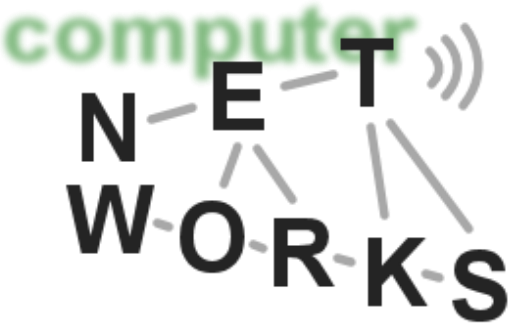
Introduction to Social Networks

Advanced Computer Networks

Summer Semester 2013



computer NETWORKS

Online Social Networks (OSNs)

- OSNs have become extremely popular within the last decade
  - E.g., Facebook: more than 1 billion users
- A giant pool of data, large-scale structures, communication, …
  - Research in this direction very interesting and multi-faceted:
    - What about data protection / privacy?
    - Arabic Spring: Political influence of OSNs?
    - Data propagation: How is information conveyed in OSNs?
    - Connections among people: useful for applications?

Terminology

- Social Network
  - A network made up by a set of individuals interconnecting with each other basing on social relationships (such as friendships, partnerships, etc.)
- Entity: a basic unit of the network
- Link: interconnection between entities
- Behavior and dynamics
  - Each individual's actions have implicit consequences for the outcomes of everyone in the system
  - Individual actions are not in isolation: cause-effect
    - Changes in a product, a Web site, or a government program
    - The rich get richer; winners take all; small advantages are magnified to a critical mass; new ideas get attention that becomes viral

Network: Friendship

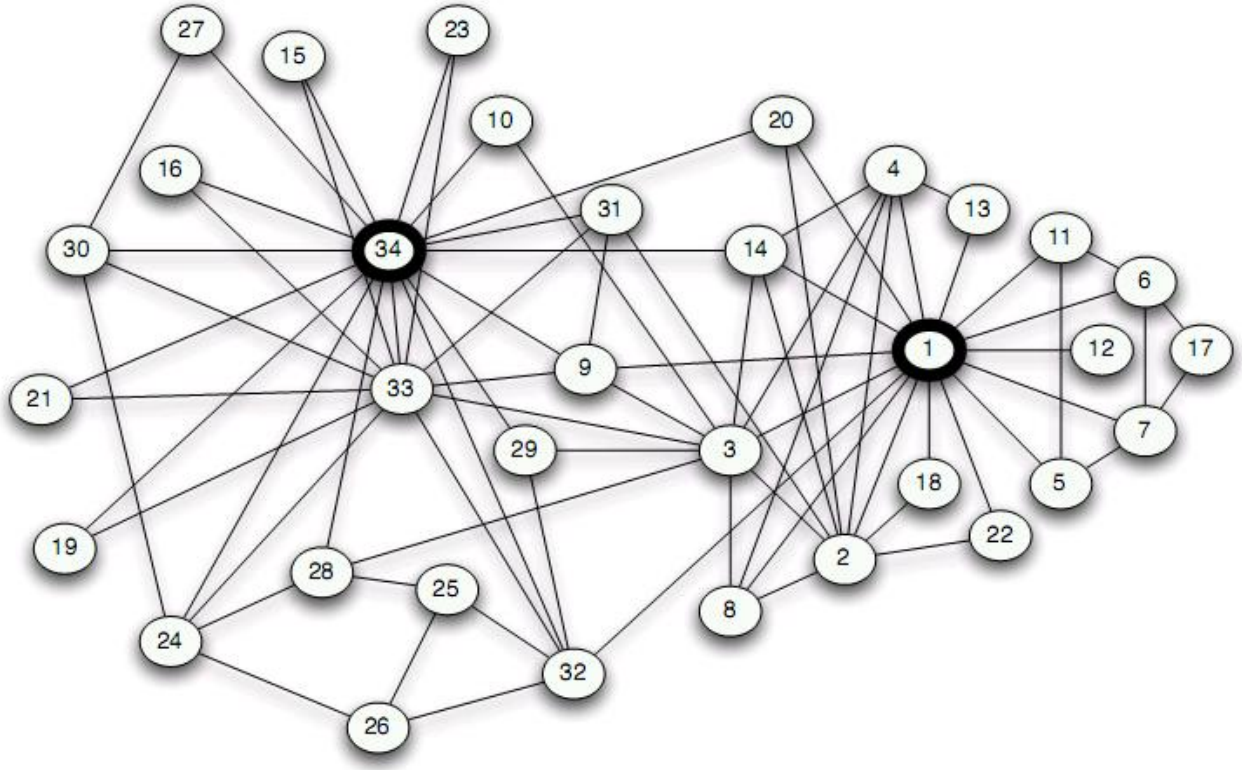
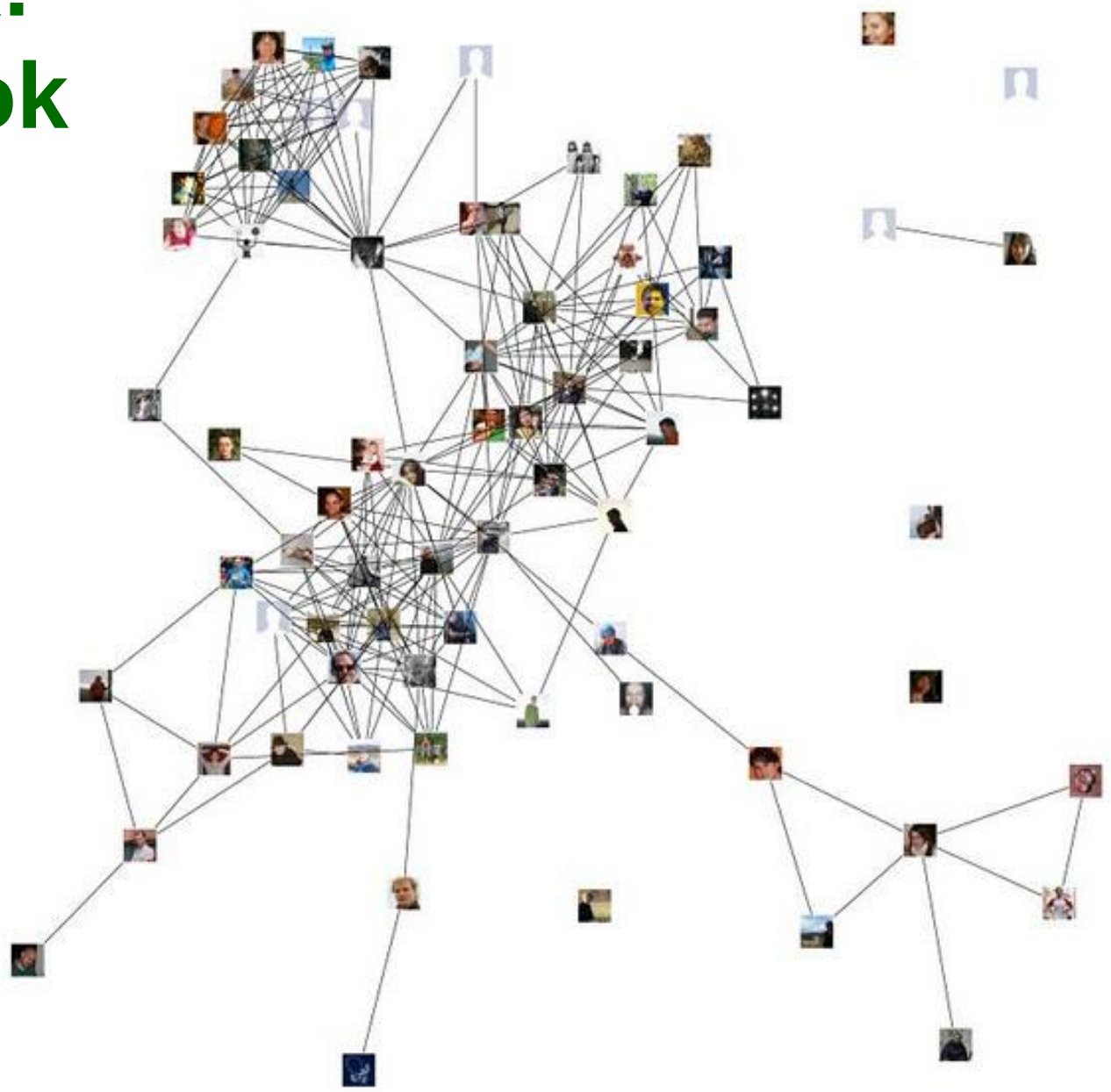


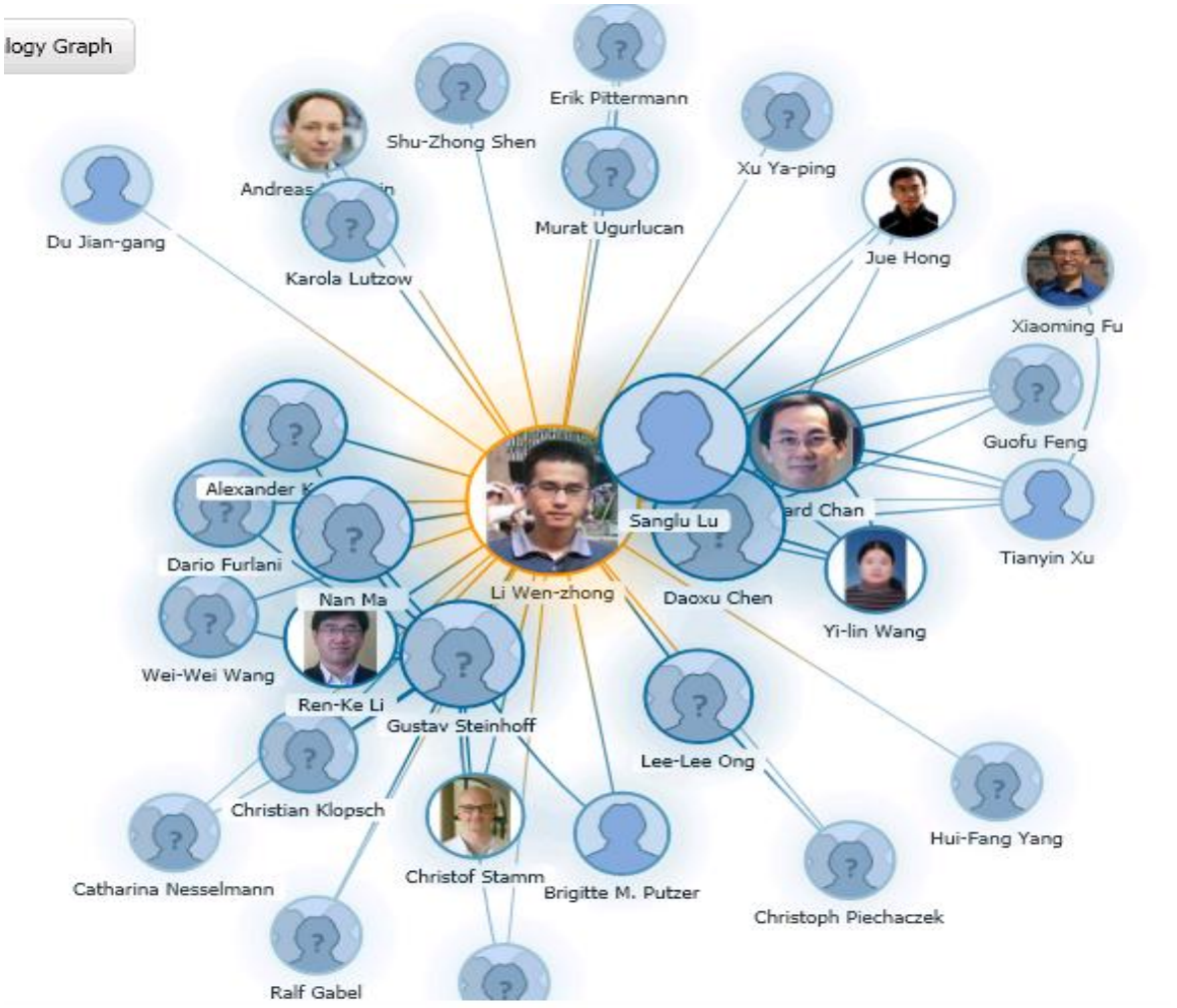
Figure 1.1: The social network of friendships within a 34-person karate club [421].

Network: Facebook

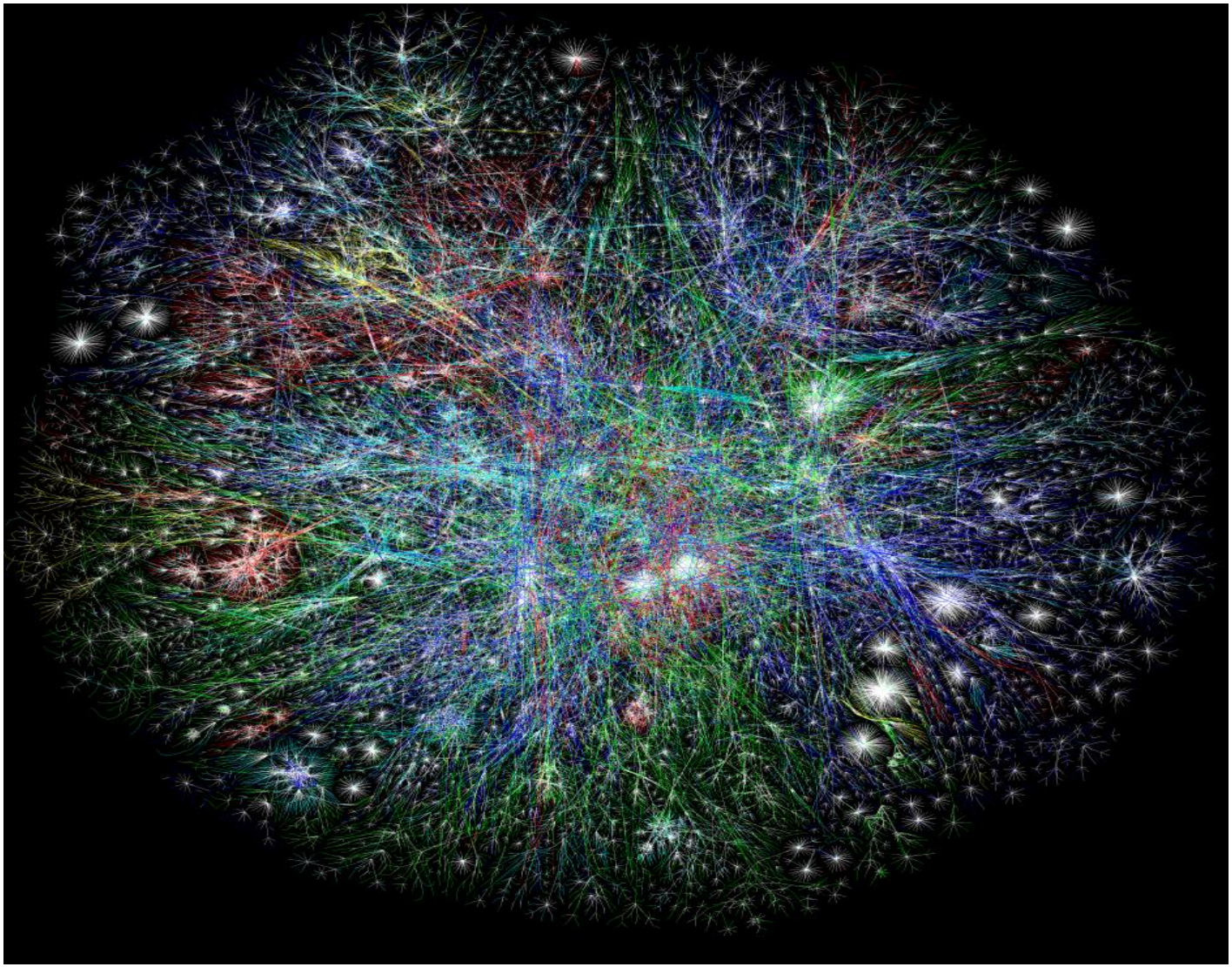


http://revolution-computing.typepad.com/.a/6a010534b1db25970b016760ccd666970b-pi

Network: Co-authorship



Network: Communication



Network: Information

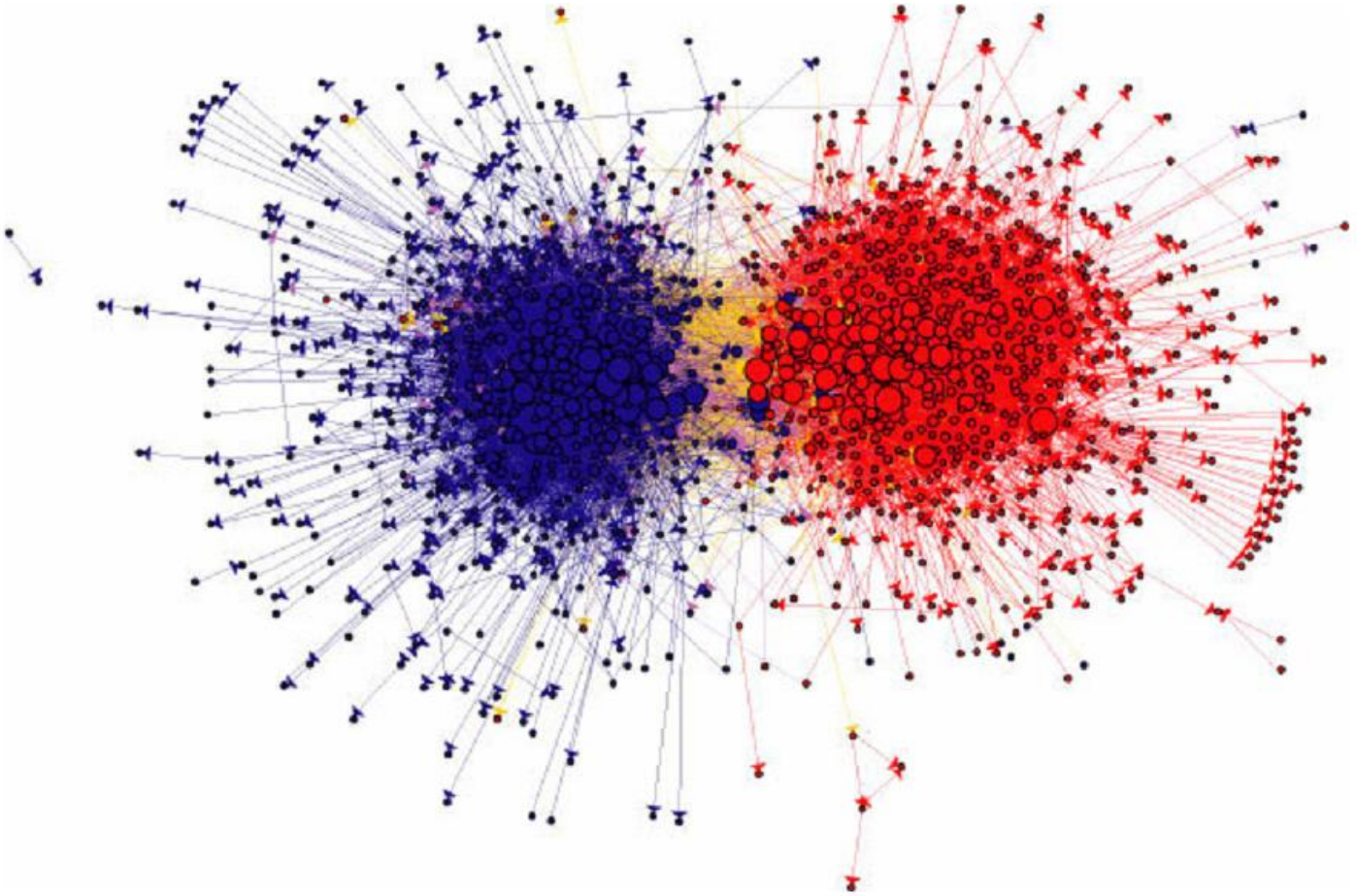
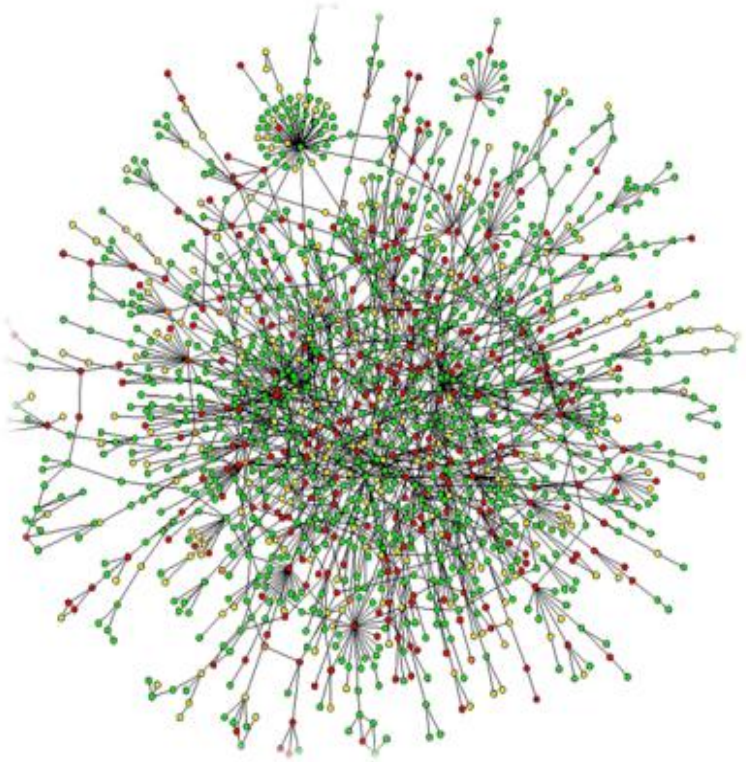


Figure 1.4: The links among Web pages can reveal densely-knit communities and prominent sites. In this case, the network structure of political blogs prior to the 2004 U.S. Presidential election reveals two natural and well-separated clusters [5]. (Image from http://www-personal.umich.edu/ ladamic/img/politicalblogs.jpg)

Network: Biological



Protein-Protein Interaction Networks:

Nodes: Proteins

Edges: 'physical' interactoins

Human brain has between
10-100 billion neurons

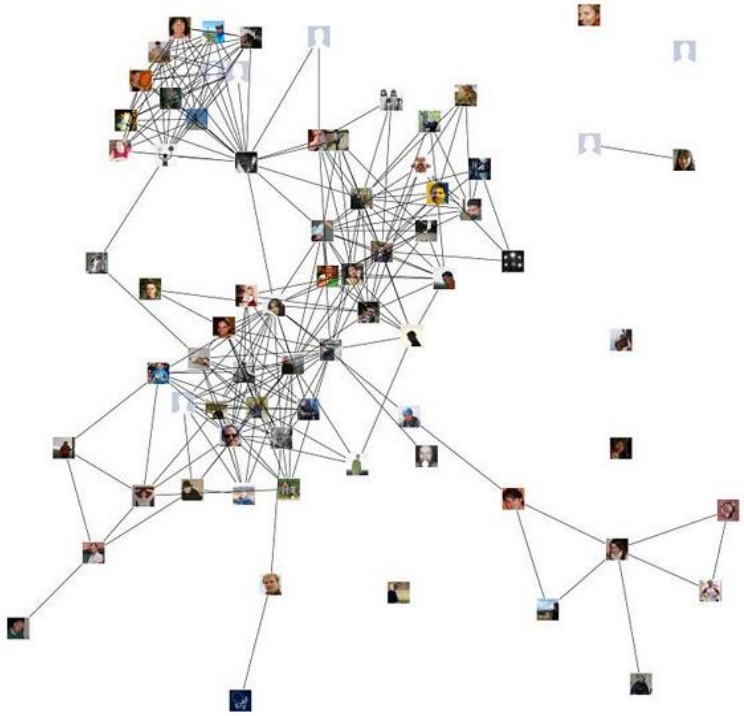
Commonalities among Networks

- A network that defines the interactions between the components
  - Seems random, but displays signatures of order and self-organization
- Characteristics
  - Virtual: it does not physically exist
  - Complex: it consists of a large scale number of nodes
  - Grouping: it forms communities due to different interests
  - Dynamic: its structure is evolving over time

Social Network Analysis

Research Questions

- Structure and evolution
  - What is the structure of a network?
  - Why and how has this structure evolved?
- Processes and dynamics
  - Social networks provide "skeleton" for spreading of information, behavior, …



Methods

- Empirical:
  - Study network data to find organizational principles
- Mathematical models:
  - Probabilistic, graph theory
- Algorithms
  - Algorithms for analyzing graphs

Targets of this part of the lecture

- Learn about patterns and statistical properties of network data
- Design principles and models
- Understand why social networks are organized the way they are (prediction)

Topics in the upcoming weeks

- Structure of networks
  - Connectivity
  - Communities
- Power-law and small-world phenomenon
  - Decentralized search in networks
  - Distributed routing strategies
- Epidemics
  - Spreading of diseases
  - Information propagation in social networks
- …

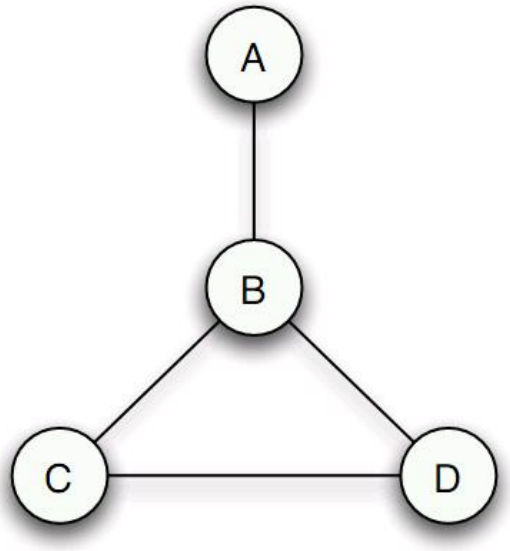
Research Work Done by the Lab

- Cuckoo: Scaling Microblogging Services with Divergent Traffic Demands
- GEMSTONE: Empowering Decentralized Social Networking with High Data Availability
- LENS: Leveraging Social Networking and Trust to Prevent Spam Transmission
- Exploring Regional and Global Population Growth in Online Social Networks
- Exploring User Social Behaviors in Mobile Social Applications
- Rethinking Routing Information in Mobile Social Networks: Location-based or Social-based?
- On the Effectiveness of OSN based Sybil defenses

Modeling Social Networks

Network as a graph

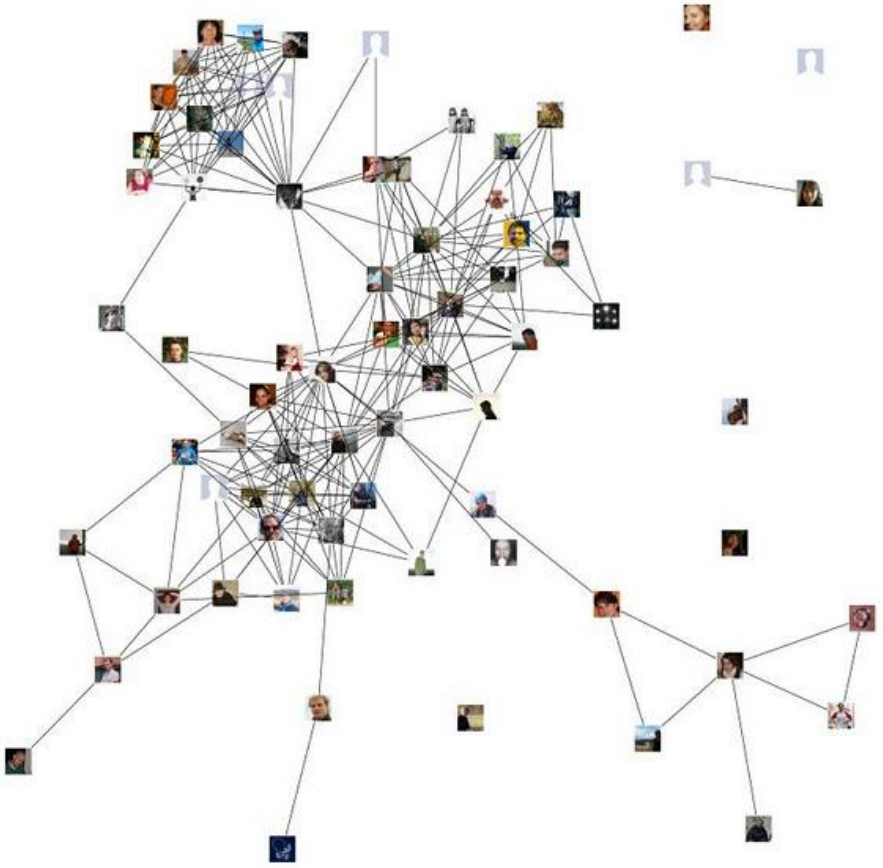
- A network can be represented by a graph mathematically
- Node: an object in the network
- Edge: a link between objects
- Neighbors: nodes connected by edg



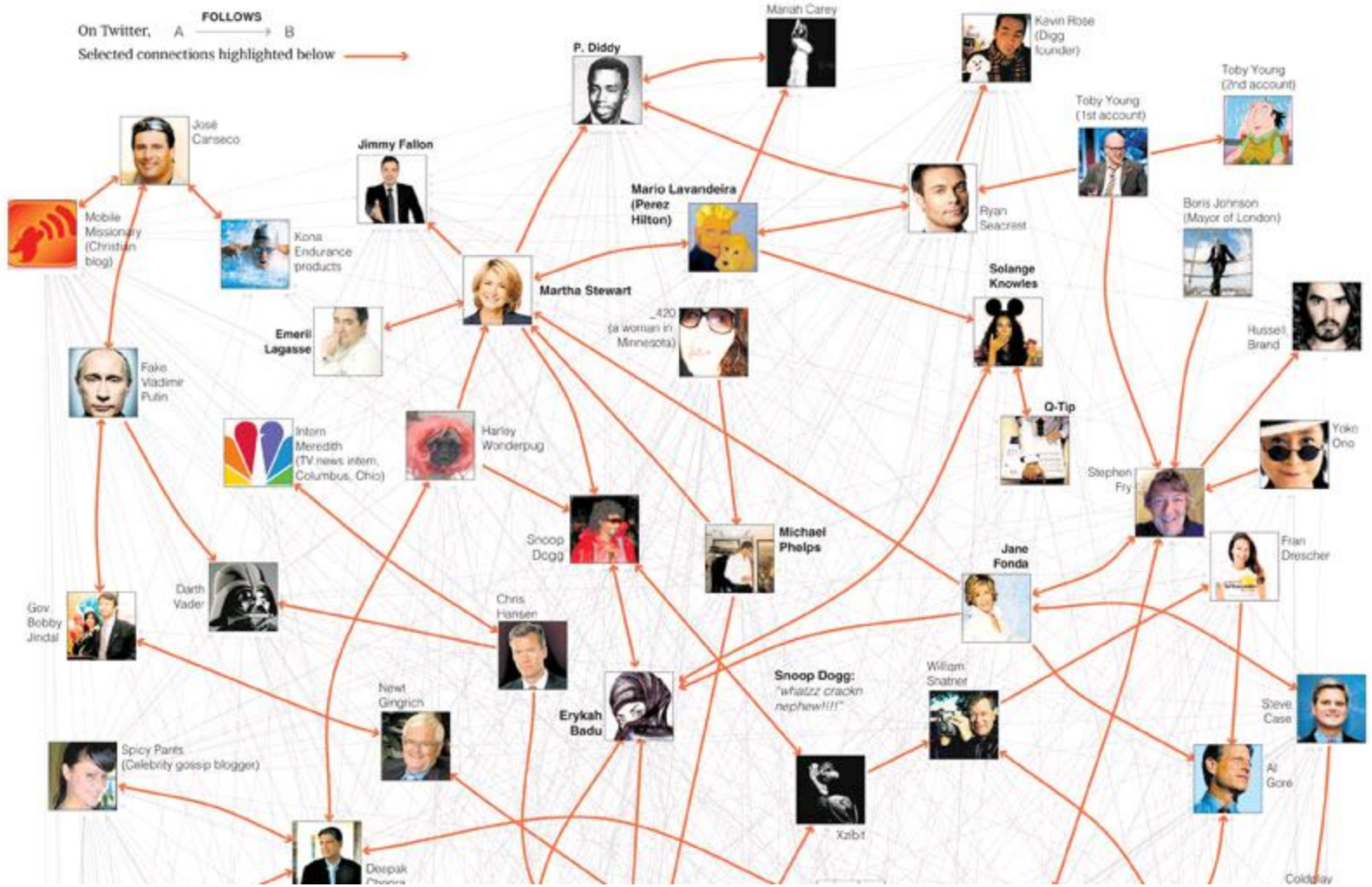
(a) *A graph on 4 nodes.*

Undirected Graph

- Facebook friendship network



Directed Graph



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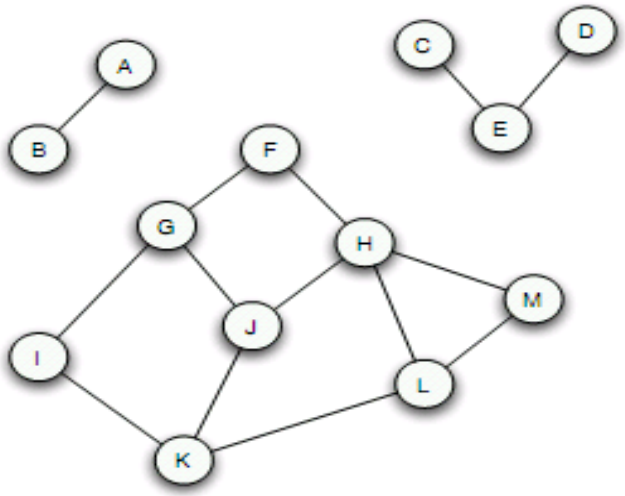
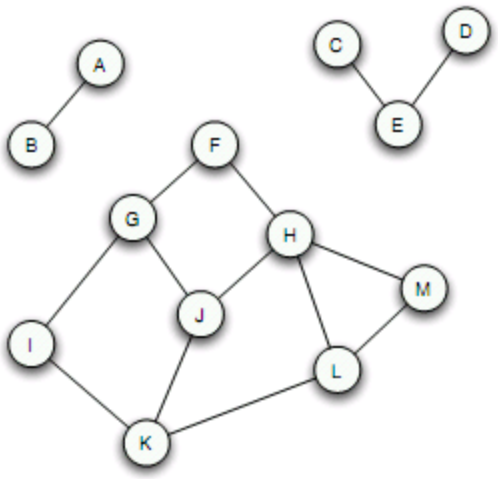
- Path: a sequence of interconnected nodes
- Cycle: a path, the first and last nodes are the same, but other nodes are distinct.
- Connectivity:
  - A graph is connected if for every pair of nodes, there is a path between them



Components

- If a graph is not connected, it breaks apart into several connected subgraphs
- A connected component is a subset of the nodes such that (i) every node in the subset has a path to every other; and (ii) the subset is not part of some larger set with the property that every node can reach every other



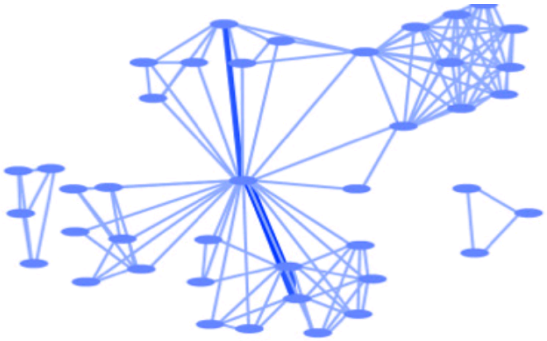
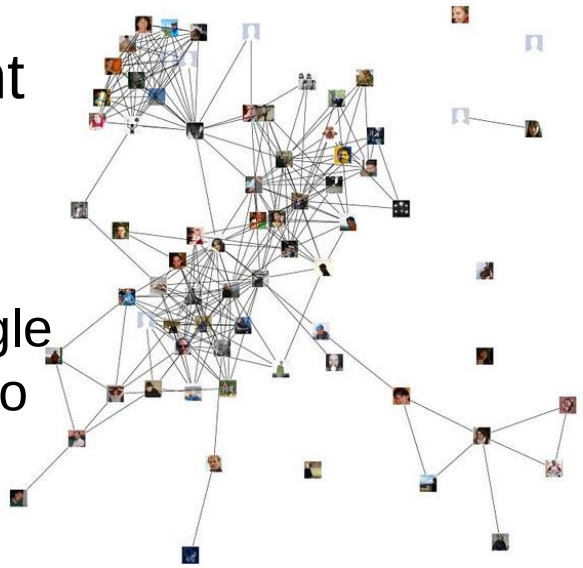


Figure 2.6: The collaboration graph of the biological research center *Structural Genomics of Pathogenic Protozoa (SGPP)* [134], which consists of three distinct connected components. This graph was part of a comparative study of the collaboration patterns graphs of nine research centers supported by NIH's Protein Structure Initiative; SGPP was an intermediate case between centers whose collaboration graph was connected and those for which it was fragmented into many small components.

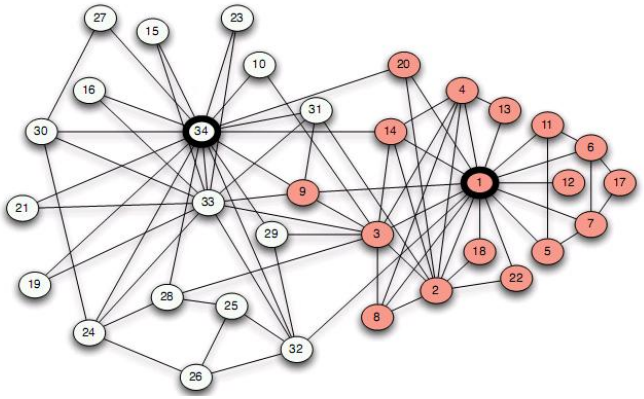
Example: Giant Component

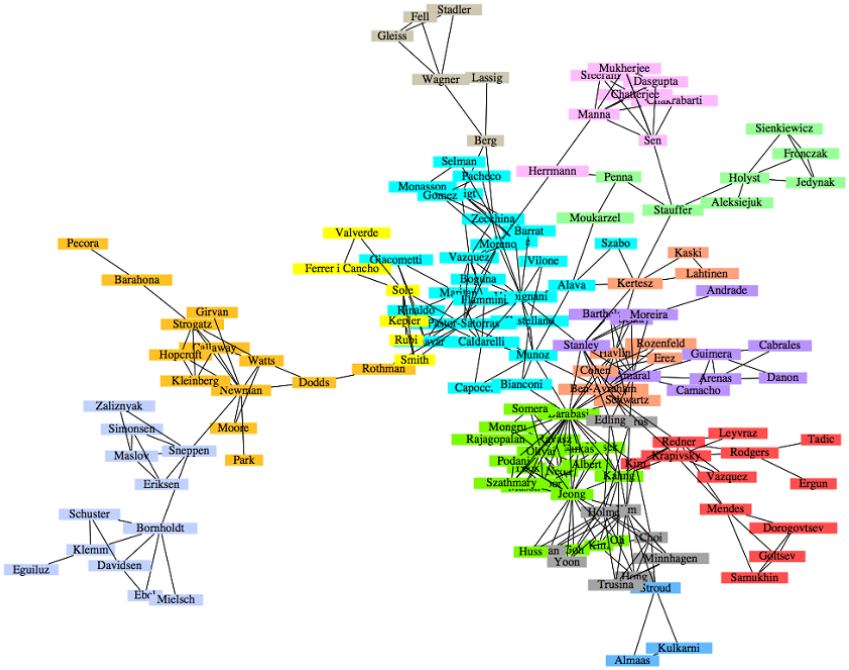
- Is the global friendship network connected?
  - Not necessary, some nodes may have no friends
  - Large complex networks often have a giant component, a connected component that contains a significant fraction of all the nodes
  - Why only one?
    - If there are two, there must not be a single connecting link between nodes in the two components, which is unlikely.



Community

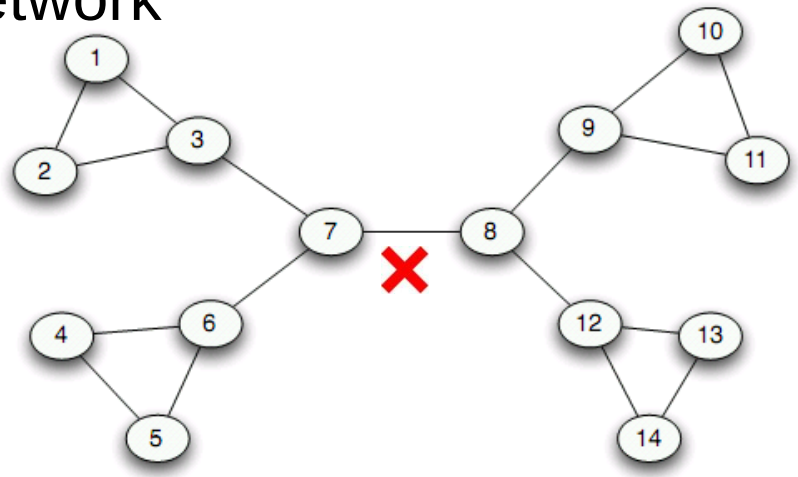
- Social networks tend to group into clusters due to different interests
- Communities
  - Sets of nodes with lots of connections inside and few to outside





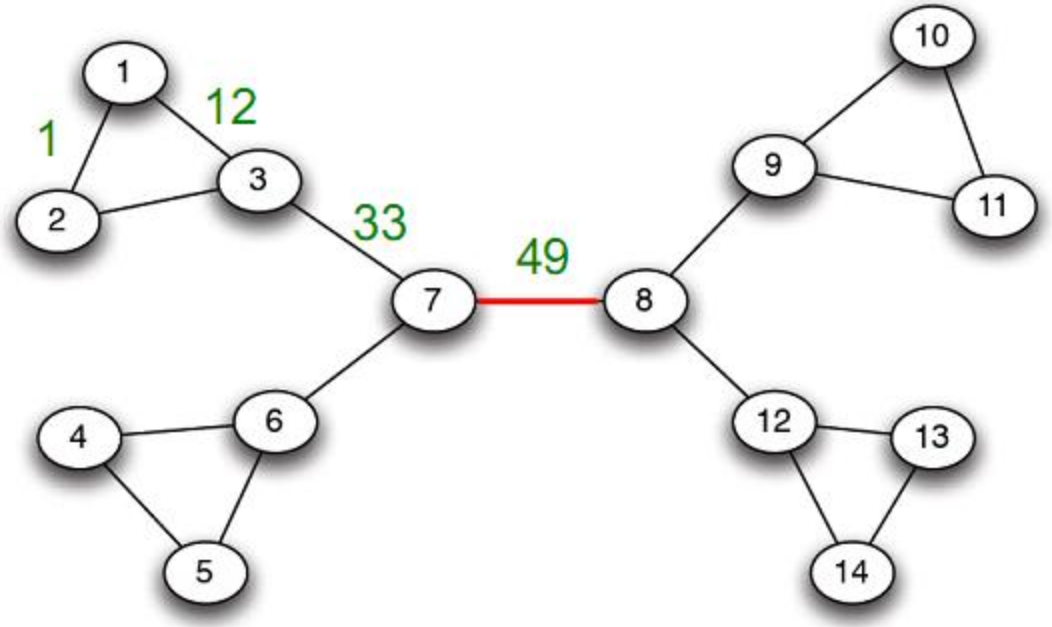
Community Detection

- How to divide a network into communities?
  - By observation?
  - Automatically?
- A possible idea
  - Finding the most important edges to divide the network
  - Imagine traffic flows in the network



Most important edges?

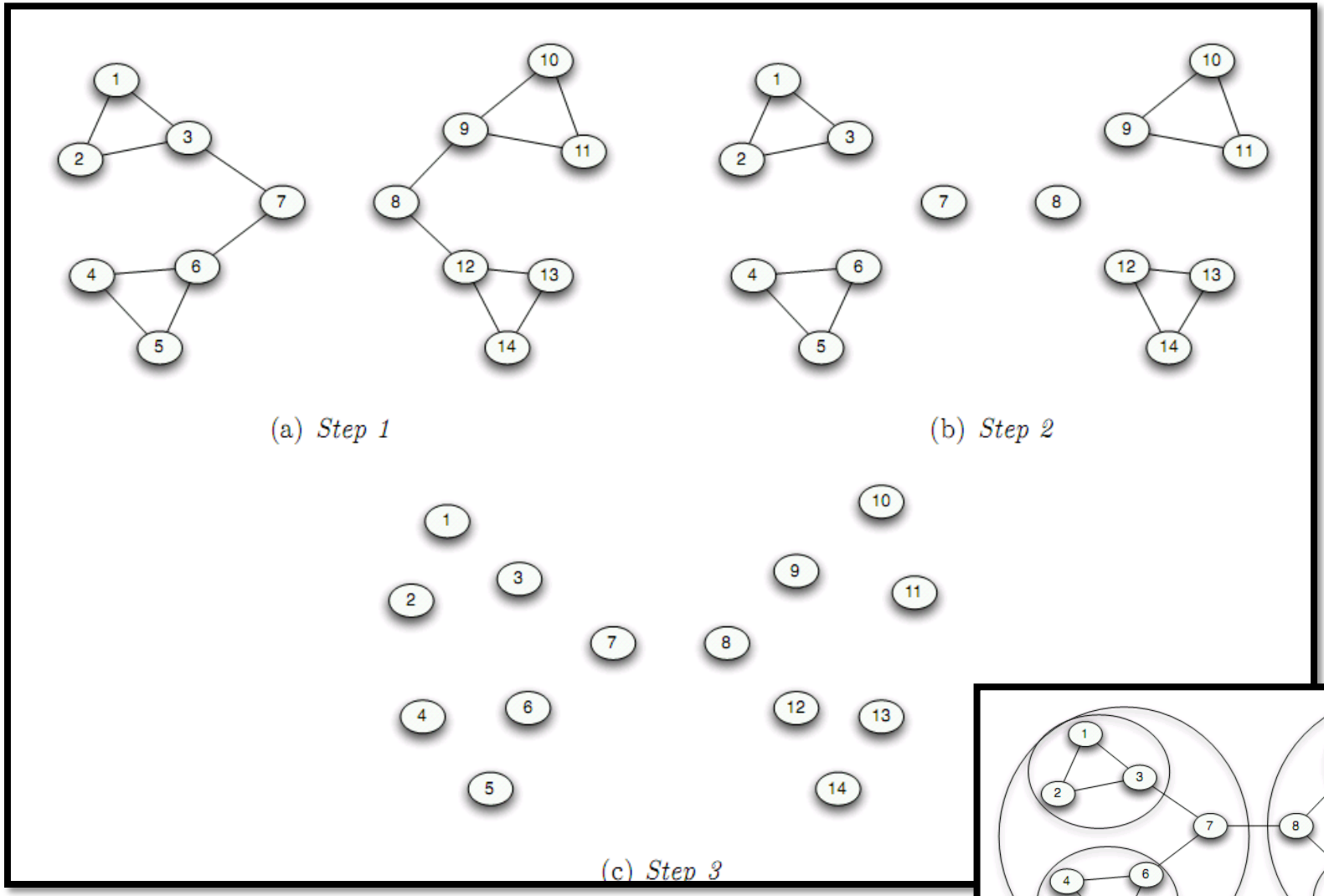
- Metric: Betweenness
  - The number of shortest paths passing through the edge

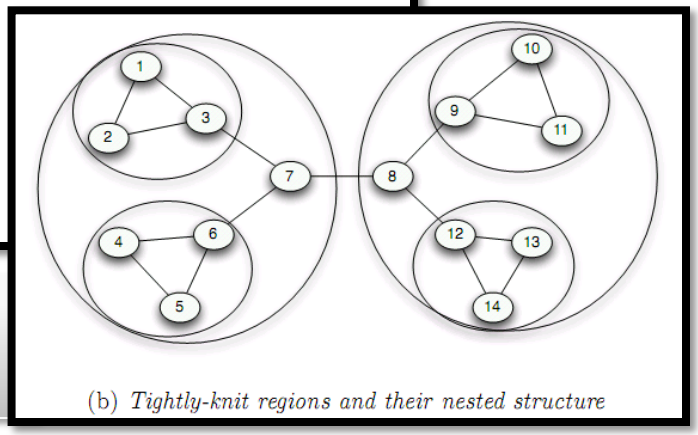


Girvan-Newman Algorithm

- Process
  - 1. Calculate betweenness of each edge
  - 2. remove edges with highest betweenness
  - 3. repeat 1,2 until the number of communities reaches a threshold or no edges are left

Example





(b) *Tightly-knit regions and their nested structure*

- Works for undirected unweighted graph
- Gives a hierarchical decomposition of the network

Louvain Method

- Iterative approach based on modularity:
  - Concentration of nodes within modules compared to random distribution of links
- Idea:
  - Start with small (1-node) communities
  - Optimize modularity on small level
  - Aggregate nodes in the same community and build a new network existing of aggregate nodes
  - Repeat until no modularity gain is possible
- Can also provide hierarchical structure
- Seems to run in O(n log n)

Example

Blondel et al.: Fast unfolding of communities in large networks, Journal of Statistical Mechanics, 2008

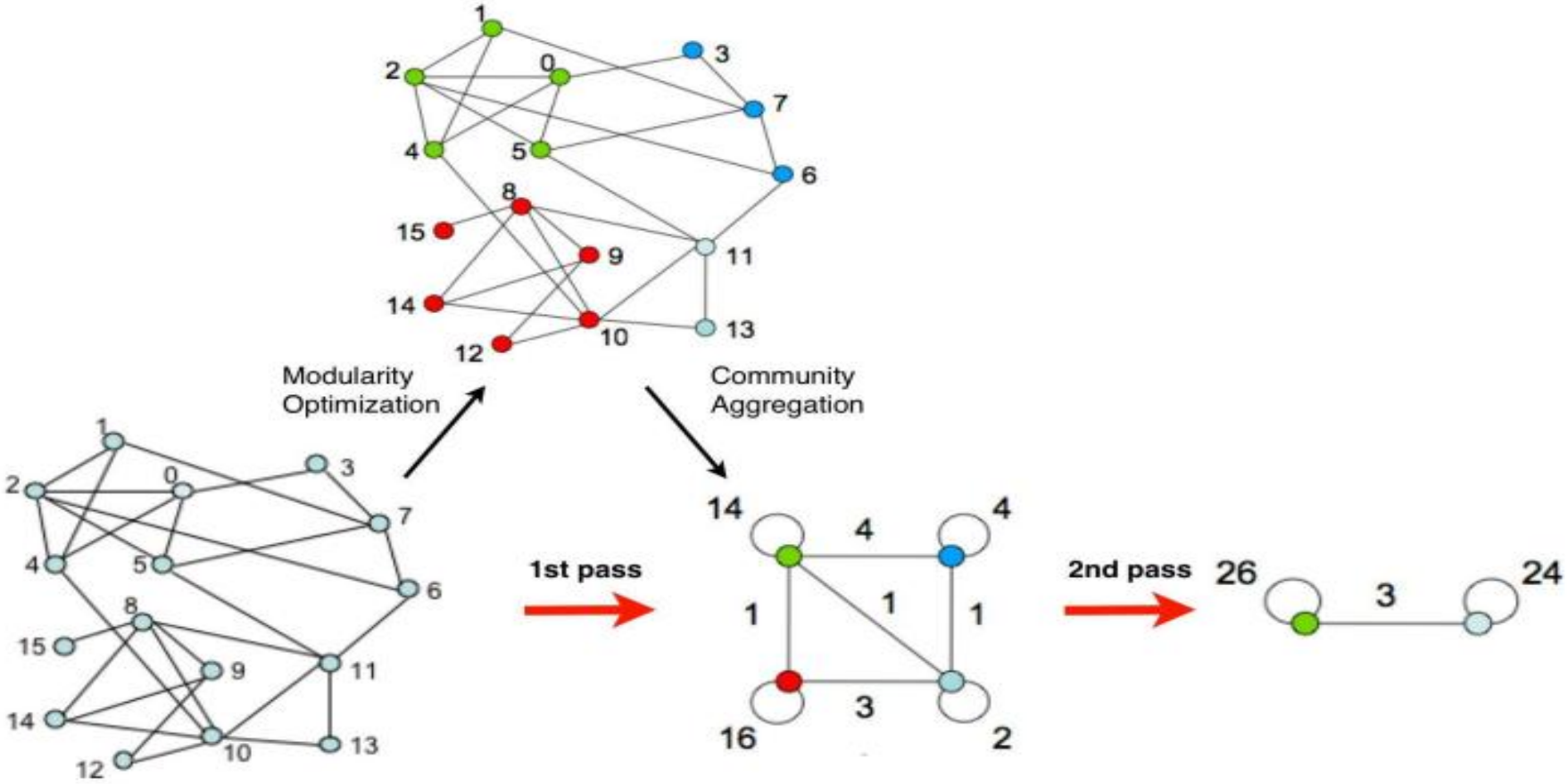
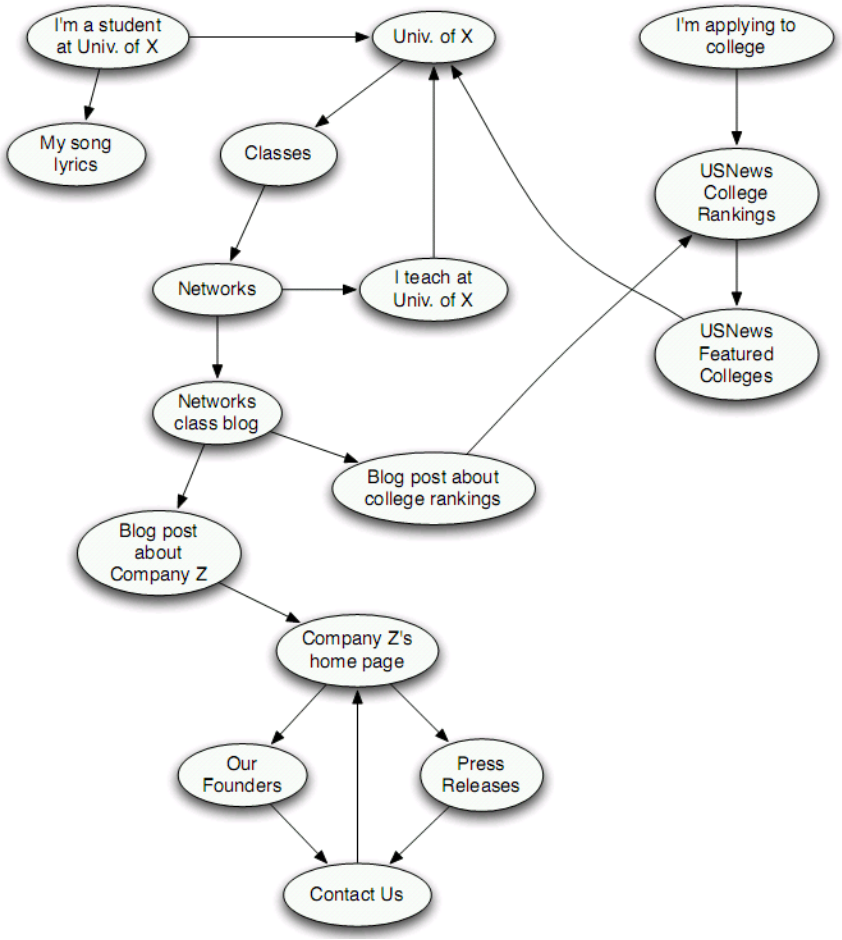


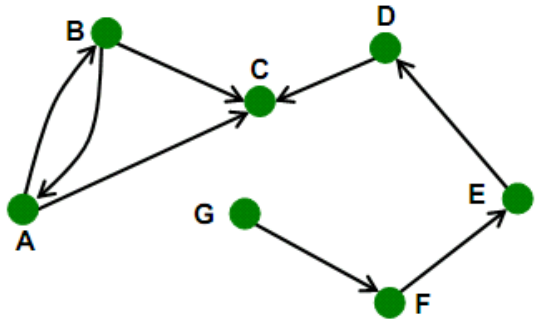
Figure 1. Visualization of the steps of our algorithm. Each pass is made of two phases: one where modularity is optimized by allowing only local changes of communities; one where the found communities are aggregated in order to build a new network of communities. The passes are repeated iteratively until no increase of modularity is possible.

The Structure of the Web

- Web as a directed graph
  - Nodes: pages
  - Edges: hyperlinks (directed)
- Question: What does Web look like at a global level?
  - Giant component?
  - Small Communities?



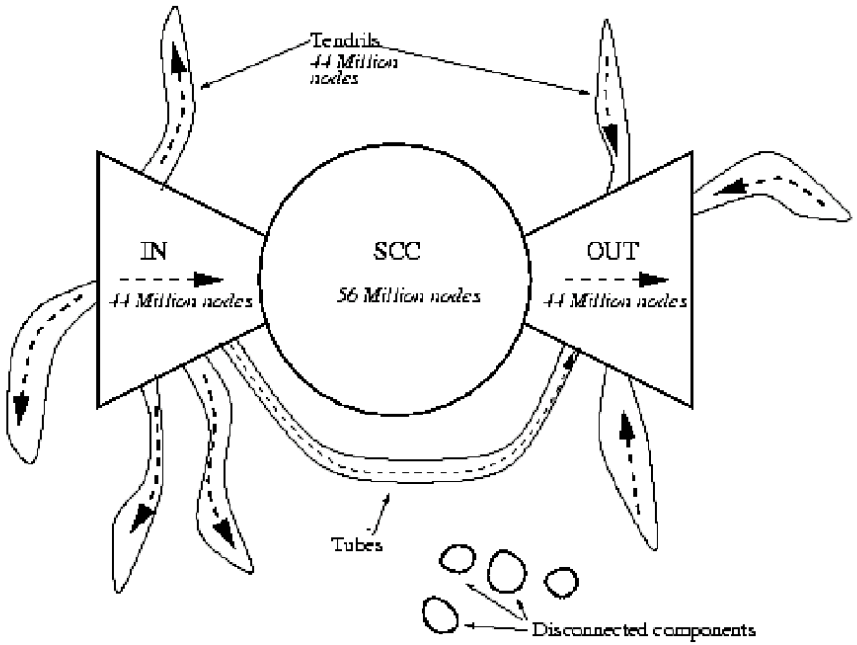
Directed Graph



- Path: directional
- Strong connectivity
  - A directed graph is strongly connected if there is a path from every node to every other node
- Strongly connected component (SCC)
  - A subset of the nodes that (i) every node in the subset has a path to every other; and (ii) the subset is not part of some larger set with the property that every node can reach every other.

The Bow-Tie Structure of the Web

- 250 million pages, 1.5 billion links (1999)
- A giant SCC (56 million nodes)
- IN set (44 million nodes)
  - Nodes that can reach the giant SCC but cannot be reached from it
- OUT set (44 million nodes)
  - Nodes that can be reached from the giant SCC but cannot reach it
- Tendrils (44 million nodes)
  - The nodes reachable from IN that cannot reach the giant SCC
  - The nodes that can reach OUT but cannot be reached from the giant SCC.
- Tubes
  - The nodes reachable from IN to OUT
- Disconnected



Conclusion

- Introduction to the structure and modeling of social networks
  - Directed and undirected graphs in different networks
  - (Giant) Connected components
  - Communities and their detection

- Next week:
  - How does the graph look like in OSNs?
    - Power-Law distribution and Small-World phenomenon
  - Cascades of information in OSNs