Introduction to Complex Networks

Lecture 1

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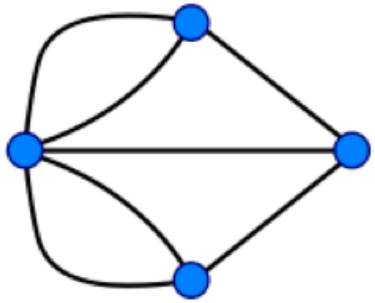
Thanks

- Many slides in this lecture are borrowed from Prof. Moez Draief

Graphs: a simple model

- entities – set of vertices
- pairwise relations among vertices – set of edges
- can add directions, weights,. . .
- graphs can be used to model many real datasets
  - people who are friends
  - computers that are interconnected
  - web pages that point to each other
  - proteins that interact

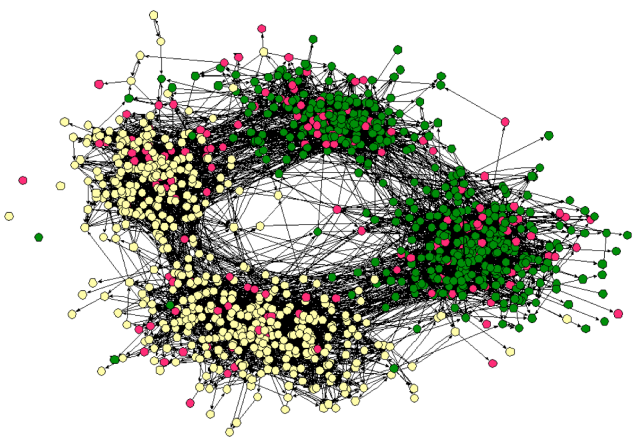


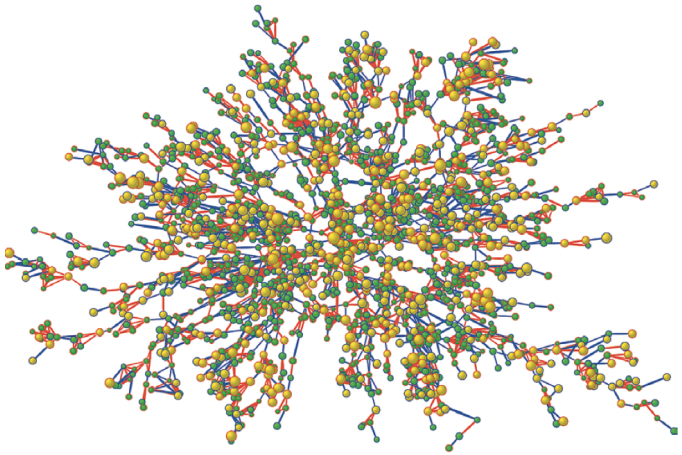
Graph theory

- graph theory started in the 18th century, with Leonhard Euler
  - the problem of Königsberg bridges
  - since then, graphs have been studied extensively

Analysis of graph datasets in the past

- graphs datasets have been studied in the past
  e.g., networks of highways, social networks
  - usually these datasets were small
  - visual inspection can reveal a lot of information





Analysis of graph datasets now

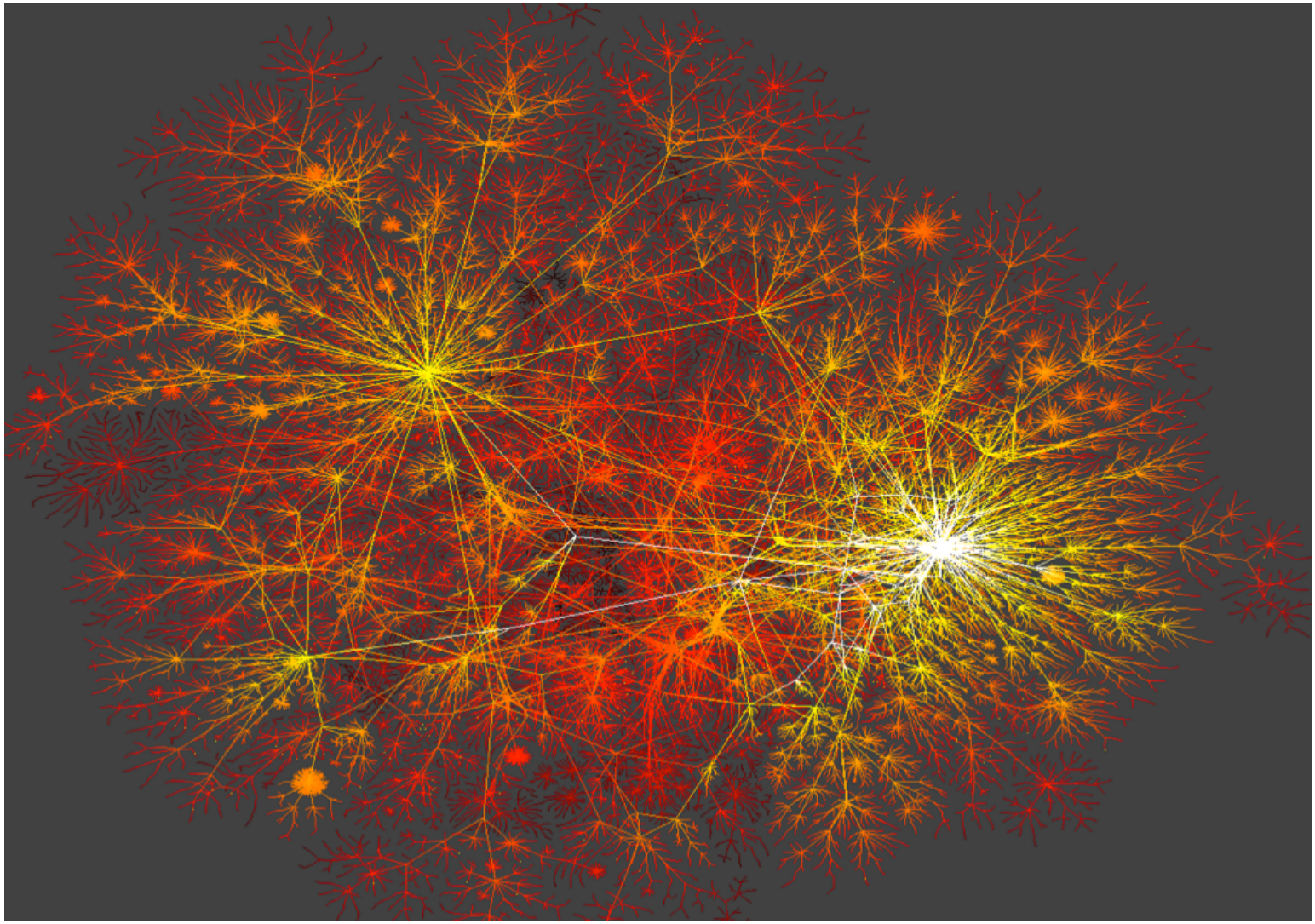
- more and larger networks appear
  - products of technological advancement
    - e.g., internet, web
  - result of our ability to collect more, better-quality, and more complex data
    - e.g., gene regulatory networks
- networks of thousands, millions, or billions of nodes
  - impossible to visualize

Complex networks

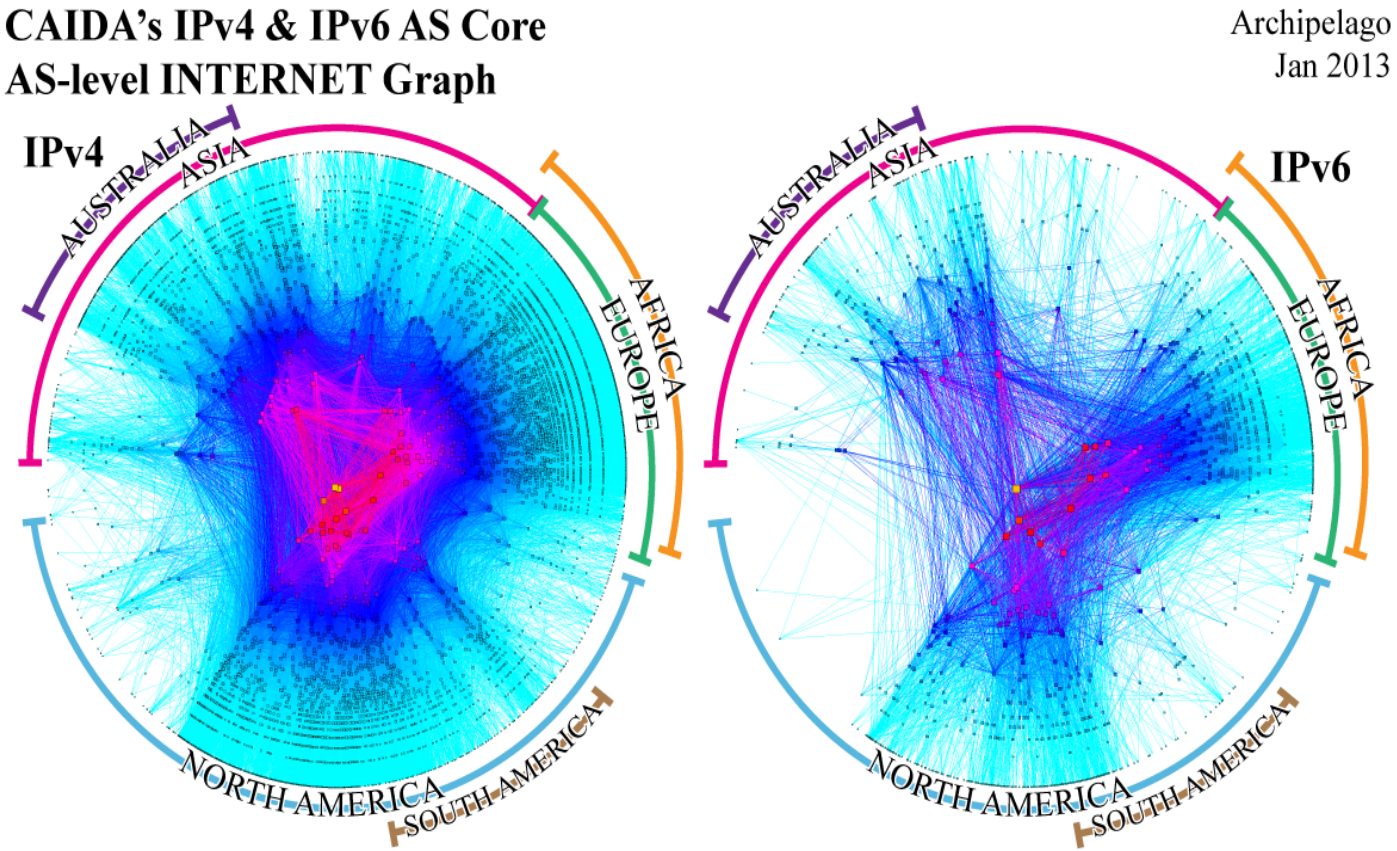
Large-scale systems of simple interacting units

- infrastructure networks: transportation, power, gas, and water distribution, Internet
- informational networks: WWW, citation networks, Wikipedia
- social networks: friendships, family ties, Facebook etc.
- economic networks: supply chains, input-output models in economics
- financial networks: borrowing-lending nets
- biological networks: neural networks, gene/protein interactions
- ecological networks: food webs, herding/flocking behaviour, ...

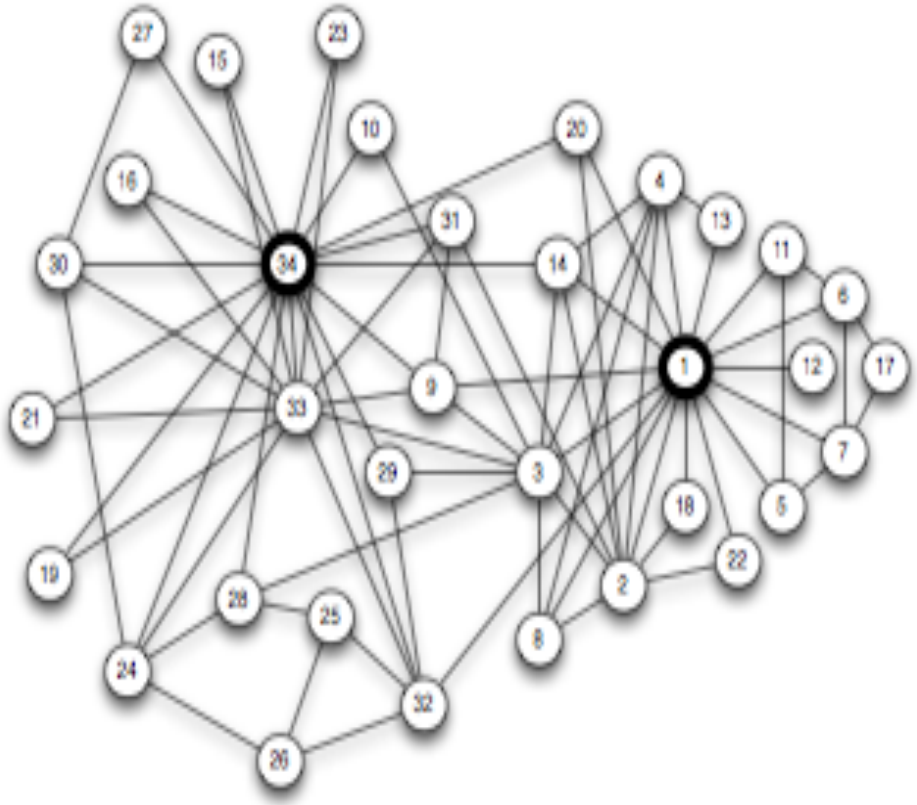
Internet map



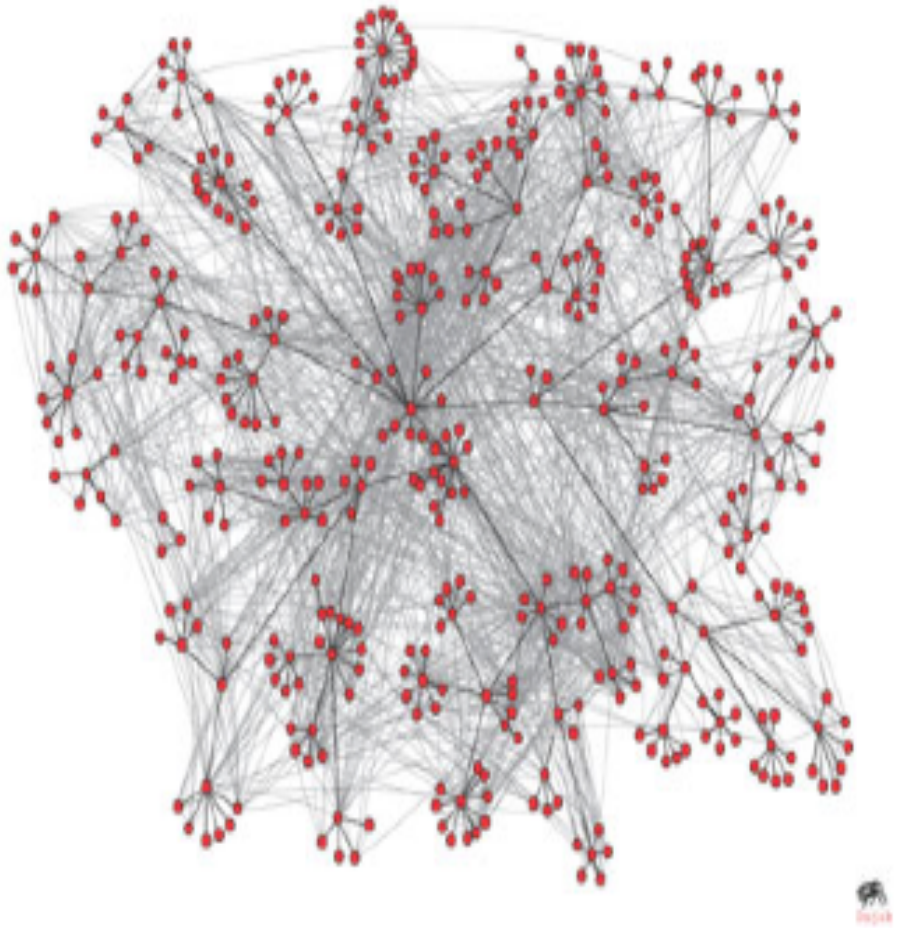
Internet Autonomous System map



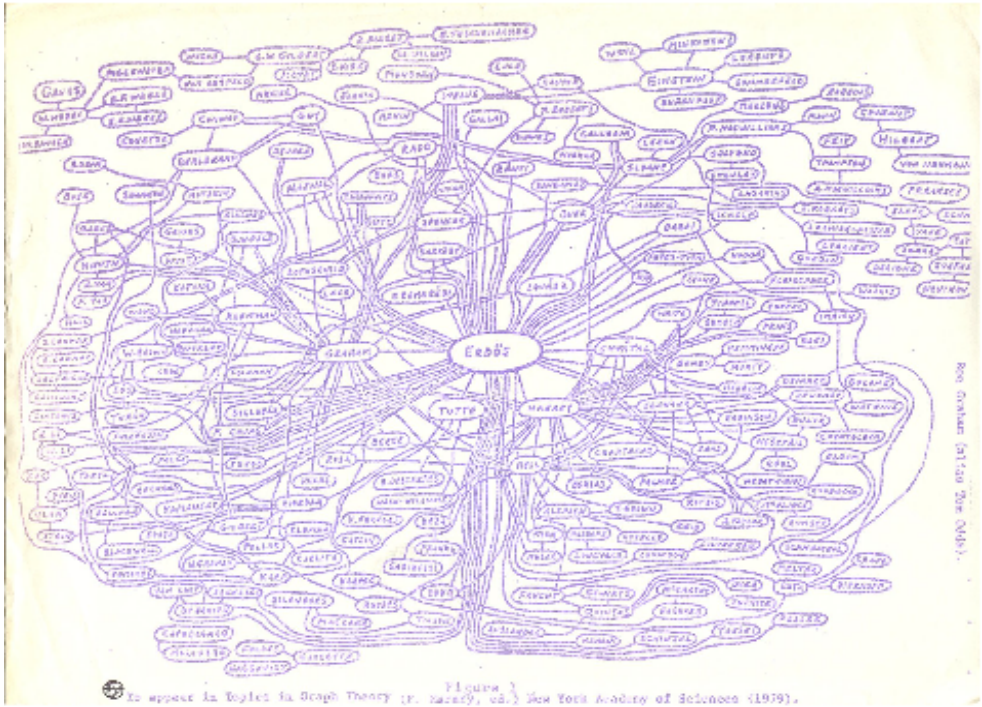
Social network of friendships within a 34-person karate club



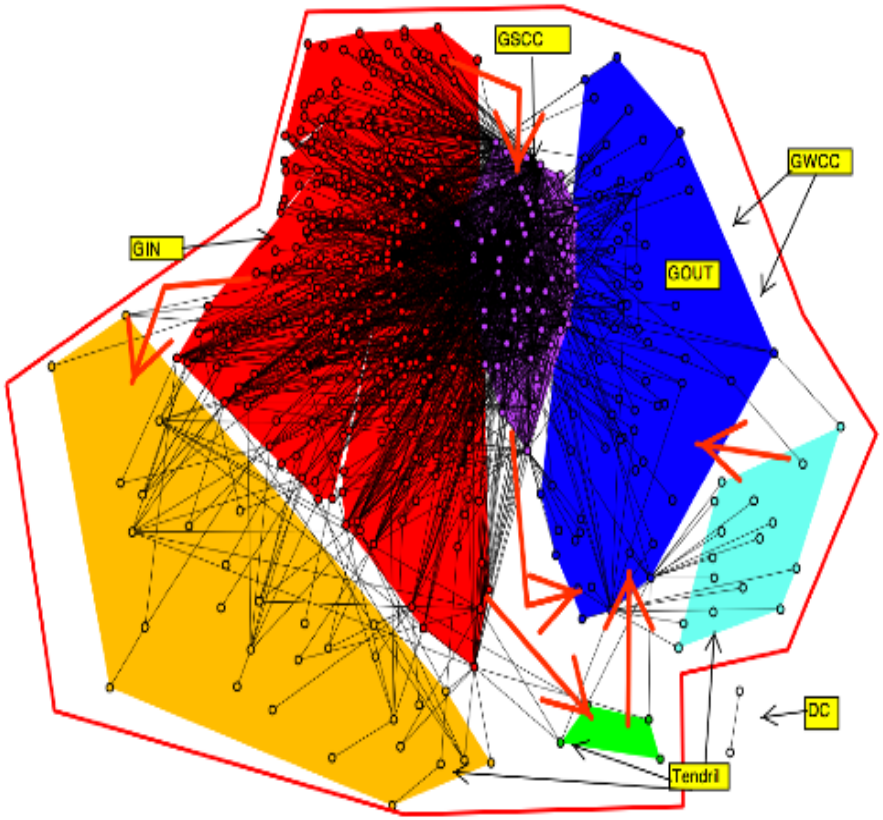
Pattern of e-mail communication among 436 employees of HP Research Lab



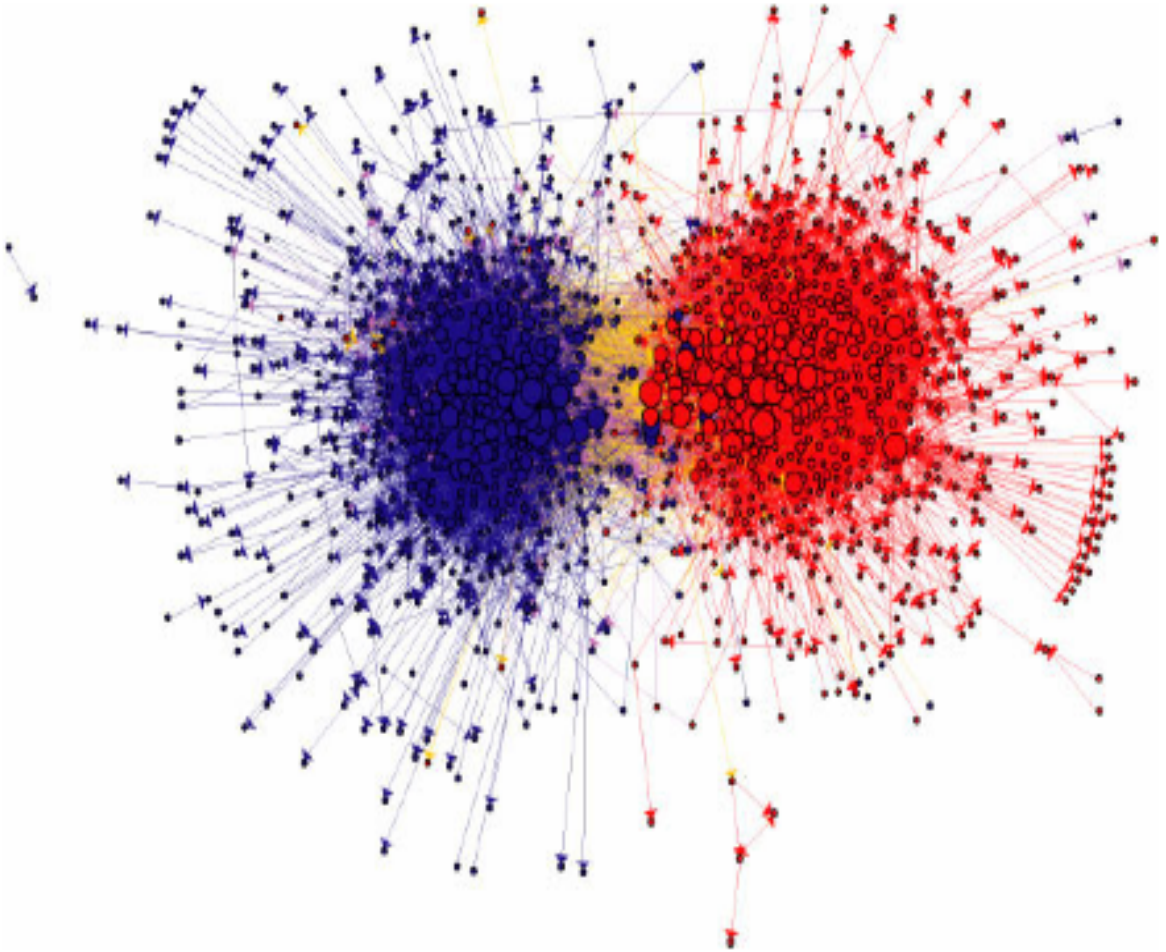
Co-authorship among mathematicians



Network of loans among financial institutions



Network structure of political blogs prior to the 2004 U.S. Presidential election



Network Dynamics

Microscopic rules of interaction between neighbouring units

- infrastructure networks: cascading failures
- informational networks: “influential” units
- social networks: product adoption and behavioural change
- economic networks: Interdependence between sectors
- financial networks: “contagion”, micro-prudential regulation
- biological networks: gene alignment between species, phylogenetics
- ecological networks: understanding animals social behaviour

Network science

- the world is full with networks
- what do we do with them?
  - understand their topology and measure their properties
  - study their evolution and dynamics
  - create realistic models
  - create algorithms that make use of the network structure

What this course is about …

- Model complex networks
- Try to answer the interesting questions under such complex networks mathematically
- Asymptotic analysis
  - Complex typically means “large-scale”
  - Study what happens when N goes to infinity
  - N: typically the number of nodes