Social and Technological Networks

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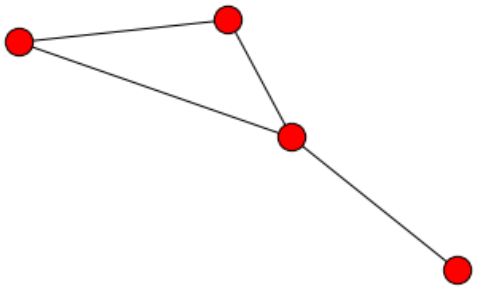
University of Edinburgh, 2018.

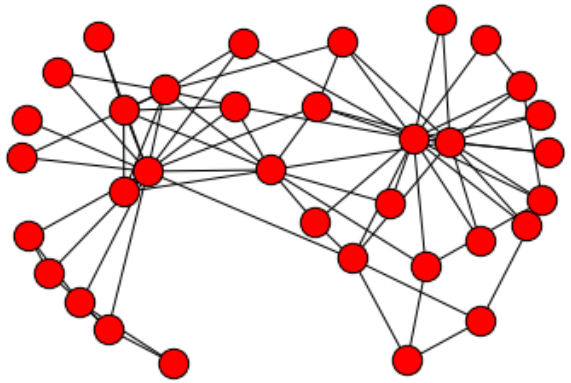
Course specifics

- Lectures
  - Tuesdays 12:10 – 13:00
    - Lister G01.
  - Fridays 12:10 – 13:00
    - 7 George Square, F21.
- Web page
  - http://www.inf.ed.ac.uk/teaching/courses/stn/
- Lookout for announcements on the web page
- Reading materials, slides, problem sets will be uploaded to the web page.

Network or Graph

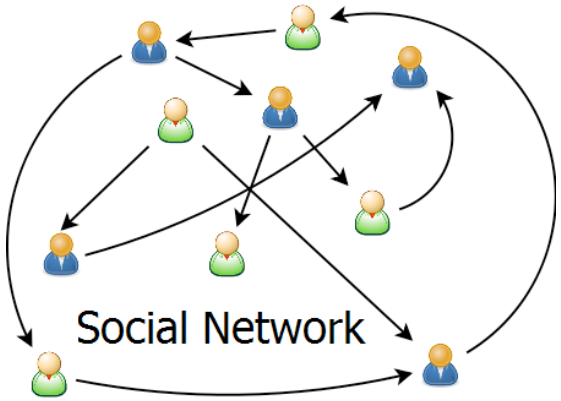
- A set of entities or nodes: V
- A set of egdes: E
  - Each edge e = (a, b) for nodes a, b in V
  - An edge (a,b) represents existence of a relation or a *link* between a and b



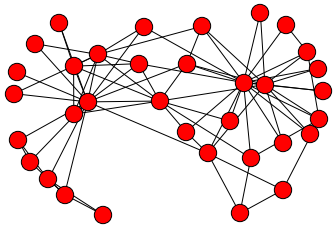


Example: Social networks

- Facebook, Linkedin, twitter..
- Nodes are people
- Edges are friendships

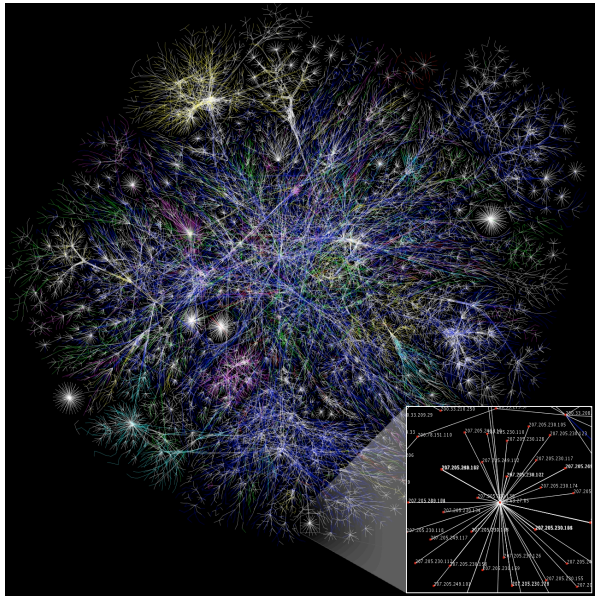


- The network determines society, communities, etc..
- How information flows in the society
- How innovation/influence spreads
- Who are the influential people
- Predict behaviour
- Make recommendations



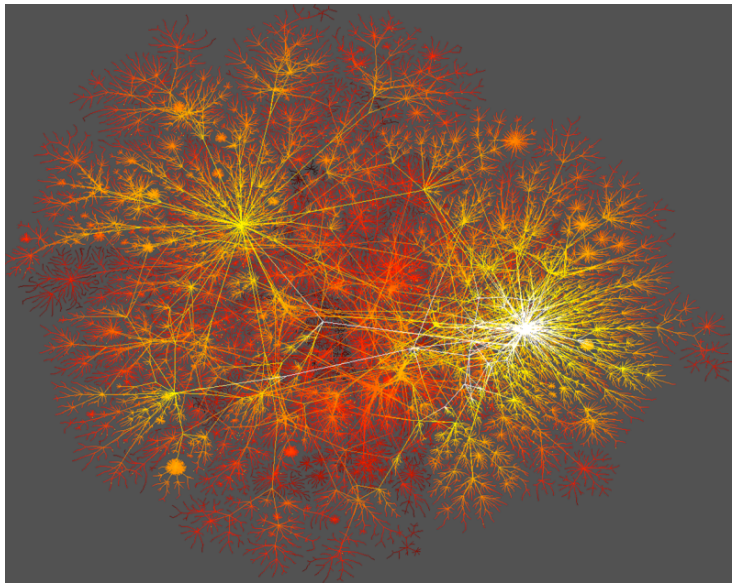
World wide web

- Links/edges between web pages
- Determines availability of information
- Important pages have more links pointing to them
- Network analysis is the basis of search engines



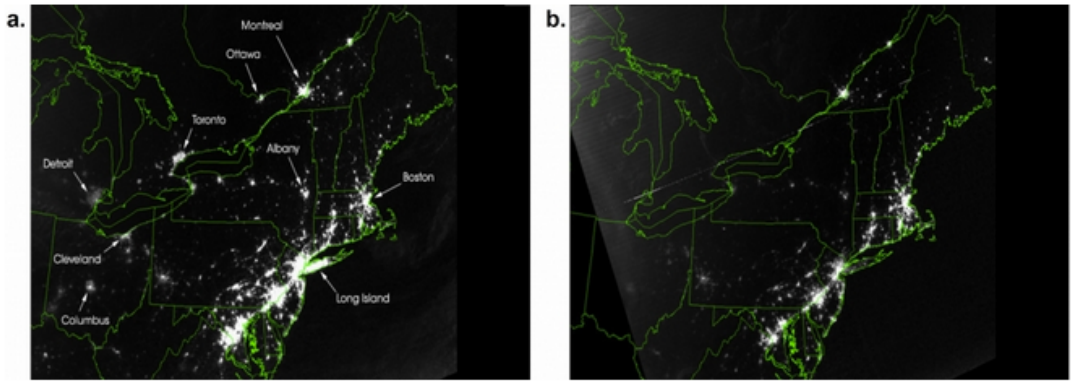
Computer networks

- What can we say about the internet?
- How reliable are computer networks?



Electricity grid

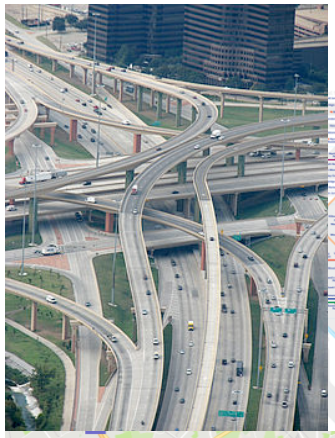
- Network of many nodes, redistributing power
- Critical infrastructure
- Failure can disrupt … everything
- Small local failures can spread
  - Load redistributes
  - Trigger a casdade of failures
- Network strcuture is critical

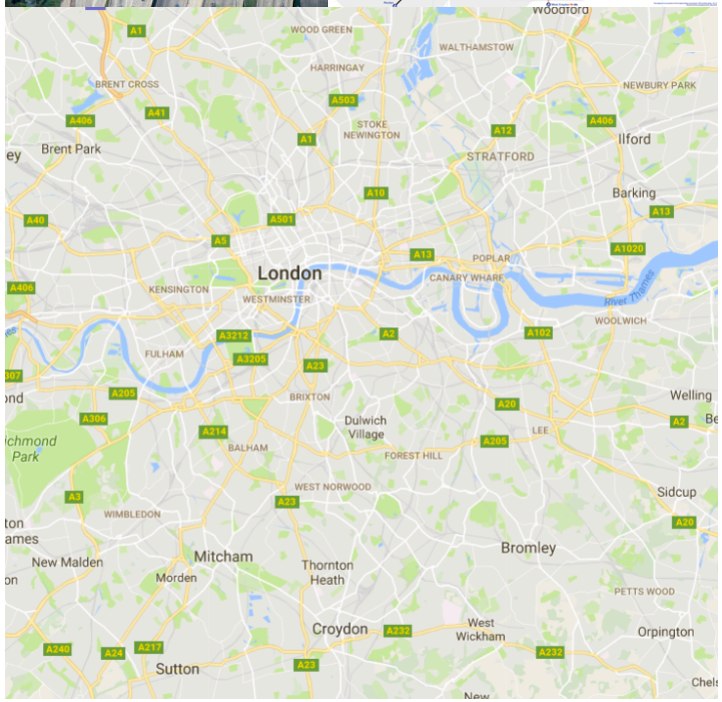


From Barabasi: Network Science

Road network and transportation

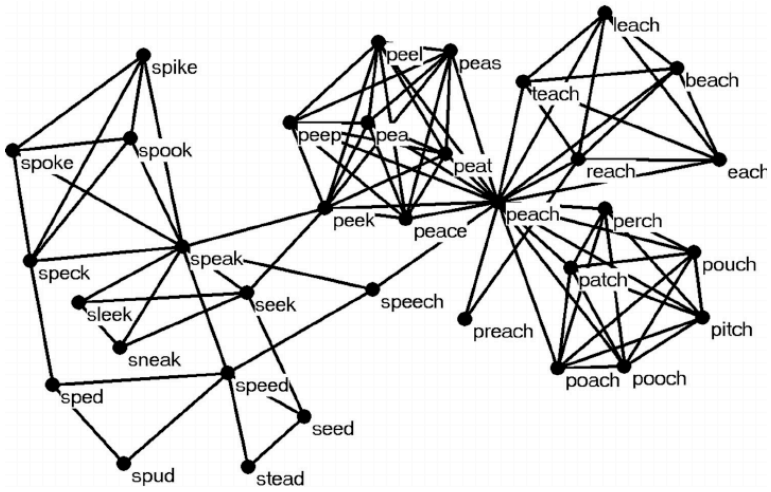
- Mobility patterns of people
  - Location data
- Suggest bus routes
- Suggest travel plans
- Traffic engineering
- Increasing importance
  - More vehicles
  - Self driving cars





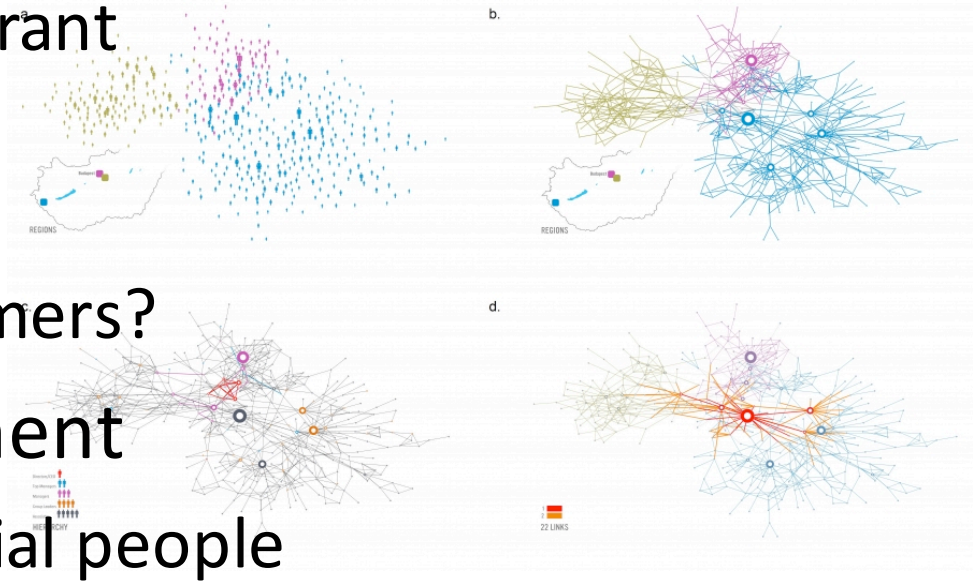
Linguistic networks

- Networks of words
- Show similarities between languages
- Show differences between languages
- Document analysis



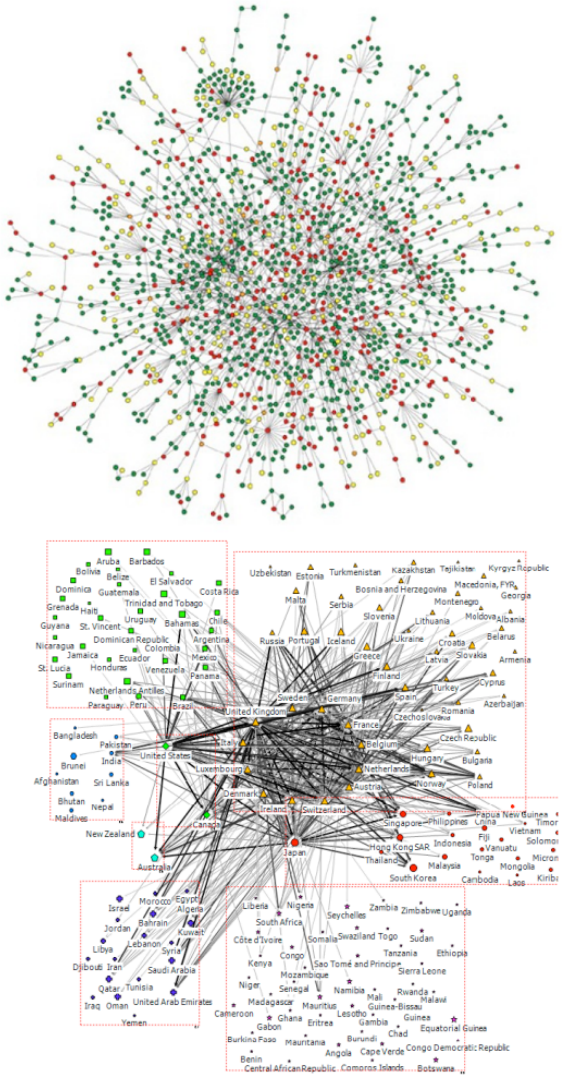
Business and management and marketing

- Business
  - What makes a restaurant successful?
  - Nearby restaurants? Community of customers?
- Marketing/management
  - Who are the influential people in spread of ideas/products?



Other networks

- Chemistry/biology
  - Interactions between chemicals
  - Interactions between species
  - Ecological networks
  - Networks of neurons, blood circulation
- Finance/economies
  - Dependencies between institutions
  - Resilience and fragility
- Neural (Brain) networks

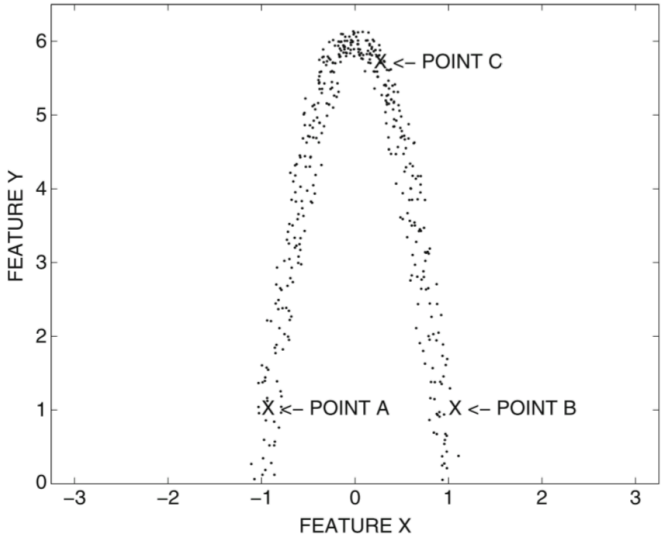


Network analysis in data science

- Data getting more complex
- Many types of data are not points in R^d space
  - Data carry relations – networks
  - Simple classification inadequate
  - Network knowledge can make ML more accurate, efficient
  - E.g. data from social network or social media, www, IoT and sensor networks

Relation with machine learning

- Network analysis helps ML
  - Networks reflect the *shape* of data
  - E.g. Connect nearby points with edges
  - Analyse resultant network
- ML helps network analysis
  - Clutering, classification…
  - Requires more powerful techniques that standard machine learning



Topics of study

- Random graphs What are their properties? What can we expect?
  - Erdos renyi graphs
  - Construction of random graphs
- Power law and scale free networks
  - Power law occurs in many places: www, social nets etc..
  - What is the process that generates this? How do we know that it is the right process?
- Metric spaces and distance measures in networks
  - Basis of distance analytics, route planning etc
  - Wireless networks, random graphs, other types of networks

Topics of study

- Network anaysis in general data
  - How to construct networks from datasets
  - Apply network ideas to other datasets
- Small world networks
  - What is the deal with six degrees of separation
  - How are people so well connected?
- Web graphs and ranking of web pages
  - Google's origins and pagerank
  - How do you identify important web pages?
  - Analysis of the algorithm
- Spectral methods

Topics of study

- Network embedding
  - How to represent network in a Normed space?
  - So that we can visualize networks
  - Apply ML
- What are the communities (close knit groups)?
  - How do communities affect social processes?
  - Clustering/unsupervised learning

Topics of study

- Cascades – things that spread
  - Node failures
  - Epidemics, diseases
  - Innovation – products, ideas, technologies
- How can we maximize a spread?
  - Who are the most influential nodes?
  - How can we identify them?
  - Submodular optimization

Topics of study

- Shape of networks
  - What is the shape of internet?
  - What are bow tie and tree-like networks?
  - What does it mean to say a network is tree-like?

- Your suggestions
  - If there are topics you would like discussed in class, let me know

The course

- Is not about:
  - Facebook, Whatsapp, Linkedin, Twitter…
  - Making apps

The course

- Is about:
  - Mathematics and algorithms to compute and analyze properties of networks
  - How network analysis helps machine learning and vice versa
    - Fundamental aspects of machine learning and networks
    - Managing complex data

Our approach

- Rigorous definitions
  - E.g. What is a random graph?
  - What exactly is a small world?
  - How do you define ‘community’ or clustering in networks?
  - How do you define influential nodes?
- Design good algorithms to analyze networks
  - Find communities, find influential nodes
  - Understand the properties of these algorithms
  - When do they work, when do they not work
    - Why?

Our approach

- Test ideas on real and artificial networks
  - Data driven understanding
  - Do real networks have the properties predicted by theory?
  - Do the algorithms work as well as expected?

Project

- 1 project. 40% of marks
- Given: Around Oct 10 to 15.
- Due: Around Nov 15.
- Choose from one of several projects
- **Objective: Try something new in network science.**
- We will give you topics, try your own ideas on it
  - Define a clear problem, devise a way to solve it. Algorithms, ML, maths… your choice
- You are allowed to suggest your own topic
- Submit code and ≈3 page report
- Marked on originality, rigor of work (proper analysis/experiments), clarity of presentation

Possible types of projects

- Given a dataset from a particular social/technological area, find a way to solve a particular problem
  - Devise a prediction or recommendation method
  - Find interesting properties of specific networks
  - Algorithm design
- Programming is useful for evaluation/experiments
  - We will use python in class (recommended)
  - You can use other languages (python, java, c, c++)
- Theoretical/mathematical work is also fine.

Projects

- Open ended projects are common in real world
- People that can do original work are highly valued in industry
- Your BSc/MSc projects are open ended
  - You are given a topic. You have to define exactly what to do and how
- A course project can help your BSc/MSc project
  - Network science, graph theory, are relevant to most CS areas
  - It is an opportunity to learn more about the area

Theory Exam

- Standard exam, 60% of marks
- Explain phenomena, devise mechanisms, prove properties…
- Last year’s paper online..

Lectures

- Slides will be uploaded after each class
- Sometimes reading material will be given beforehand
- Lecture notes will be given covering some material left over
- Exercise problems will be given covering important material
- Ipython (jupyter) notebooks will be uploaded
- Do the exercise problems to make sure
  - You understand things
  - You can solve analytic problems
- Solutions will be given later for some exercise problems
  - Check that your solution is right
  - Check that your writing is sufficiently precise

Pre-requisites

- See Topic 0: Background at
  - http://www.inf.ed.ac.uk/teaching/courses/stn/files1819/lectures.html
- Probability, distributions, set theory
- Basic graph theory and algorithms
  - Graphs, trees, DFS, BFS, minimum spanning trees, sorting etc
- Asymptotic notations
- Linear algebra
- Take notes in class. Not everything is on slides!
- Attend lectures. Ask questions.

Course learning expectations

- Plan and execute original projects
- Use programming for data driven analysis
- Use theoretical analysis to understand ideas/models rigorously
- Present analysis and ideas
  - Precisely
  - Unambiguously
  - Clearly

- Have fun playing with new ideas!