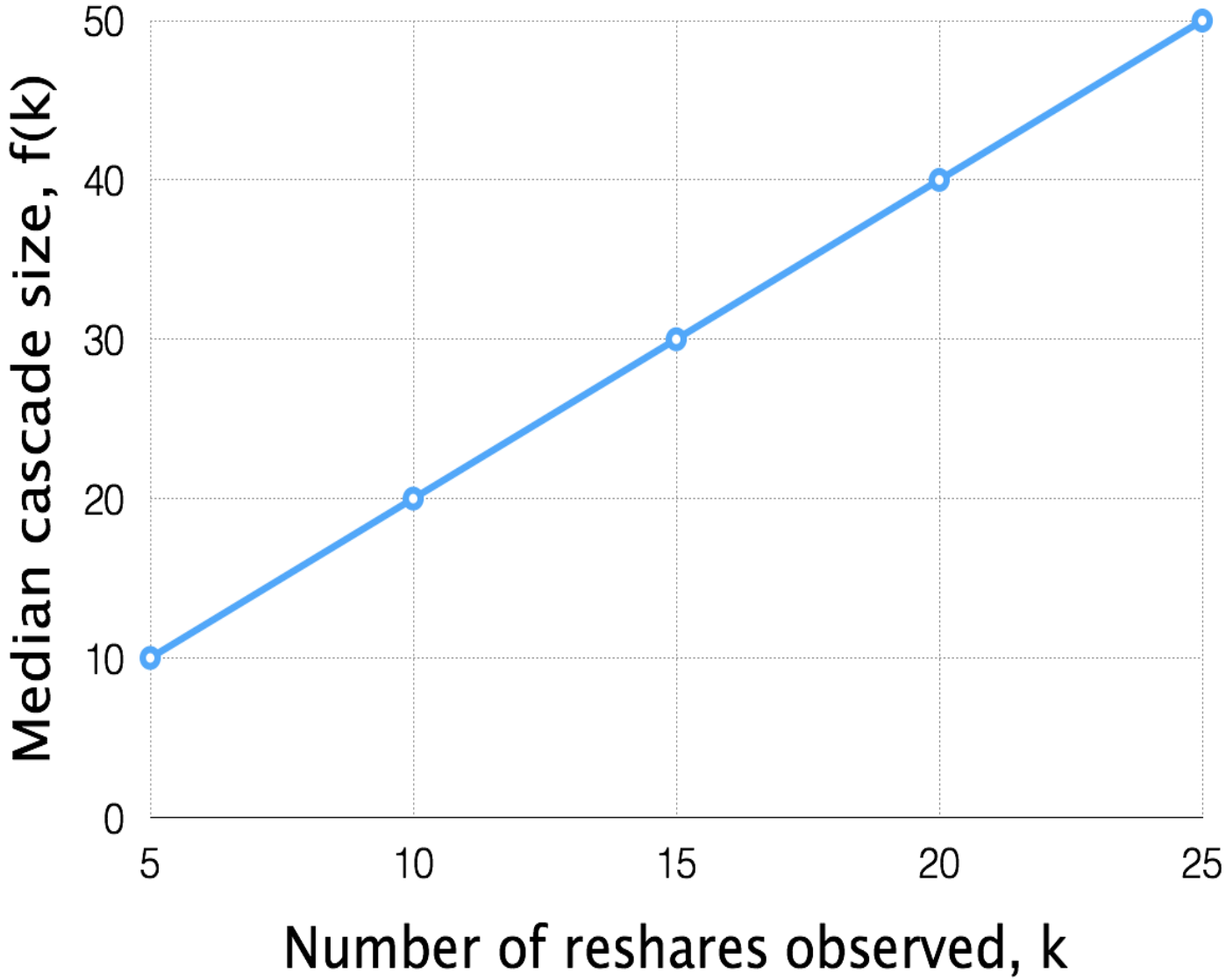


?

more than the median *f(k)*

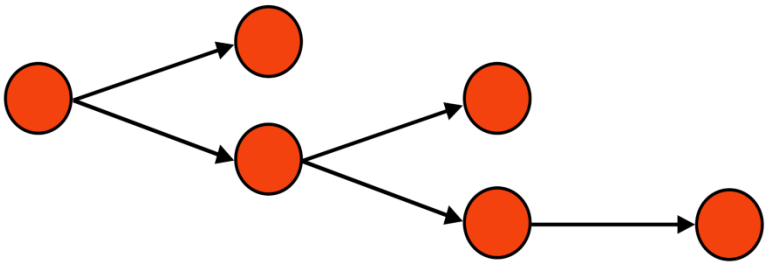
For cascades of size $\geq k$ let the $f(k)$ be their median final size

> Median? ≡ Will it double?

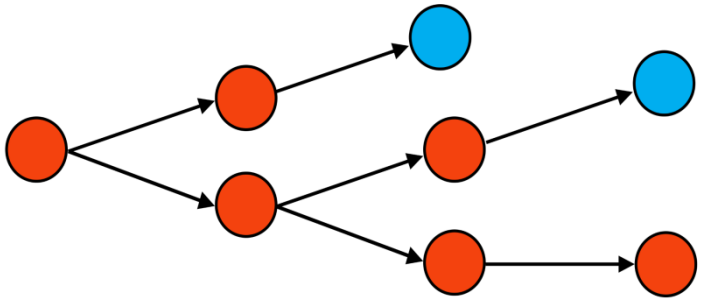


Problem Formulation

- **Will a cascade double in size?**

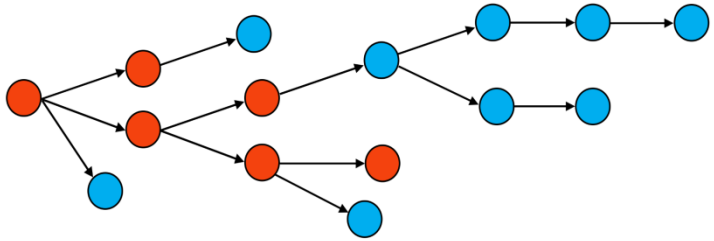


k reshares



?

≤2*k* reshares = *f*(*k*)



?

>2*k* reshares = *f*(*k*)

Cascade Growth Prediction Problem

Given that a cascade has obtained *k* reshares, will it grow beyond the median size *f(k)=2k*?

Cascade Growth Prediction Problem

Given that a cascade has obtained *k* reshares, will it grow beyond the median size *f(k)=2k*?

balanced

can track growth over time

Facebook Data

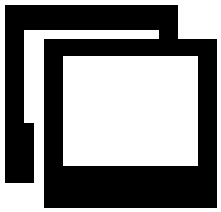
- We use **anonymized Facebook photo resharing data** from June 2013 to reconstruct reshare cascades using click, impression, and friend/follower data
- Using **features of the cascade**, we **evaluate the performance of a classifier**

350m photos/day

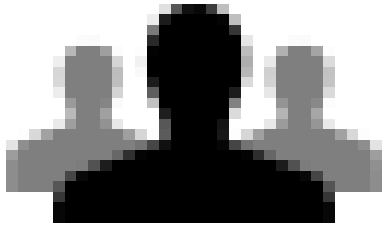
150k photos ≥5 reshares

9m reshares total

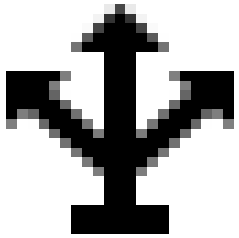
Factors of Predictability



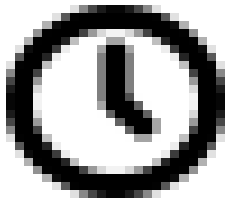
Content
(e.g. has overlaid text)



User
(e.g. follower count)

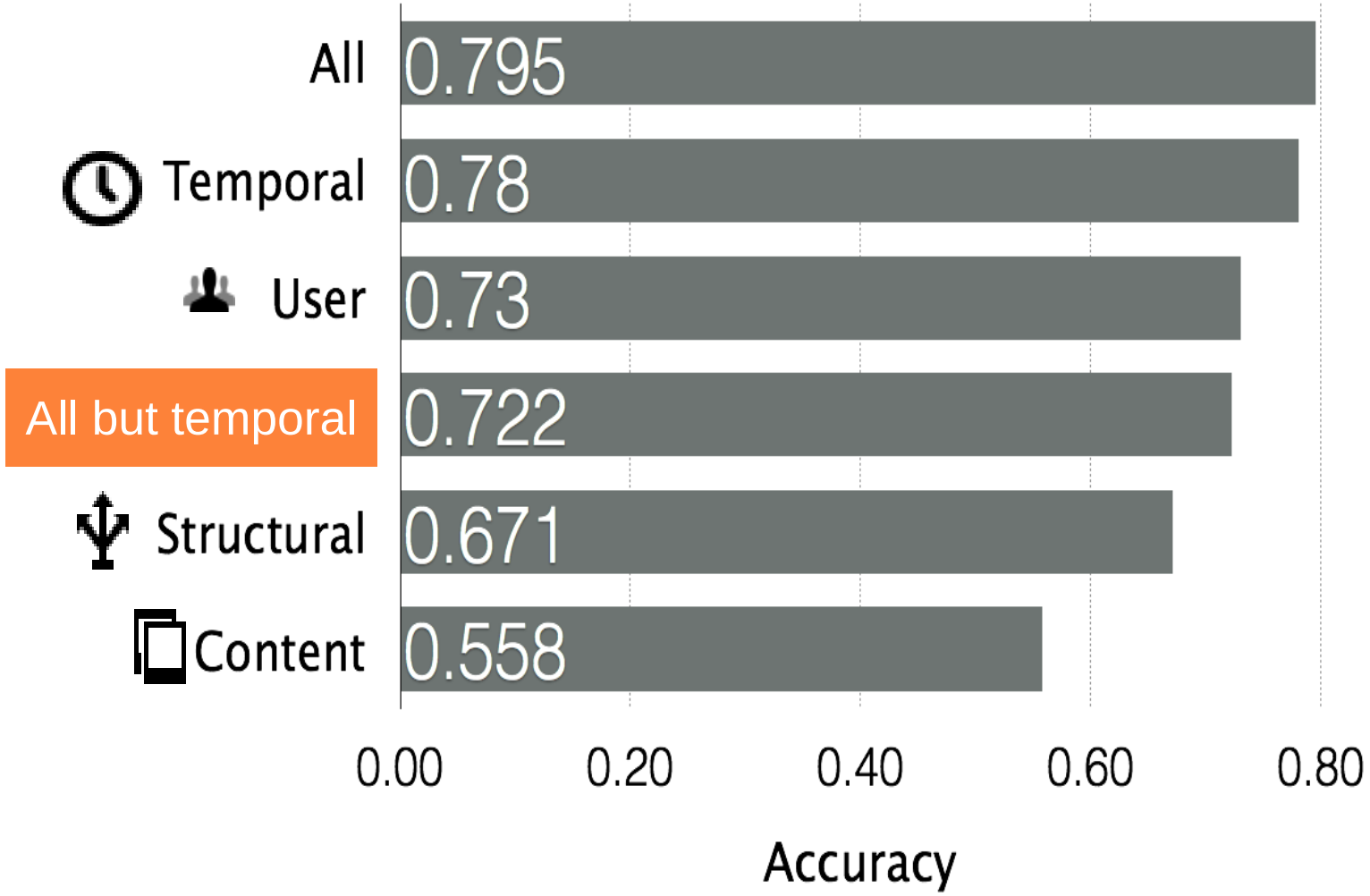


Structural
(e.g. proximity to root in *G*)



Temporal
(e.g. time between reshares)

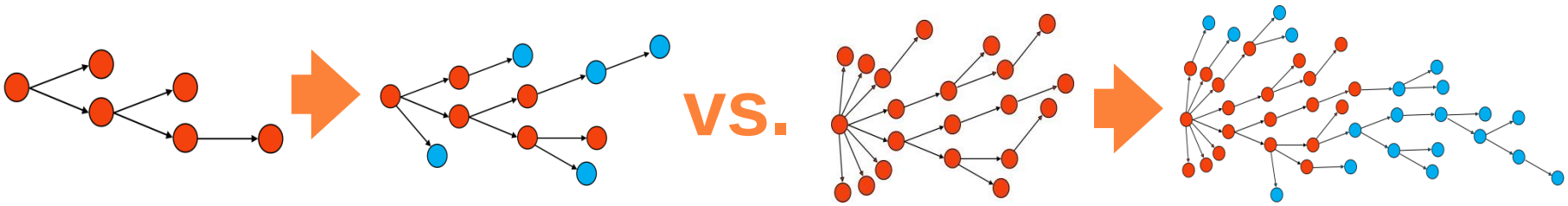
Predictability of Cascades



Will a cascade double (k=5)?

Predictability

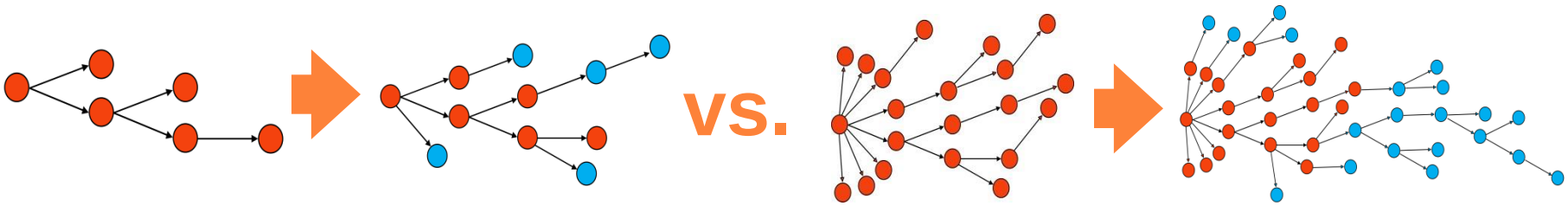
- How does predictability change with *k*?



5 reshares > 10 reshares? 20 reshares > 40 reshares?

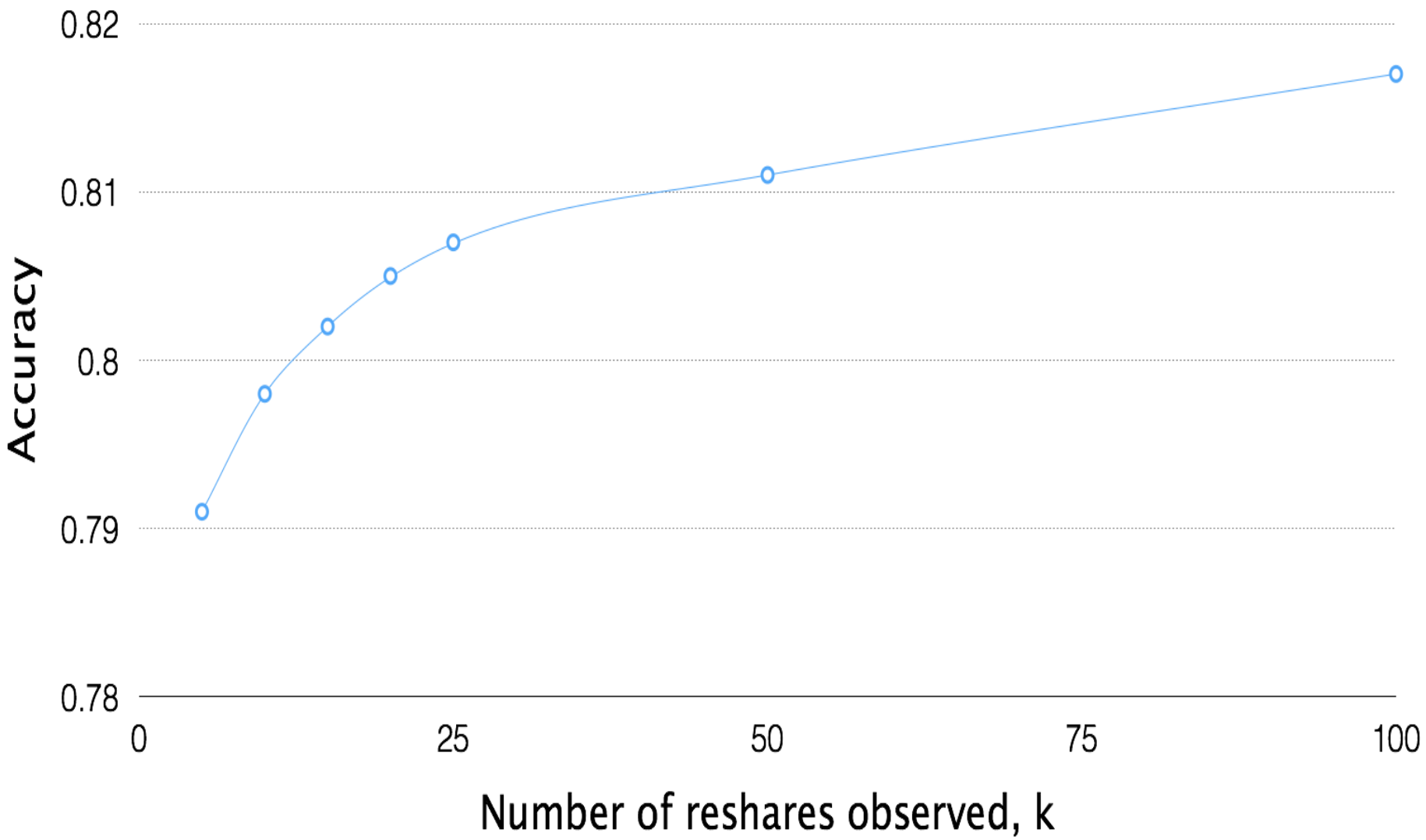
Predictability

- How does predictability change with *k*?



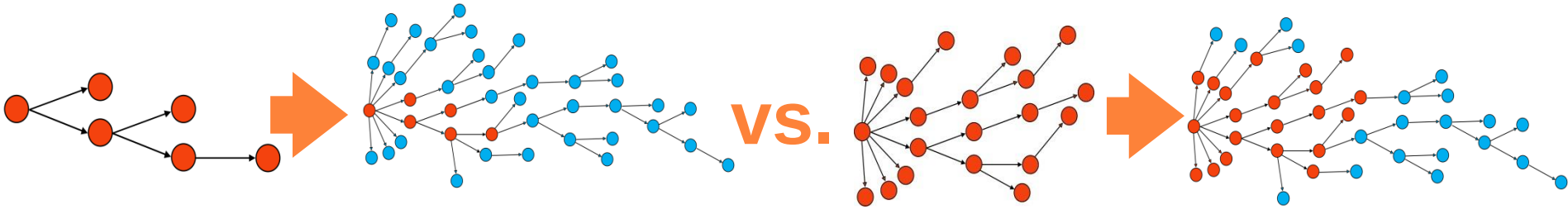
  - Two opposing arguments:
    - Easy: see more of the cascade
    - Hard: predict farther into the future

Predictability improves with *k*



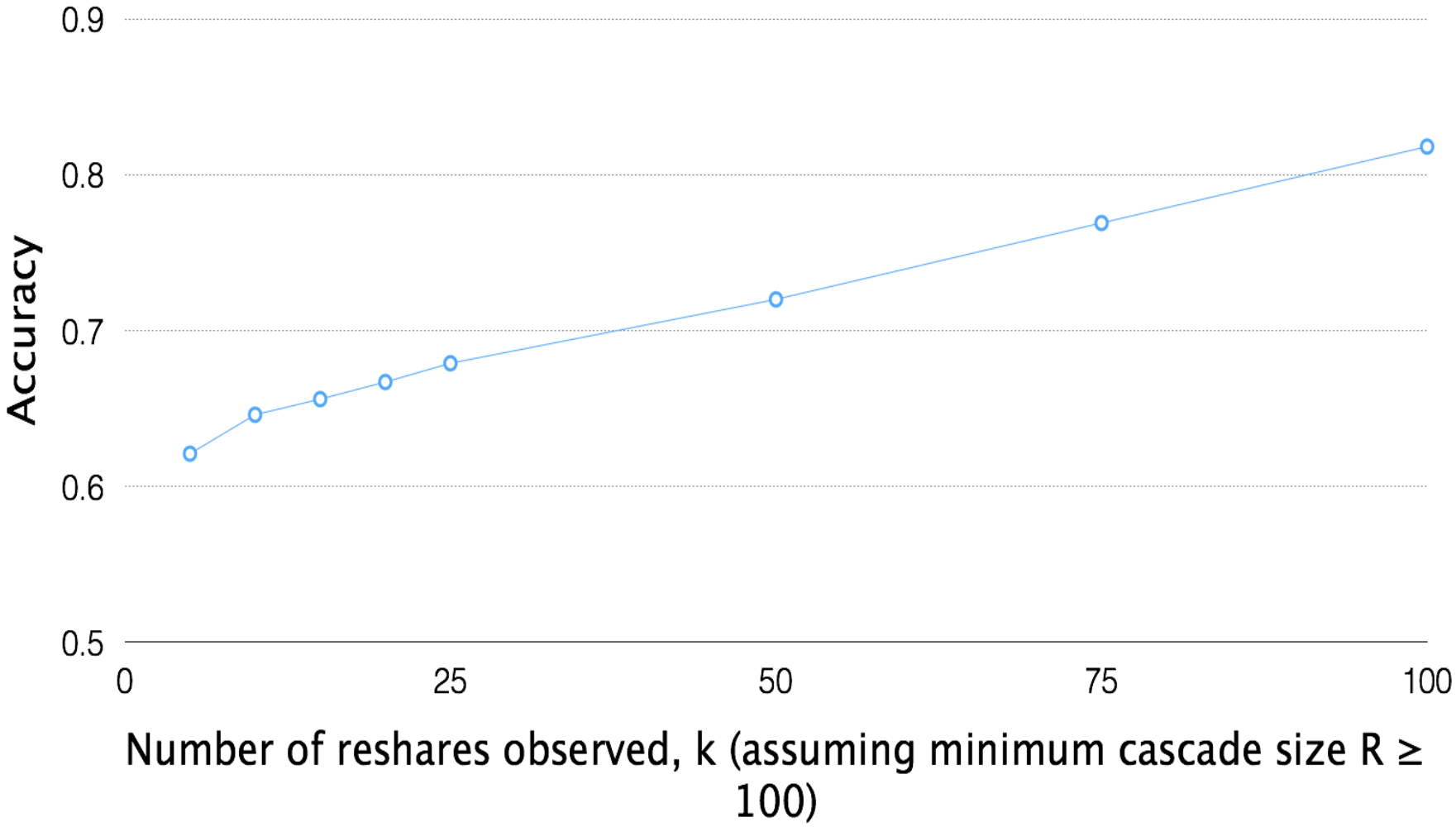
Predictability

- Fix the minimum cascade size $R \geq k$
- How does predictability change with k?

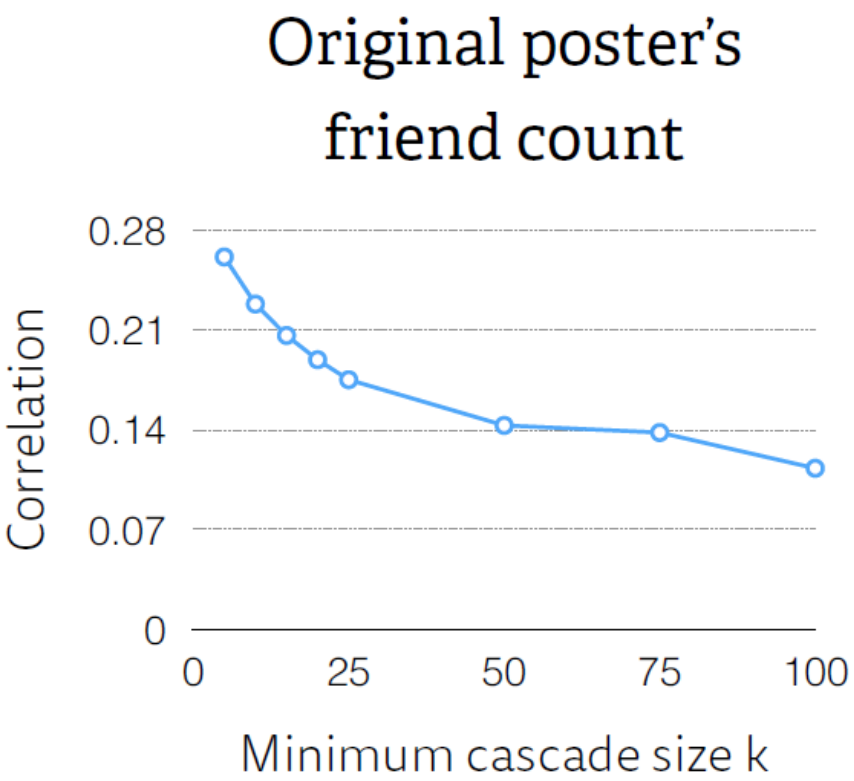


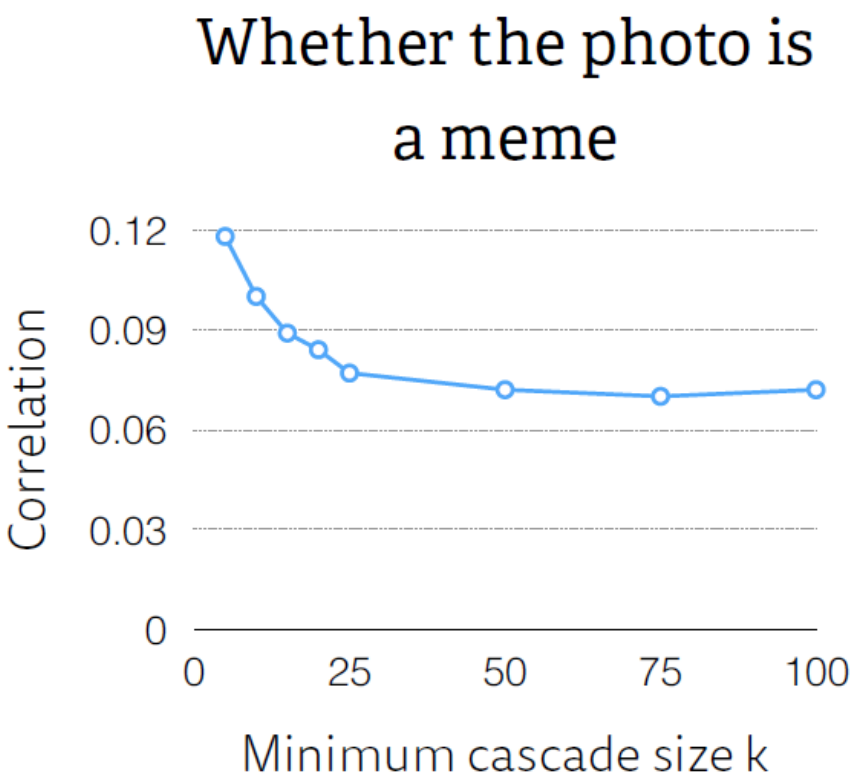
- Is there a "sweet" spot when we have enough information to be able to predict?

Predictability improves with *k*



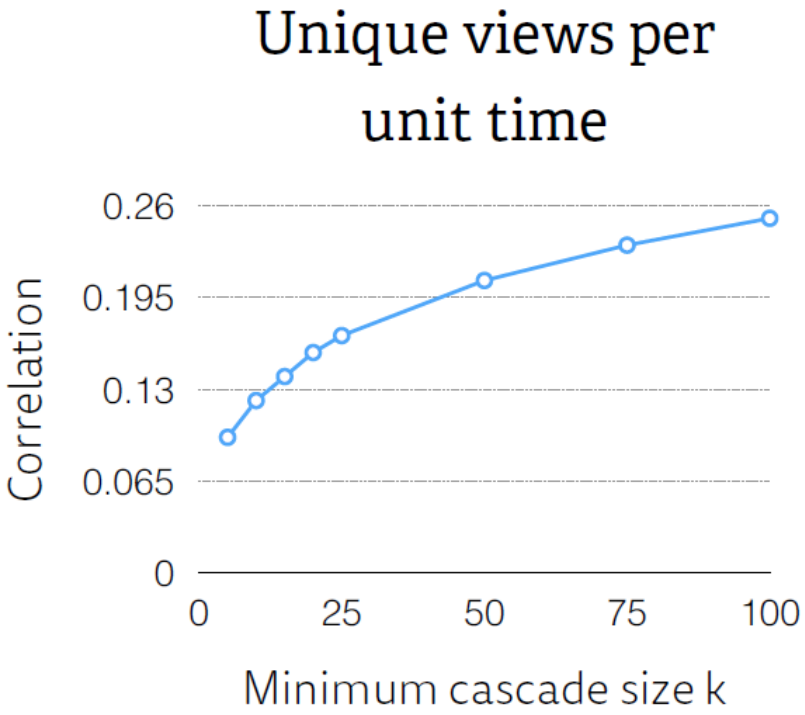
Network, Source & Content

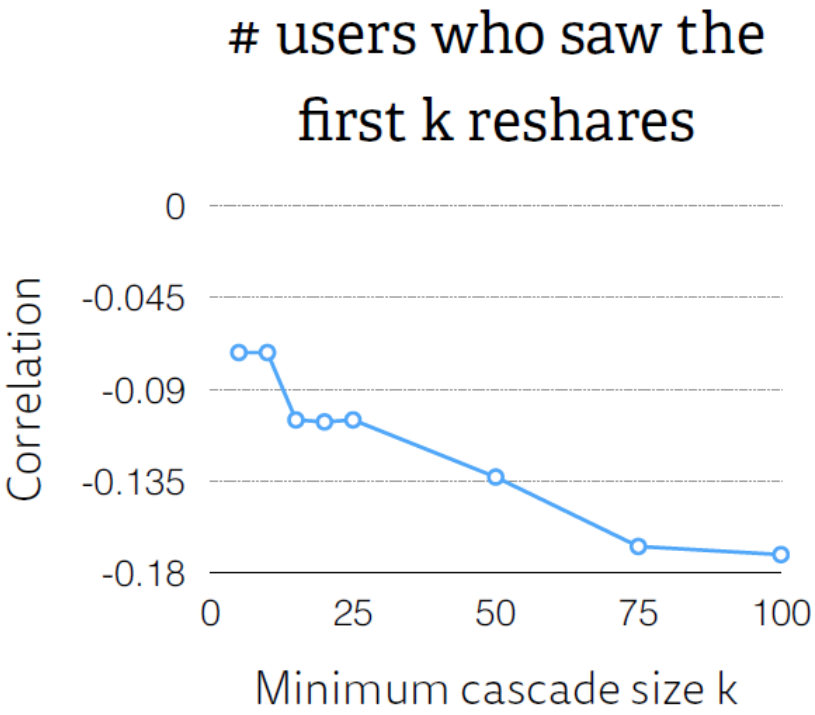




- **The original post (and poster) get less important with increasing *k***

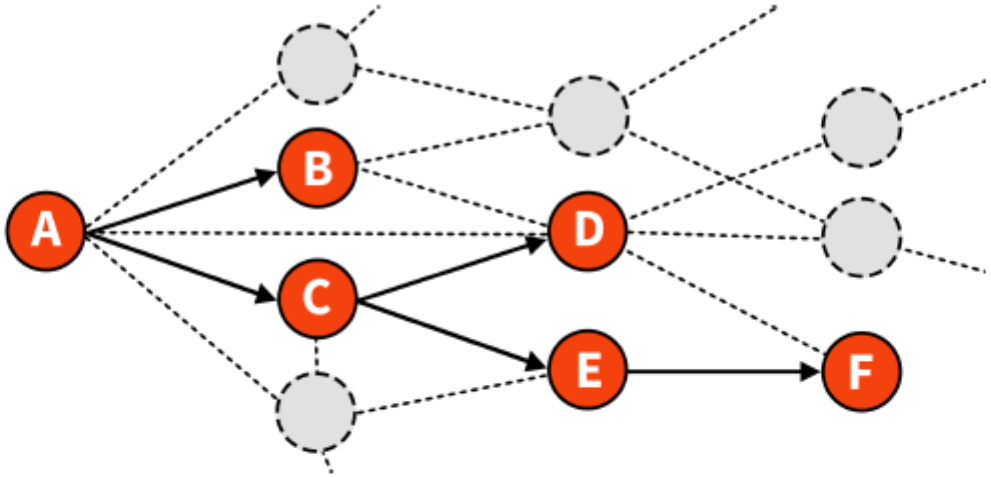
Network, Source & Content

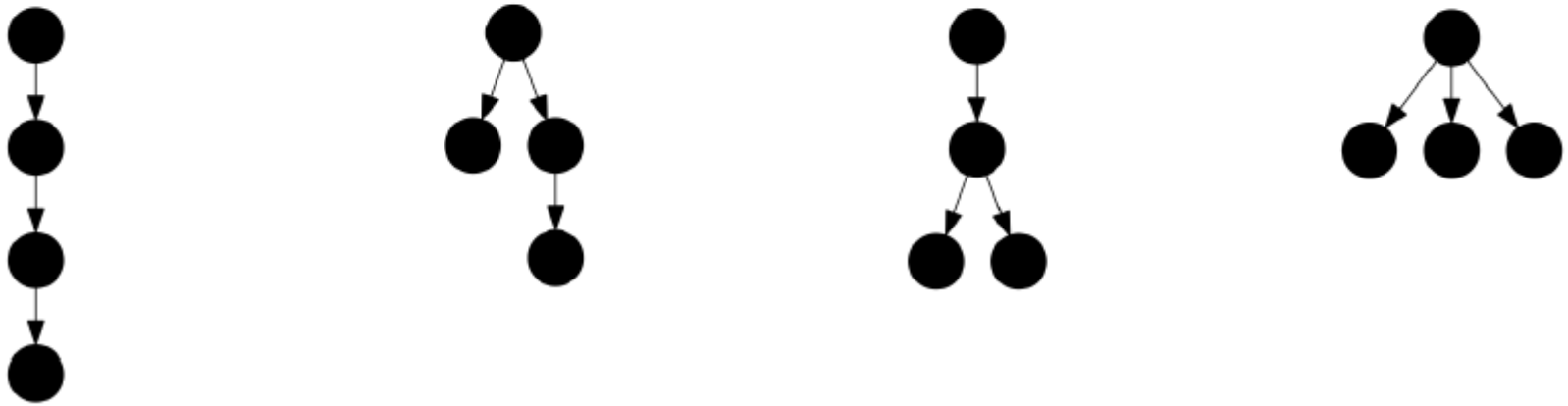




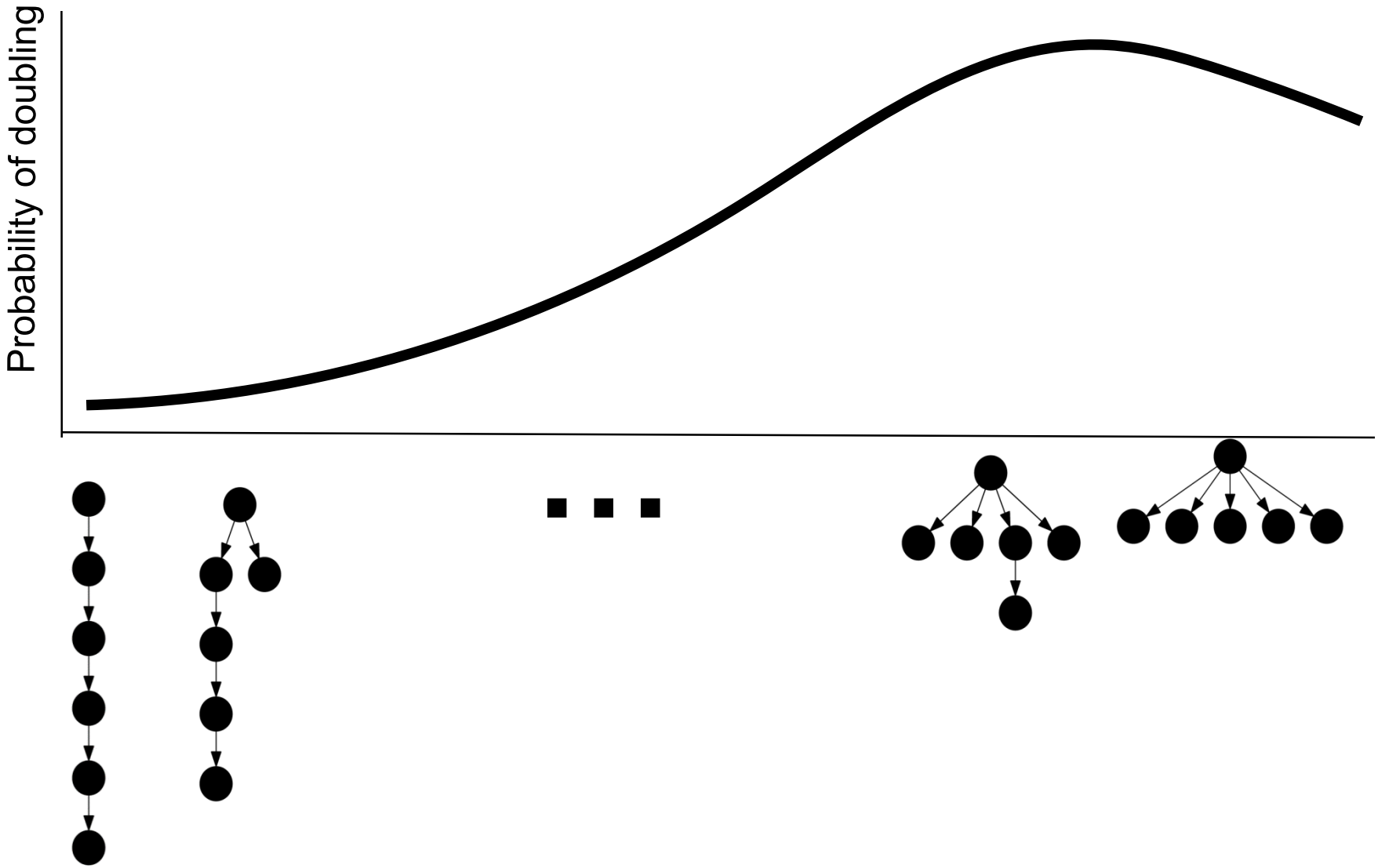
- **Successful cascades get many views quickly, and achieve high conversion rates**

Growth & the Initial Structure



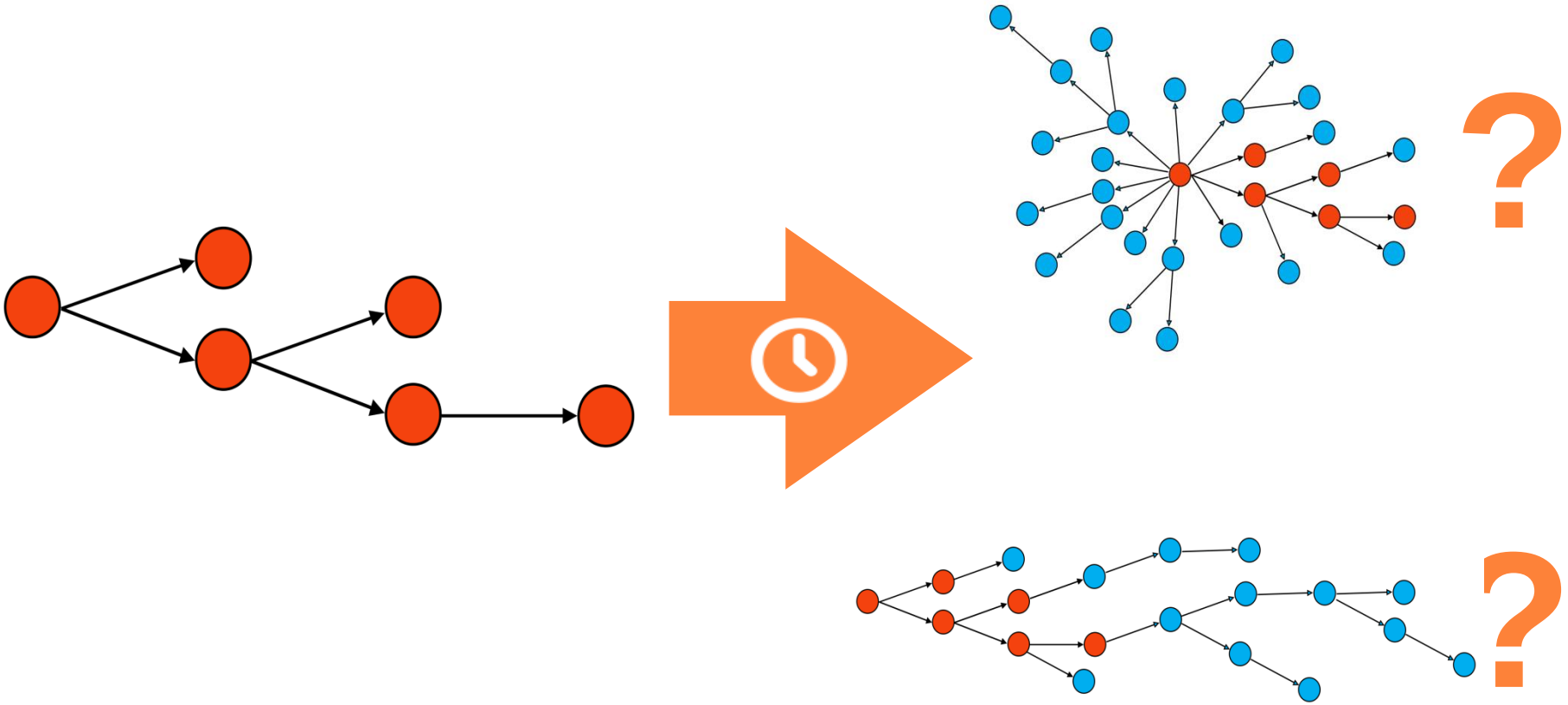


Structure and Growth



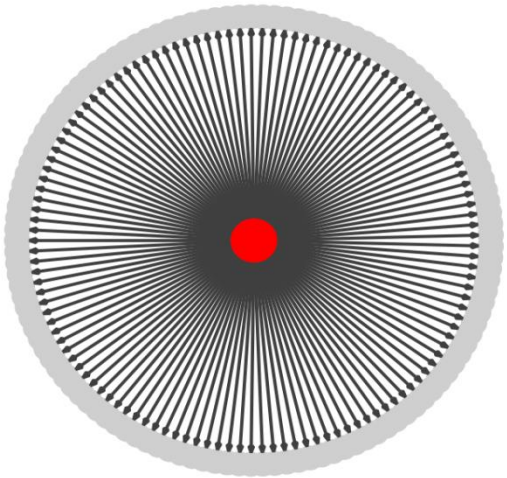
Cascade Structure

- **Predictability of cascade structure:**

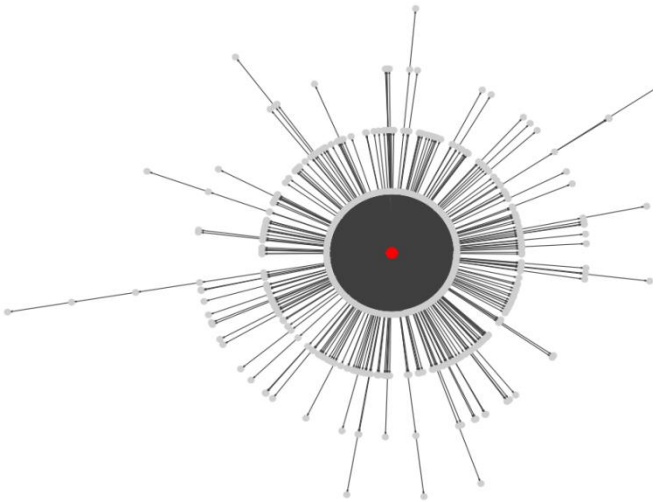


Structural Virality

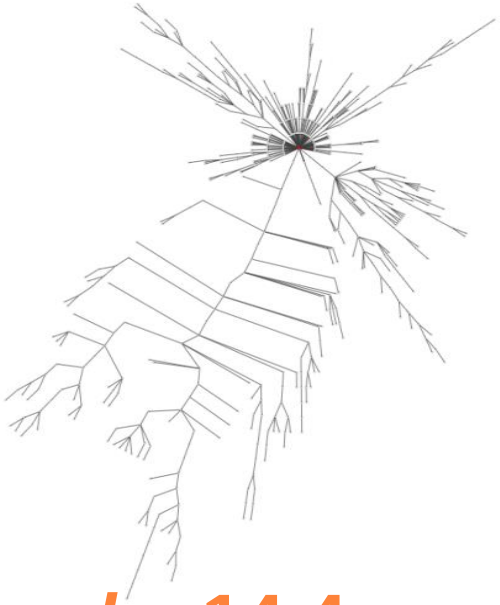
- **Wiener index:** Mean all-pairs shortest path distance in a cascade



d = 1.98



d = 2.47



d = 14.4

Anderson, A., Goel, S., Hofman, J. & Watts, D. J. The structural virality of online diffusion.

Predictability of Structure

- **Will a cascade have structural virality above the median?**

Predictability of Structure

- **Will a cascade have structural virality above the median?**

Accuracy of 0.725

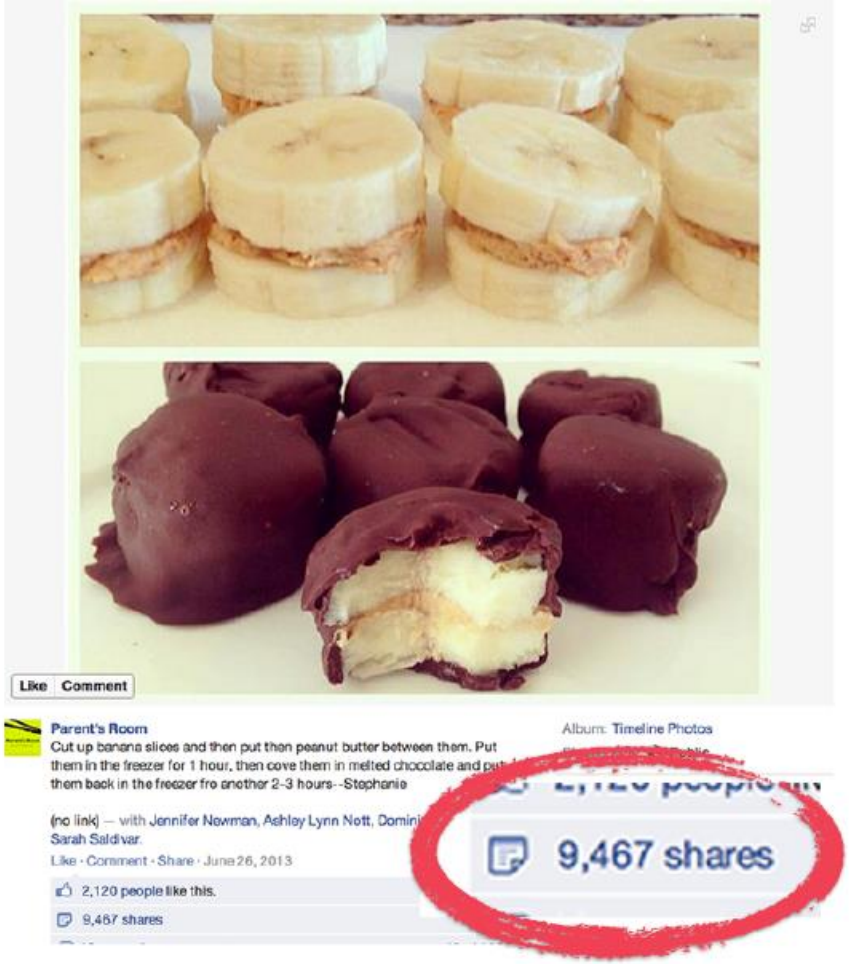
Temporal and structural features equally predictive

Predictability of Cascades

Increasing the strength of social influence increases both inequality and unpredictability of success.

Salganik, M. J., Dodds, P. S., & Watts, D. J. (2006). Experimental study of inequality and unpredictability in an artificial cultural market.

Content and Popularity



Can we differentiate cascades of the same content?

Experimental Setup

- Consider **identical photos** uploaded to Facebook, generating 983 clusters, 38k photos, 13m reshares
- For each cluster, we select **ten random cascades**, and **predict which was the largest**
  - Random guessing: 10% accuracy

Predictability

- **Can we predict the largest of 10 random chosen cascades of the identical image?**

Predictability

- **Can we predict the largest of 10 random chosen cascades of the identical image?**

Gini Coefficient of 0.787

Accuracy of 0.497

Mean Reciprocal Rank of 0.662

So…how do I make my posts go "viral"?

Maximize Content Success

- **Given a piece of content, can we maximize probability of its success?**

Factors influencing popularity

Community or Forum

Time of posting

Title of submission

Popularity of user

Previous submissions of same content

+

Content

and their confounding interplay!

Teasing Apart the Effects

How do we tease apart effects of various factors ?

A dataset which accommodates

Resubmissions of same content

Submissions across multiple communities

Communities with varying characteristics

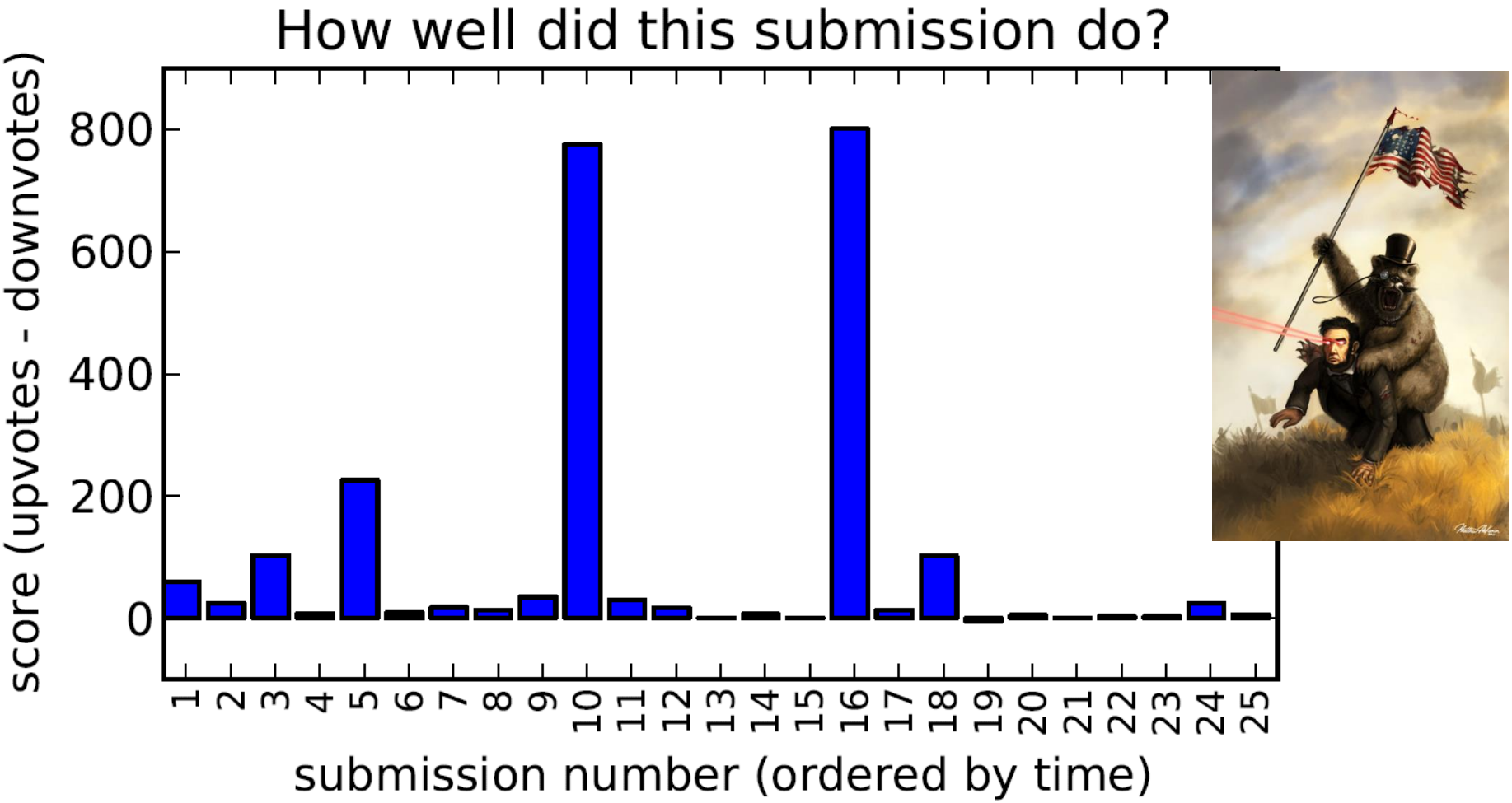
Submissions by multiple users

Dataset: Reddit!

- **Natural experiment: Every piece of content submitted multiple times**
  - 132K Reddit submissions
  - 16.7K original submissions
  - Average of 7 resubmissions per image

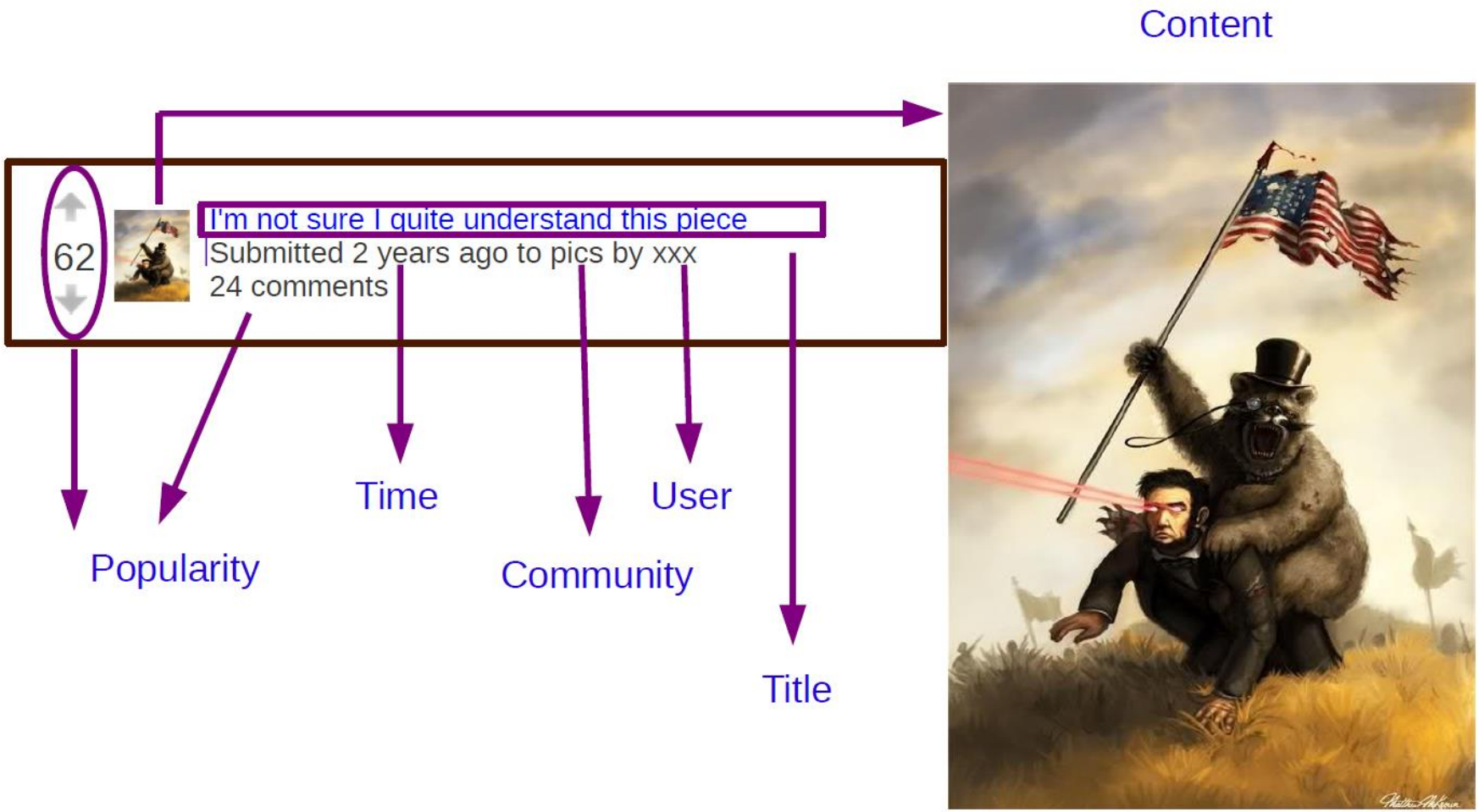
Data available at http://snap.stanford.edu/data

Content on Reddit



Content on Reddit

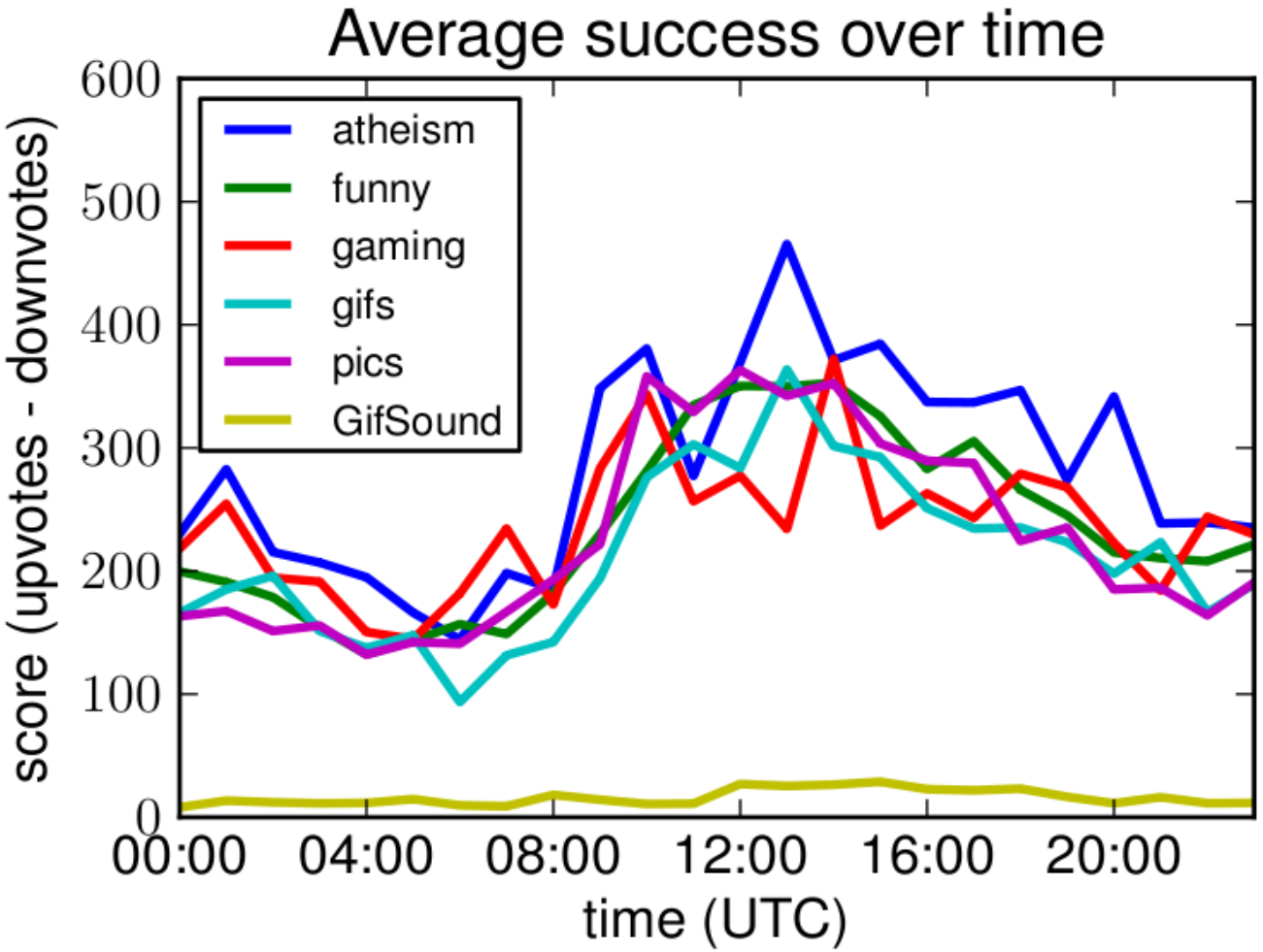
Understanding Popularity



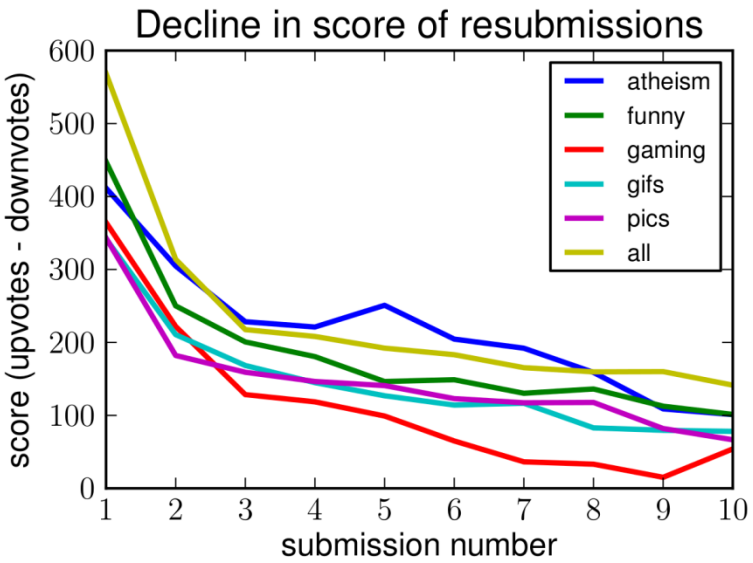
Our Approach

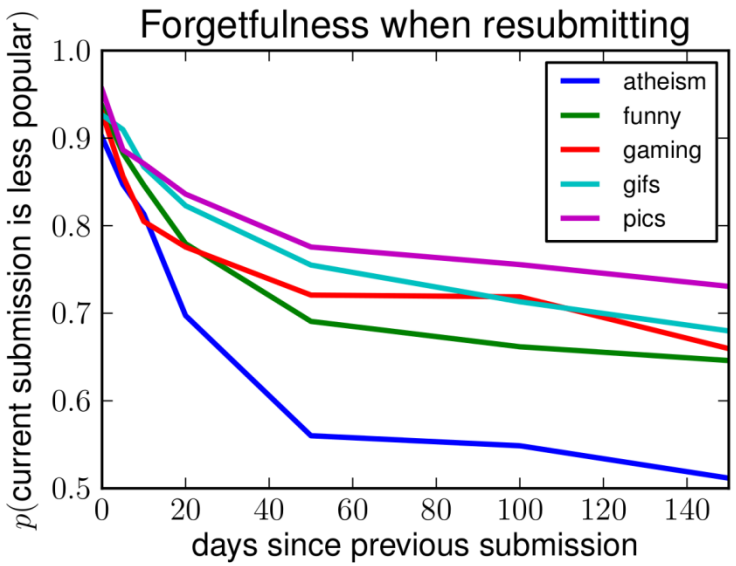
- **Popularity = Community Model + Language Model**
  - **Community model:** Choice of **community** + **time** of submission + **previous submissions** of same content
  - **Language model:** Linguistic features of submission **title** + **language of community**

Temporal Effects



Temporal Effects



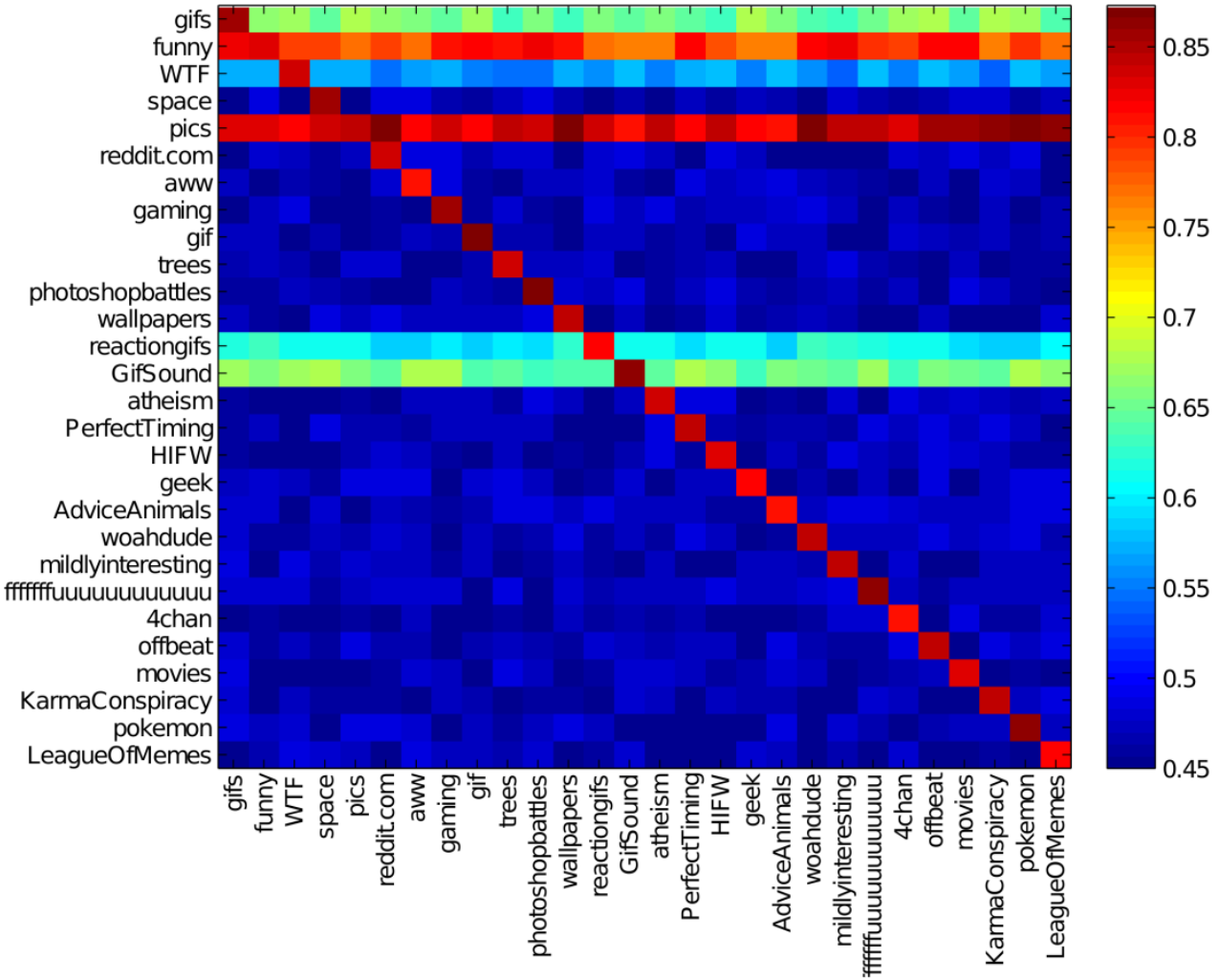


Resubmissions are less popular (left), but can still be popular if we wait long enough (right)

Inter-Community Effects

Submissions won't be successful in the same community twice (main diagonal)

Submissions won't be successful if they already succeeded in a big community (low-rank structure)



Model: Time and Community

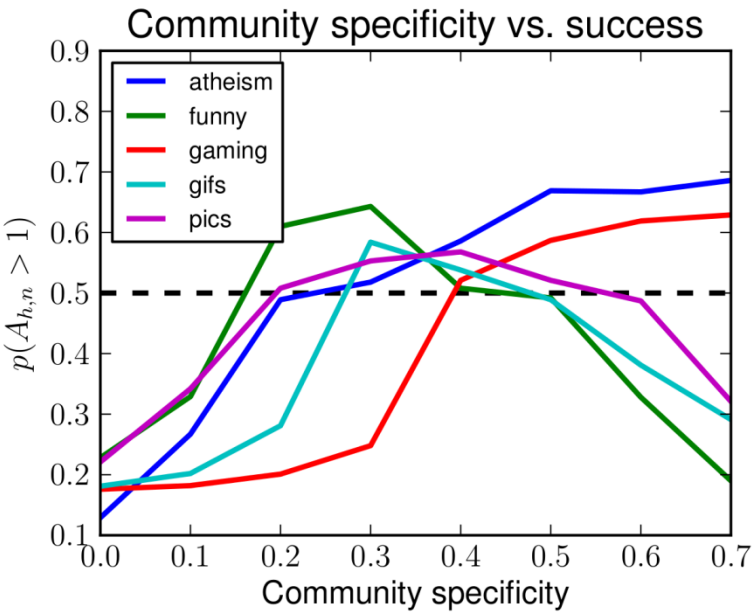
inherent popularity — forgetfulness — same community twice

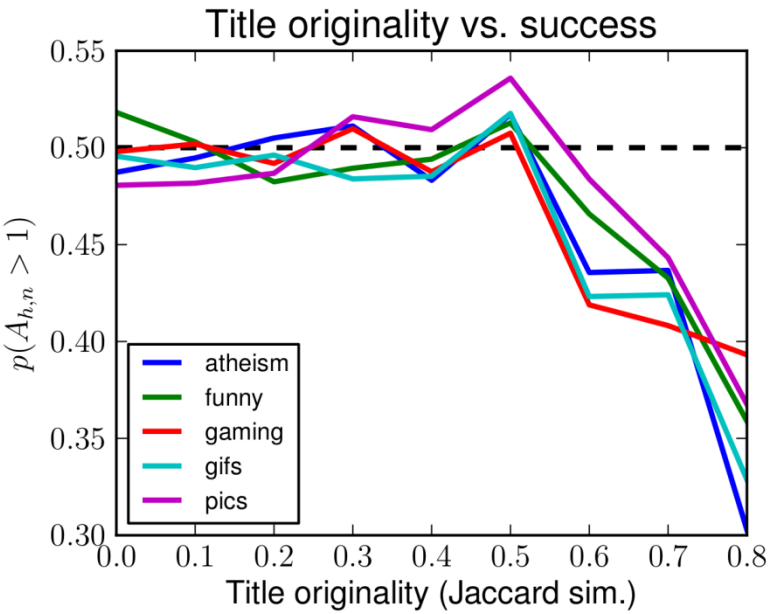
$$\hat{A}_{h,n} = \beta_h + \phi_h \exp\left\{-\sum_{i=1}^{n-1} \frac{1}{\Delta_{i,n}^h} \left(\delta(c_{h,i} \neq c_{h,n})\lambda_{c_{h,i}} + \delta(c_{h,i} = c_{h,n})\lambda'_{c_{h,i}}\right)\right\} A_{h,i}$$

decay from resubmissions — other communities — previous submissions

- **The model is designed to account for five factors:**
  1. The inherent popularity of the content
  2. The decay in popularity due to resubmitting the content
  3. This decay should be discounted for old enough submissions
  4. A penalty due to resubmitting to another community
  5. A penalty due to resubmitting to the same community (also account for other factors, like the time of day, etc.)

Model: Language effects

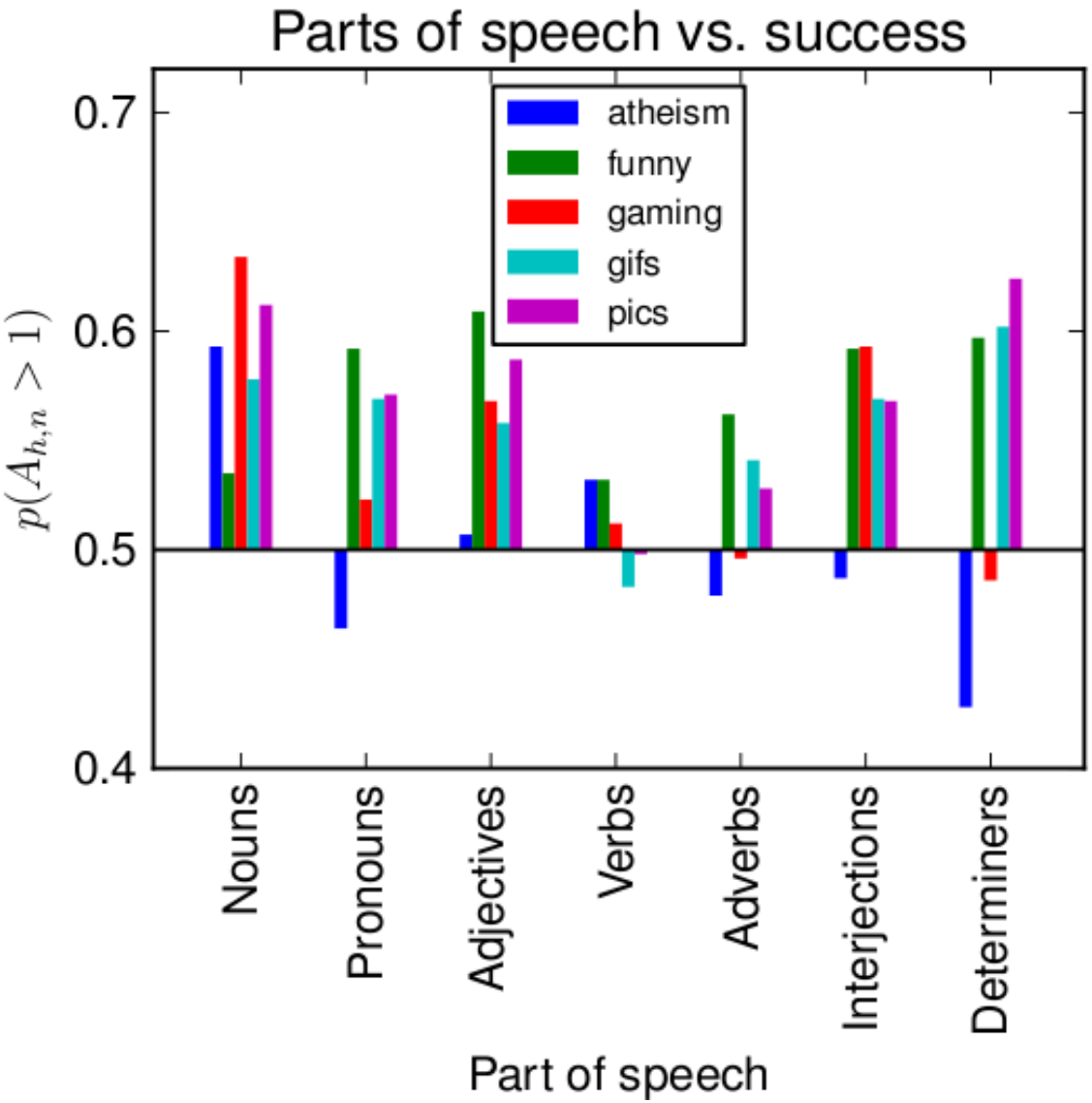




Titles should match others in the same community, but should not be too similar

Titles should differ from those previously used for the same content

Gramatical Structures



Evaluation

- **Performance on held-out test data:**

Model	R^2
Community model only	0.528
Language model only	0.081
Community + language	0.618

Rating: upvotes – downvotes

- **Attention:** upvotes+downvotes: R^2=0.58
- **Engagement:** # comments: R^2=0.68

Evaluation (2)

- We generated **pairs** of **85** posts
- We submitted them simultaneously to two different communities

- **'Good' posts got 3x as many upvotes**
  - **Five** good titles reached the **front page** of their community
  - **Two** reached the front page of r/all

- **Good title: What I would do to someone I hate**
  - Votes: 7087/ 5228, Cmts.: 518
- **Why is this good?**
  - Original title
  - Optimal length (not too short)
  - POS tags: Interesting way of sentence structure compared to a flat tone syntax

- **Bad title: Funny gif**
  - Votes: 300/124, Cmts.: 9
- **Why is this bad?**
  - Not original, too generic (no specificity)
  - Super short length
  - Flat POS tag distribution


REPOST SOMETHING
FROM REDDIT ON REDDIT
GET MORE UPVOTES THAN
ORIGINAL POST
quickmeme.com

Conclusion

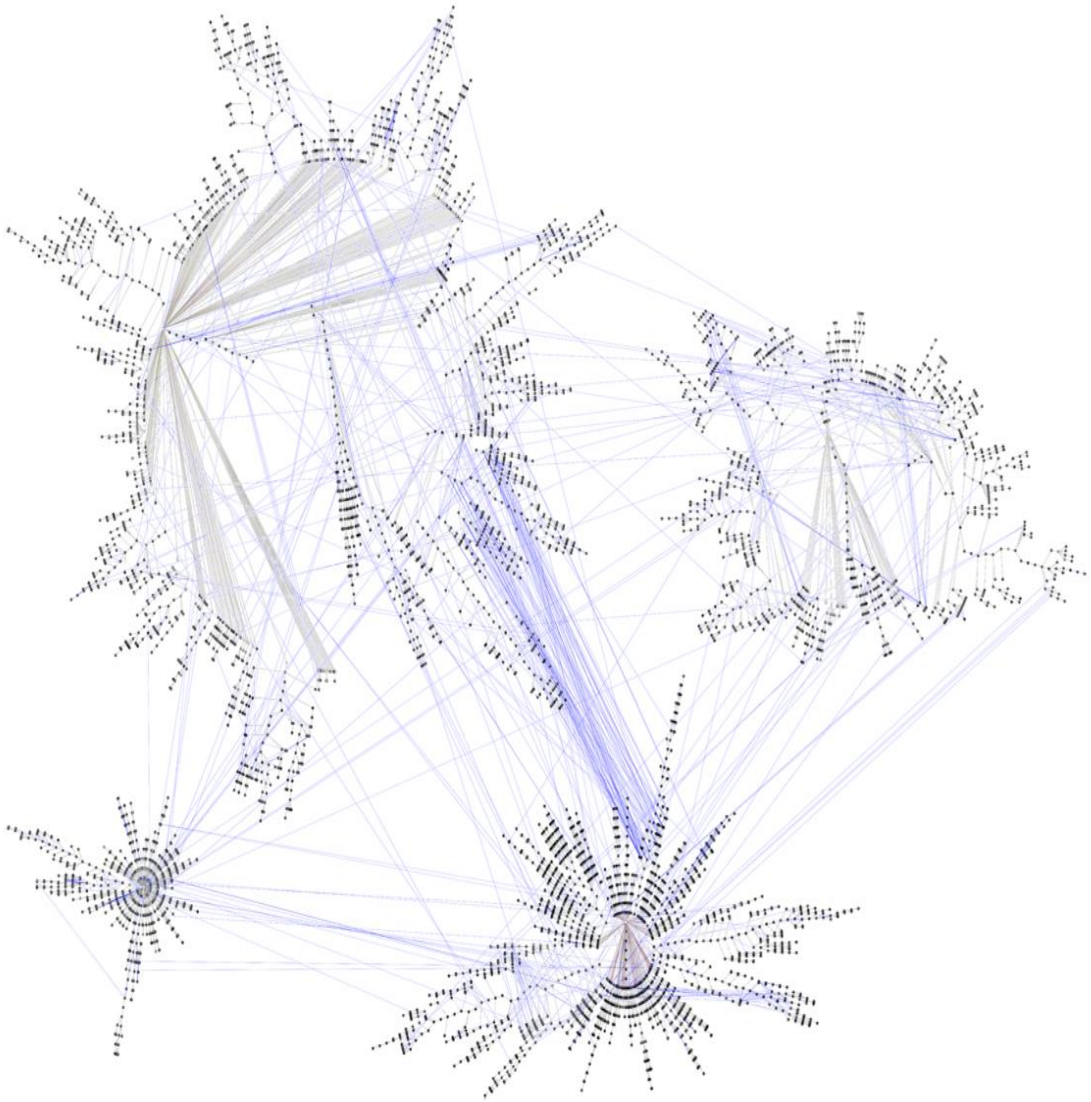
- **Cascades are predictable**
  - The cascade growth prediction problem, allows us to accurately predict the future growth of a cascade, even as it continues to grow in size
- **Cascades can be engineered**

  (to a large extent)

Conclusion

- **What have we learned about "viral" posts?**
  - Favor memes **(i.e. post popular content)**
  - Have lots of followers **(i.e. be popular)**
  - Know what your friends like, and what your friends' friends like **(i.e. be a marketing guru)**
  - Post at the right time

Further Qs: Interactions



Further Qs: Opinion dynamics

- **Can this analysis help identify dynamics of polarization?**
- **Connections to mutation of information:**
  - How does **attitude** and **sentiment change** in different parts of the network?
  - How does **information change** in different parts of the network?

Reflections

- **Messages spreading through network require new ways of thinking about information dynamics and consumption**
- **Feedback effects in networks:**
  - **The feedback from using your social connections**

    Some links are strengthened, others created:
    - Something that's been going on for millennia
  - **The feedback from media that let you observe your place in the social network**
    - A new and uncontrolled experiment


THANKS!
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