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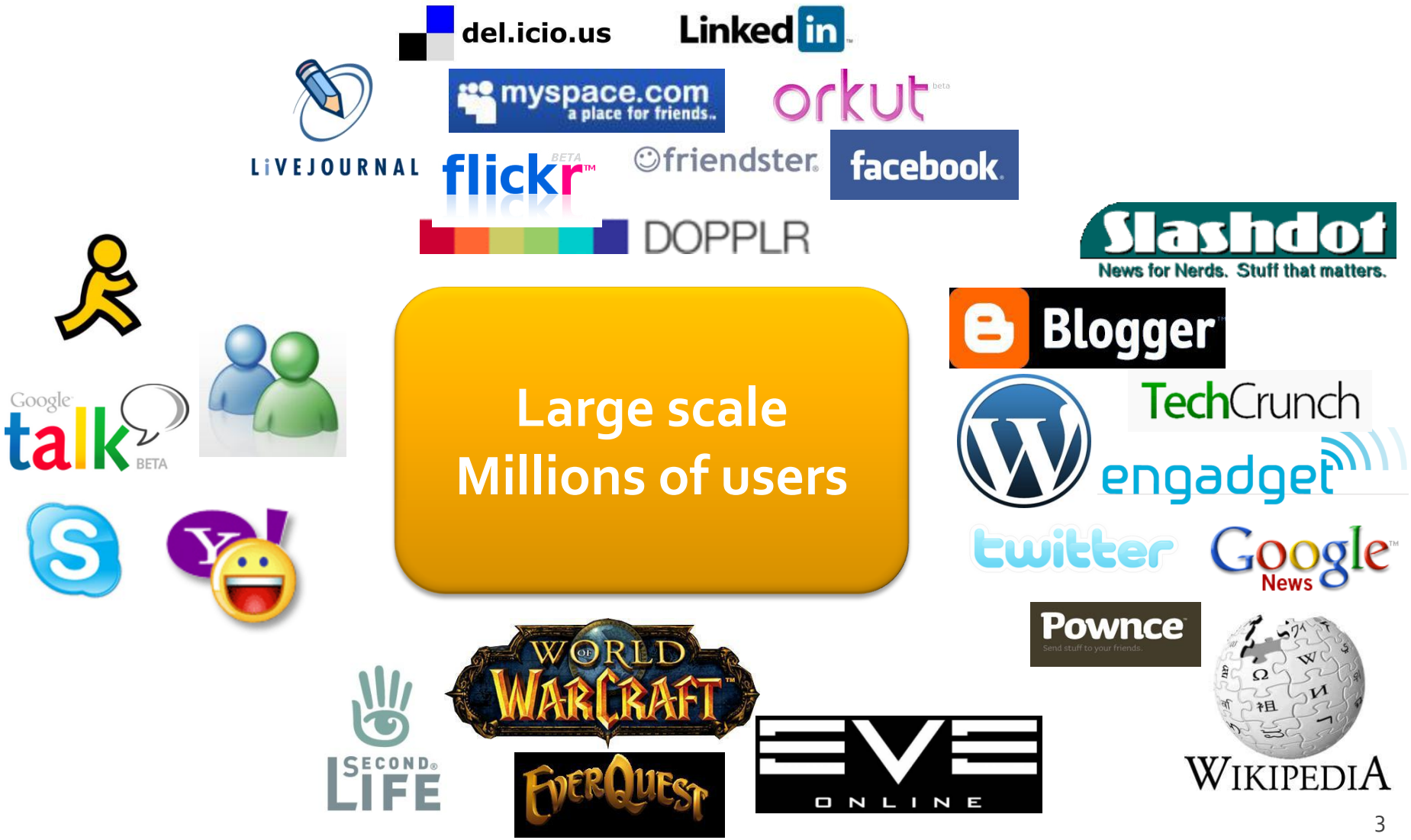
Dynamics of large networks

Web today – Diverse applications

Diverse on-line computing applications

Web today – Millions of users



Large scale
Millions of users

Web today – Rich content

Rich user generated content

Web today – Highly dynamic

Content is constantly being updated and changed

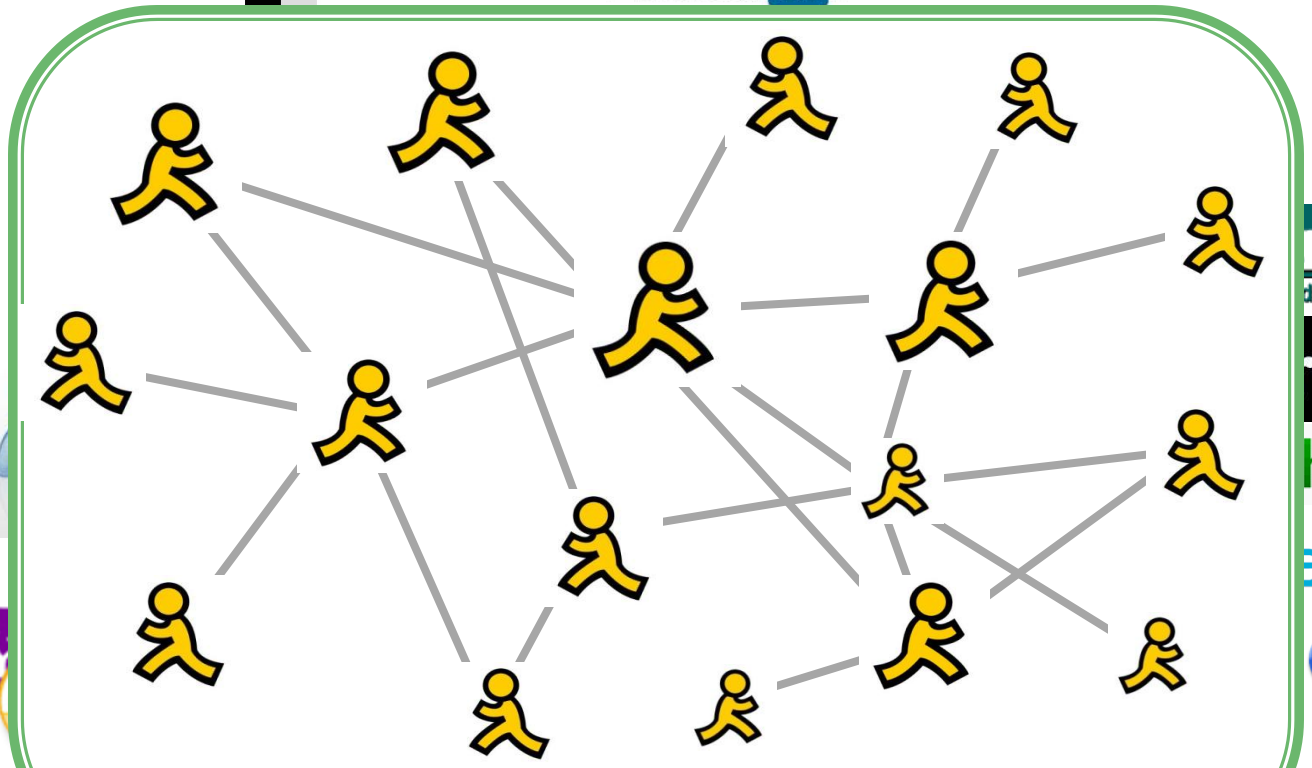
Web today – Traces of activity

Massive traces of human social activity are collected

Web today – Rich interactions

Rich interactions between users and content

Web today – Interaction networks



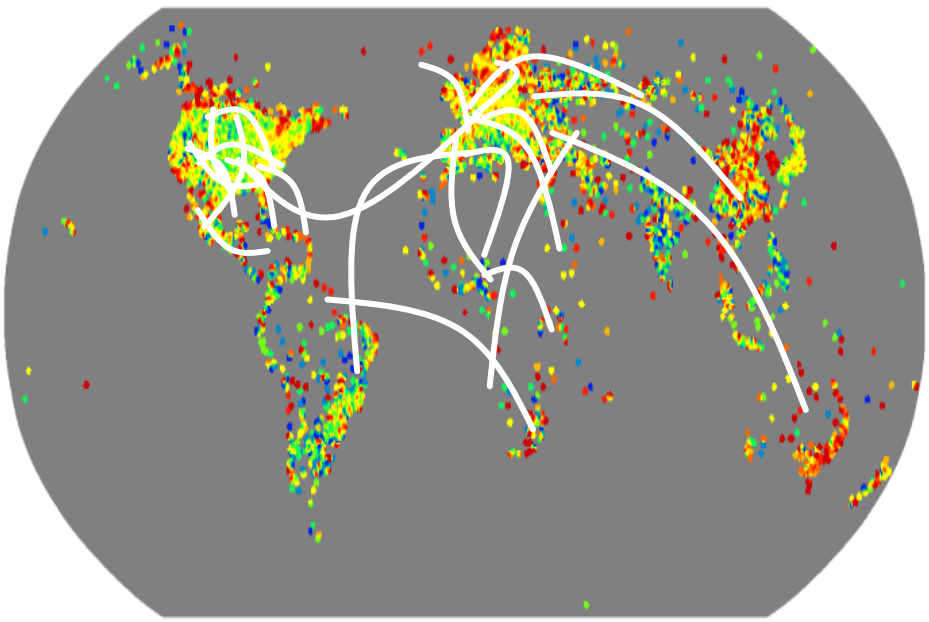
Modeled as interaction **network**

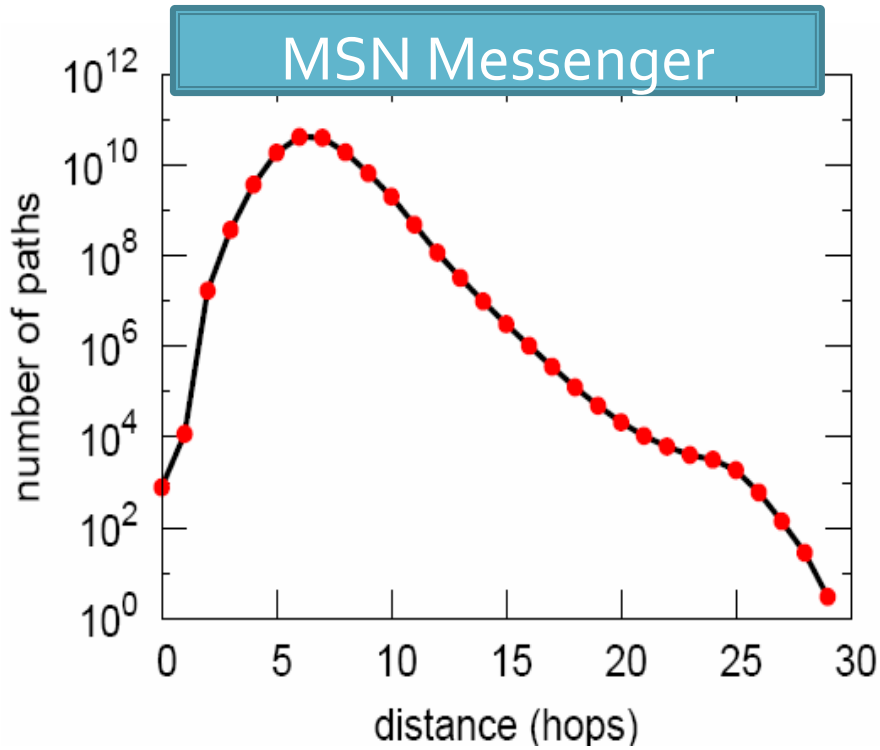
Web today – Immense posibilities

Web is like a "laboratory" for studying millions of humans

[w/ Horvitz WWW '08]

Testing the Small-world hypothesis





Network of who talks to whom on MSN Messenger: 240M nodes, 1.3 billion edges

Average path length is **6.6**
90% of nodes is reachable <8 steps

Why study web and networks?

- **Build understanding and theory:**
  - How users create content and interact with it and among themselves?
- **Build better on-line applications:**
  - How to design better services and algorithms?

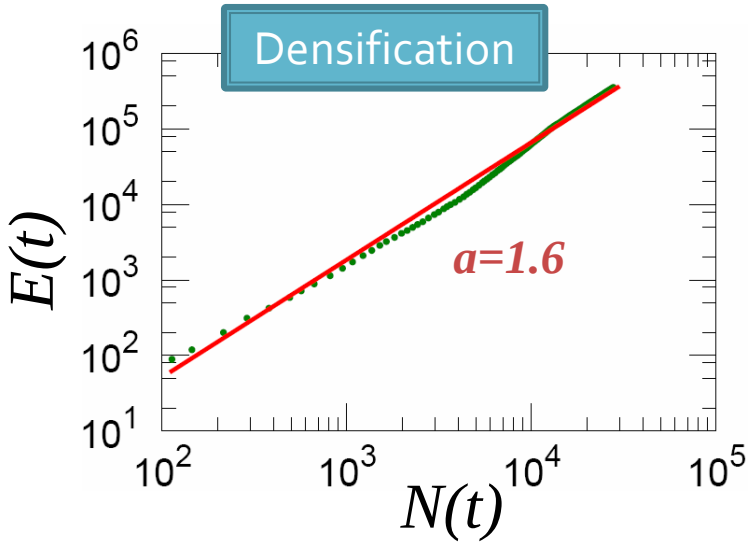
Thesis: Network dynamics

- Network evolution
  - How network structure changes as the network grows and evolves?
- Diffusion and cascading behavior
  - How does information and diseases spread over networks?

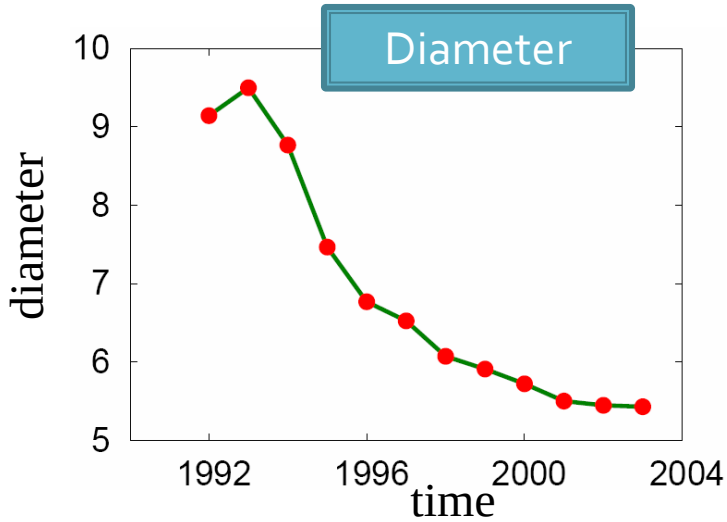
[w/ Kleinberg and Faloutsos KDD '05]

Thesis: Network evolution (1)

- **Observations:** measuring
  - **Q:** How do does network structure evolve?
  - **A:** Networks densify and diameter shrinks



$$E(t) \propto N(t)^a$$

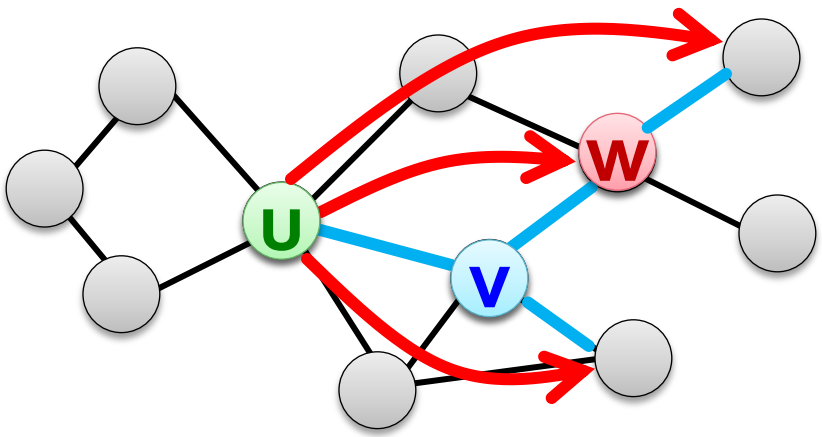


Network diameter shrinks over time

[w/ Kleinberg and Faloutsos KDD '05]

Thesis: Network evolution (2)

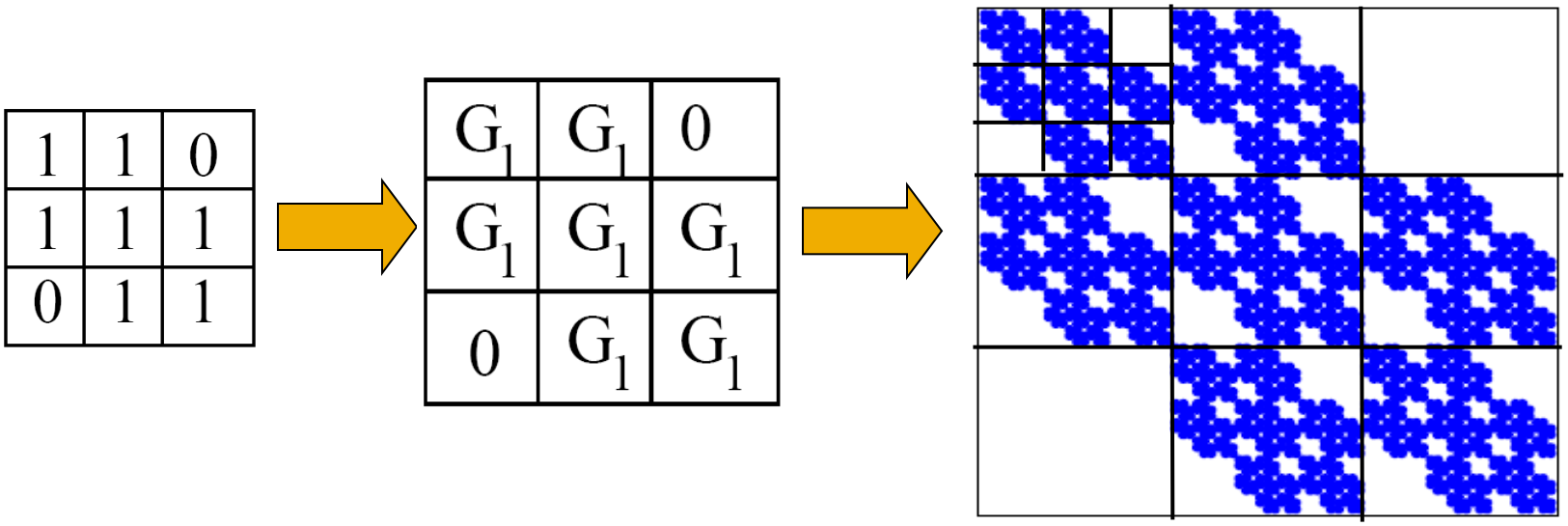
- **Models:** understanding
  - **Q:** What is a good model/explanation?
  - **A:** Forest Fire model



[w/ Faloutsos ICML '07]

Thesis: Network evolution (3)

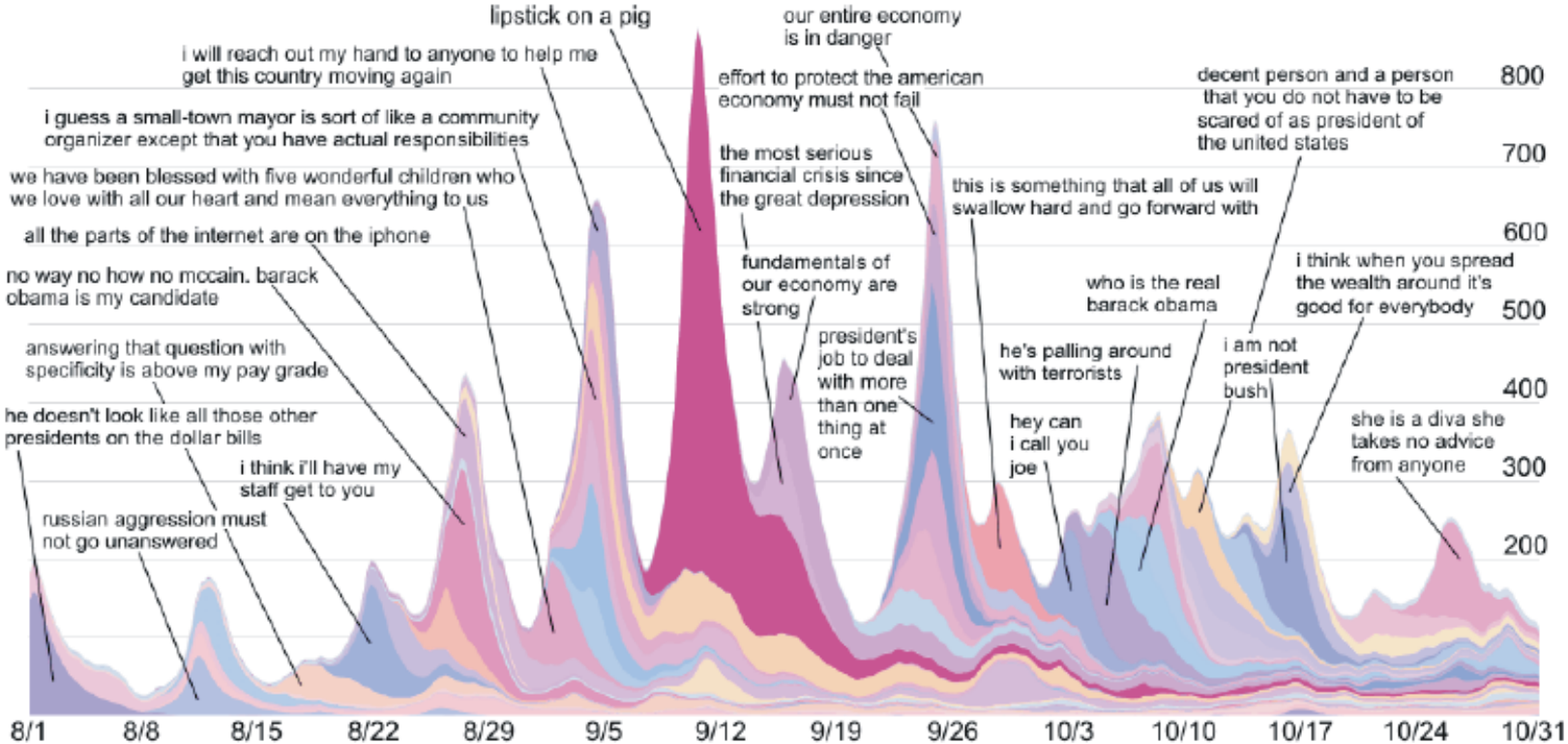
- **Algorithms:** doing things better
  - **Q:** How to generate realistic graphs?
  - **A:** Kronecker graphs



[w/ Backstrom and Kleinberg KDD '09]

Thesis: Diffusion and cascades (1)

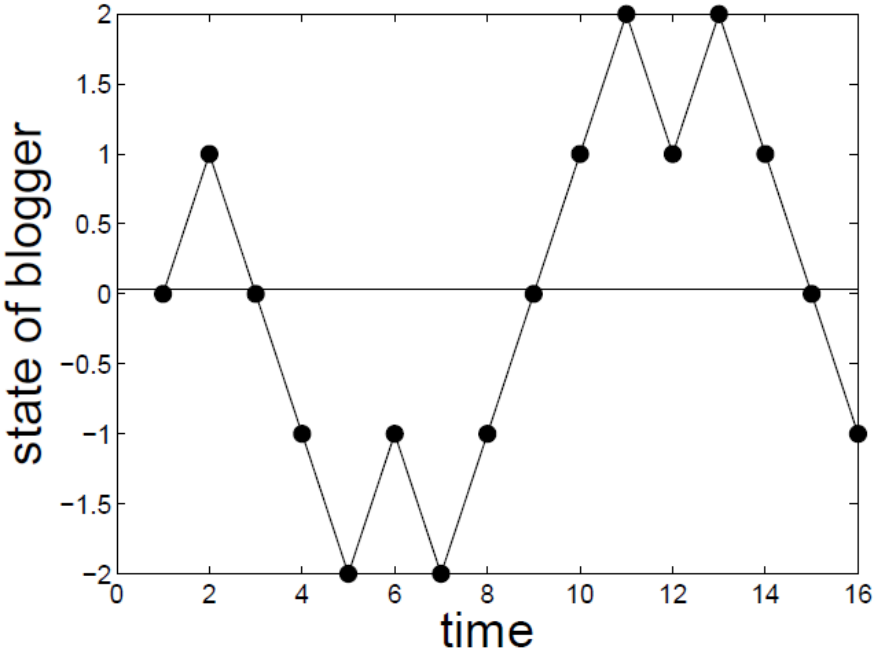
- **Observations:** measuring
  - **Q:** How does information propagate over the web?



[w/ Goetz, McGlohon and Faloutsos ICWSM '09]

Thesis: Diffusion and cascades (2)

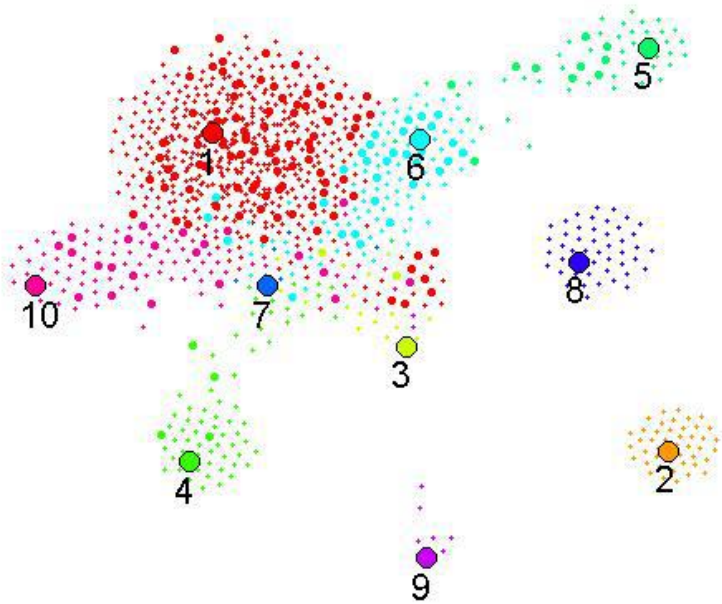
- **Models:** understanding
  - **Q:** How to information propagation
  - **A:** Zero-crossing model



[w/ Krause, Guestrin, Glance and Faloutsos KDD '07]

Thesis: Diffusion and cascades (3)

- **Algorithms:** doing things better
  - **Q:** How to identify influential nodes and epidemics?
  - **A: CELF** (cost-effective lazy forward-selection)



Thesis: Size matters

- **Massive data:**
  - MSN Messenger network [w/ Horvitz, WWW '08]
    - 240M people, 255B messages
  - Product recommendations [w/ Adamic, Huberman EC '06]
    - 4M people, 16M recommendations
  - Blogosphere [w/ Backstrom, Kleinberg KDD '09]
    - 164M posts, 127M links
- **Benefit:** Properties become "visible"
  - E.g.: In large networks only small clusters exist

    [w/ Dasgupta, Lang and Mahoney WWW '08]

Thesis: Reflections

- Why are networks the way they are?
- Only recently have basic properties been observed on a large scale
  - Confirms social science intuitions; calls others into question
- What are good tractable network models?
  - Builds intuition and understanding
- Benefits of working with large data
  - Observe structures not visible at smaller scales

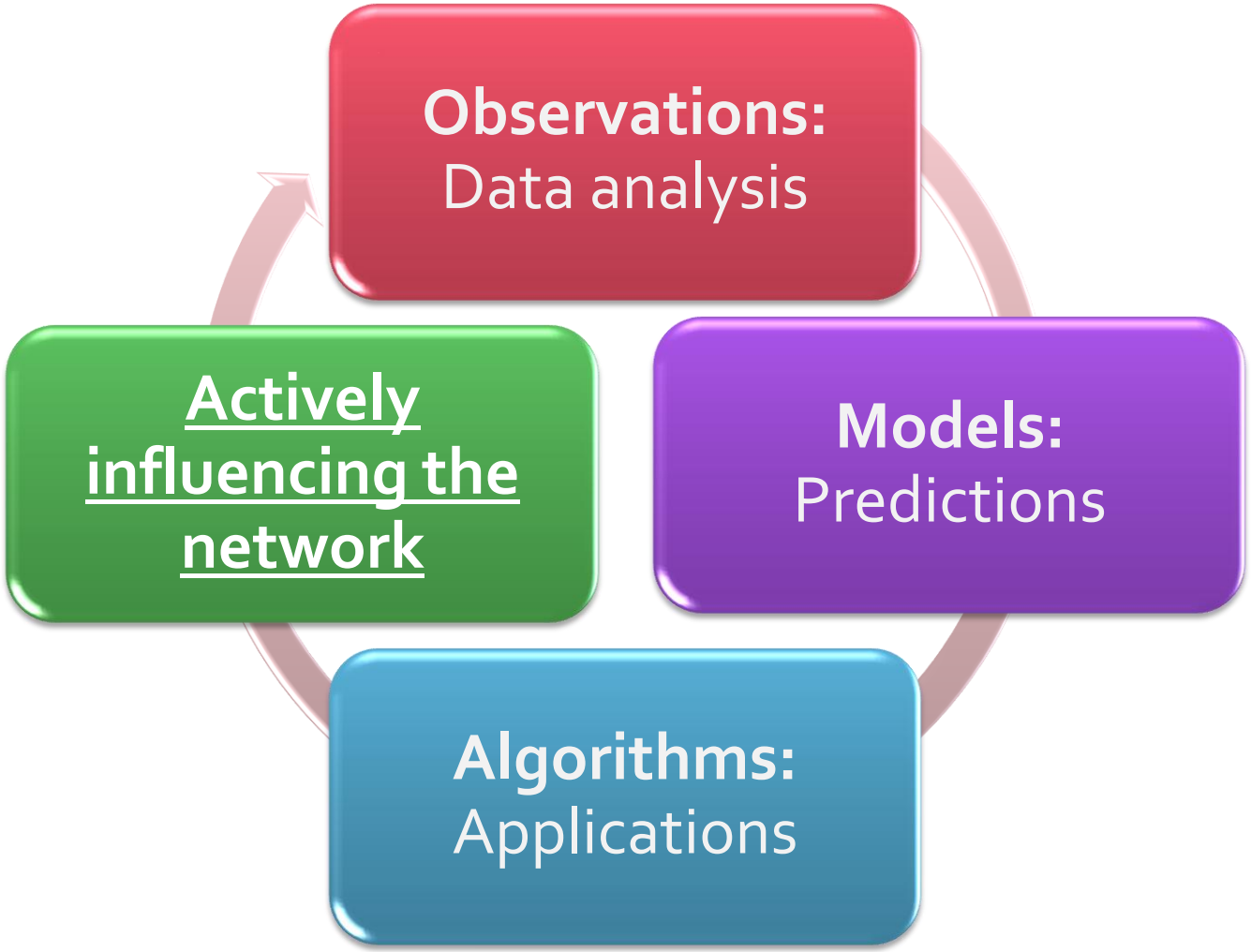
Challenges

- Why are networks the way they are?
- Richer networks, richer more detailed data
  - New findings and observations
- More accurate models
  - Predictive modeling
- Large scale
  - Will find phenomena and emergent patterns not visible at small scales

Future directions

- Global predictive models
  - Online massively multi-player games
- Information diffusion
  - When, where and what post will create a cascade?
- Where to tap the network to get right effects?
  - Social Media Marketing
- Steering the evolution of the network
  - Cultivating the social network

What's next?


Observations:
Data analysis
Models:
Predictions
Algorithms:
Applications
Actively influencing the network

Acks

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THANKS!

Questions:

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Thesis:

Google: Jure thesis

Data + Code:

http://snap.stanford.edu