Social and Technological Networks

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University of Edinburgh, 2019.

Course specifics

- Lectures
  - Tuesdays 12:10 – 13:00
    - 1 George square G8: Gaddum lecture theatre.
  - Fridays 12:10 – 13:00
    - Geography 2.13.
- Exam : 60%, Coursework project 40%.
- Exam:
  - To be held in April/May

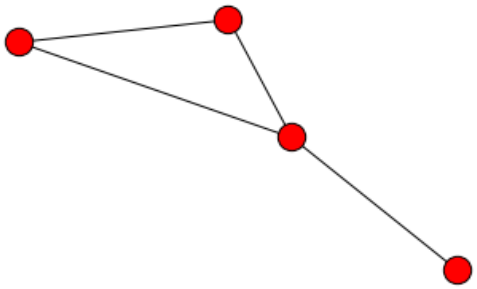
- TA: Lauren Watson.

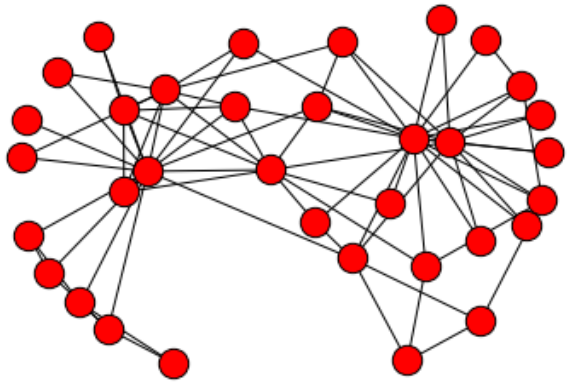
Today

- Why study networks?
- Relations to machine learning
  - Why networks are important in machine learning and vice versa
- Course page
  - Notes, exercises and course materials
- Course structure and coursework project
- Prerequisites
- Programming

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



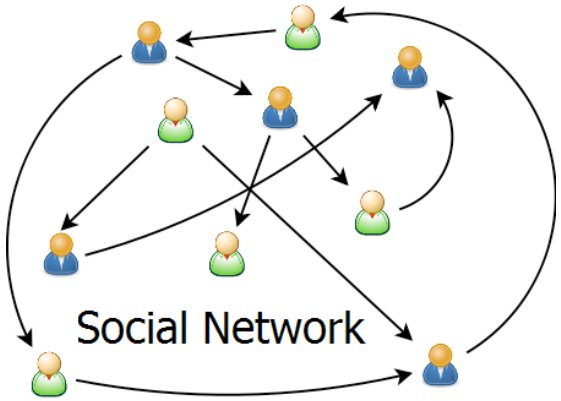


Networks exist everywhere

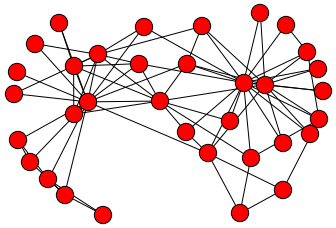
- What are some different types of networks?

Example: Social networks

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

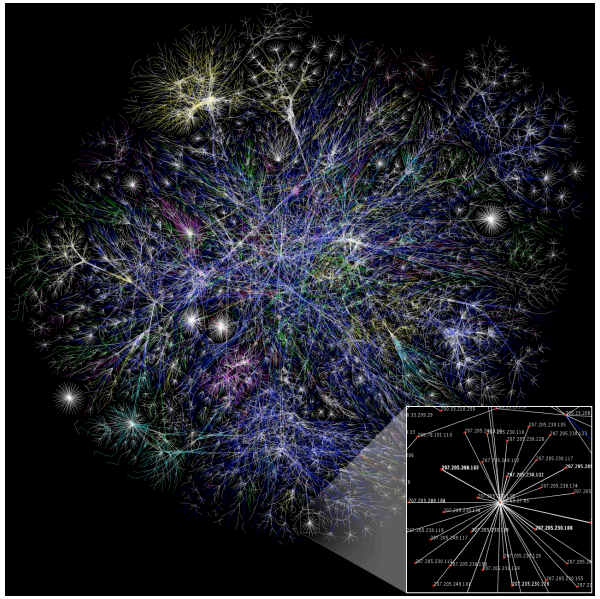


- The network determines society, communities, etc..
- How information flows in the society
- How innovation/influence spreads
- Who are the influential people
- Predict behaviour
- Make recommendations



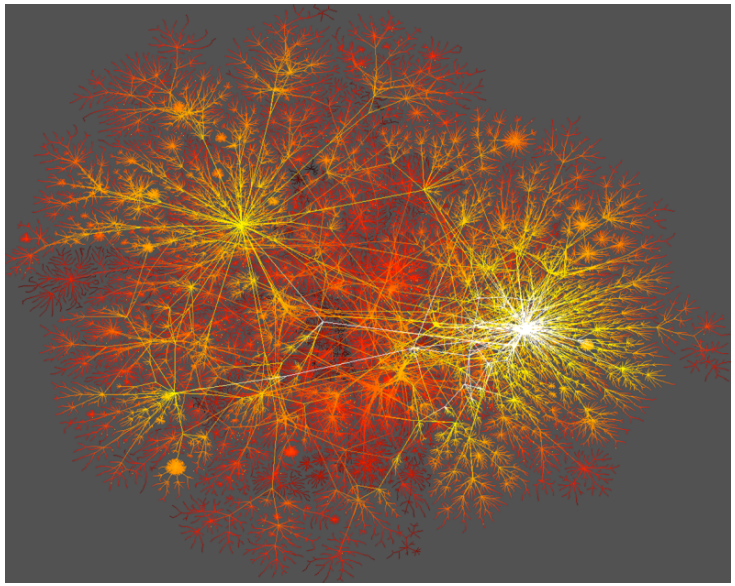
World wide web

- 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



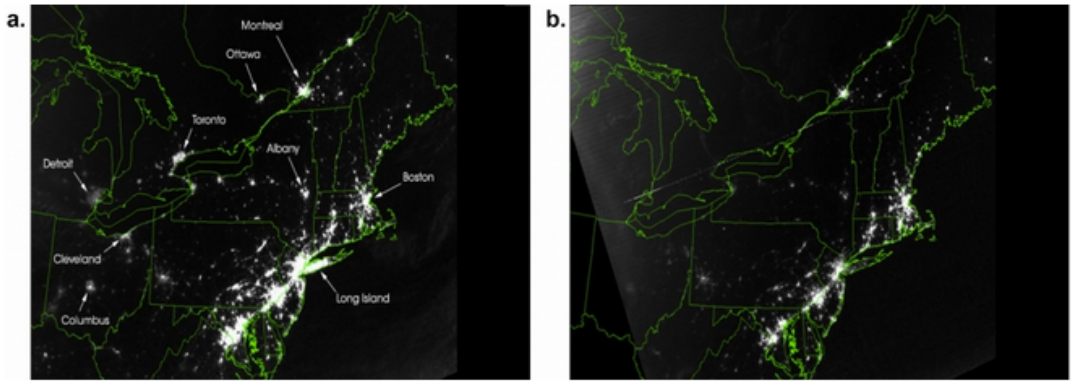
Computer networks

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



Electricity grid

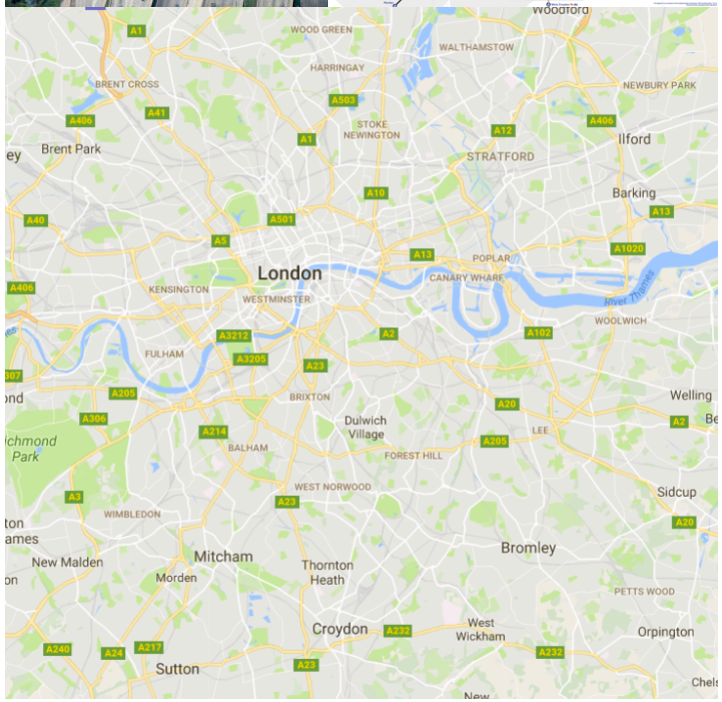
- Network of many nodes, redistributing power
- Critical infrastructure
- Failure can disrupt … everything
- Small local failures can spread
  - Load redistributes
  - Trigger a casdade of failures
- Network strcuture is critical



From Barabasi: Network Science

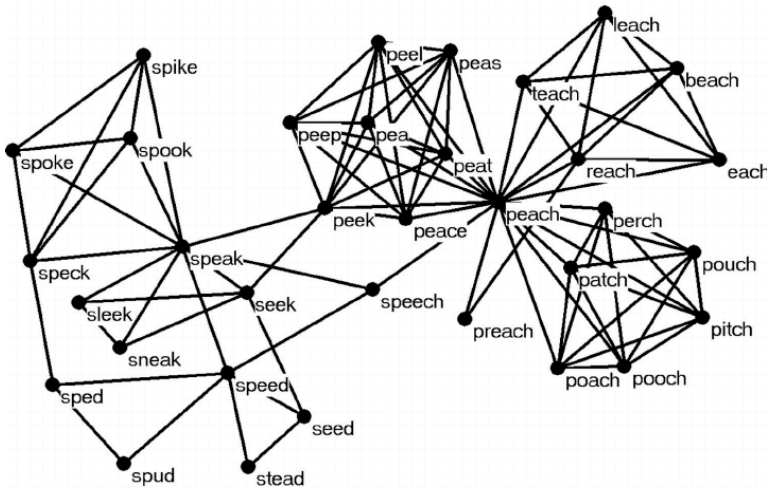
Road network and transportation

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



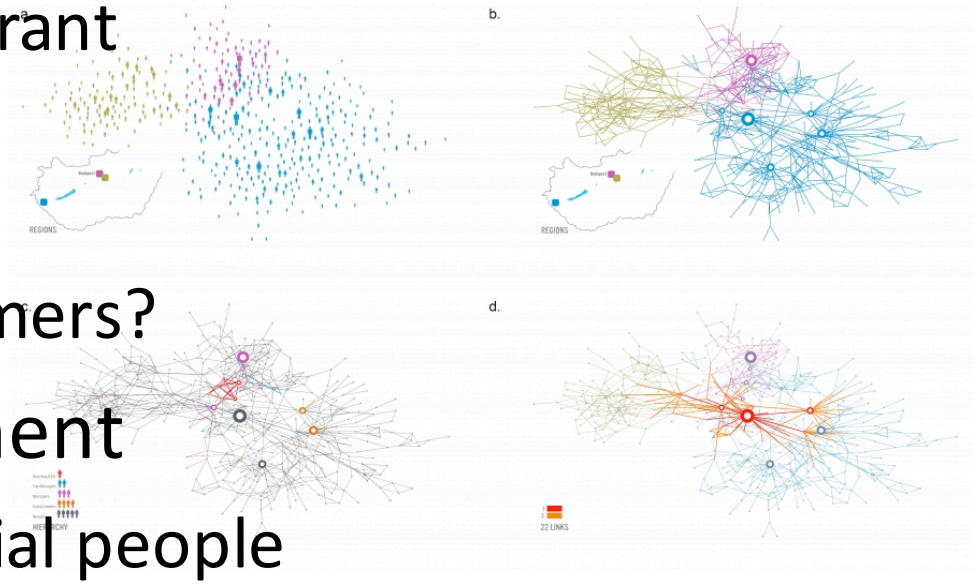
Linguistic networks

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



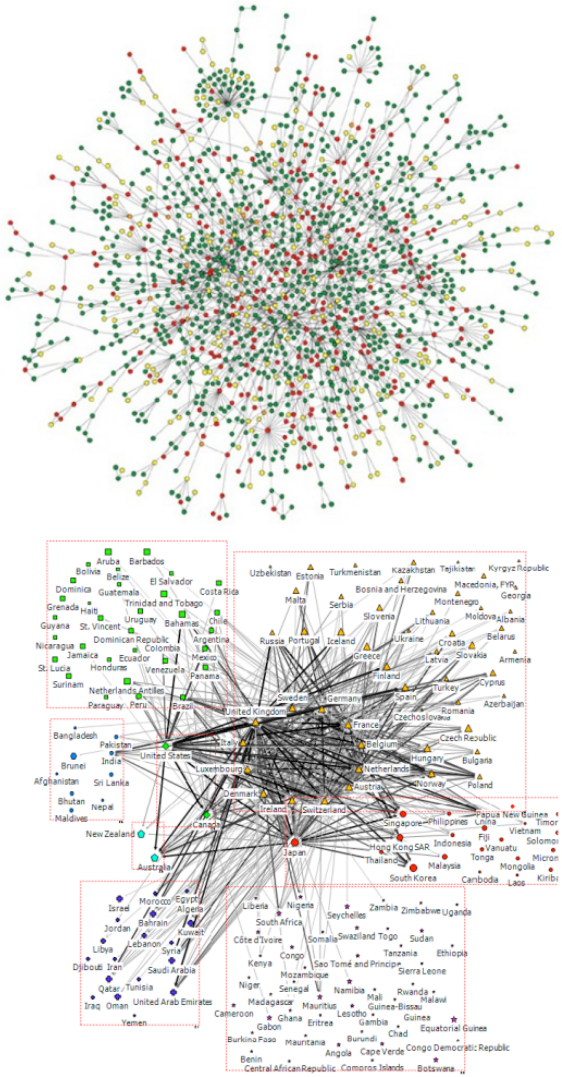
Business and management and marketing

- 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

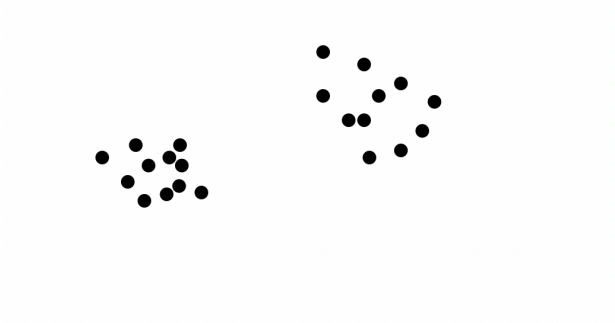
- Data getting more complex
- Many types of data are not points in R^d space
  - Data carry relations – networks
  - Simple classification inadequate
  - Network knowledge can make ML more accurate, efficient
  - E.g. data from social network or social media, www, IoT and sensor networks, road networks

Machine learning

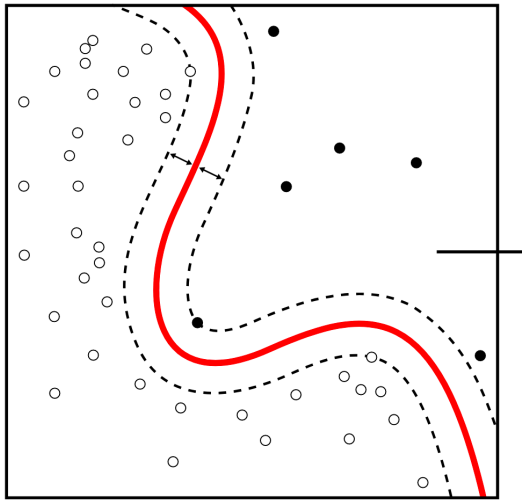
- Finding groups of points
- Separating groups of points

Machine learning

- Finding groups of points

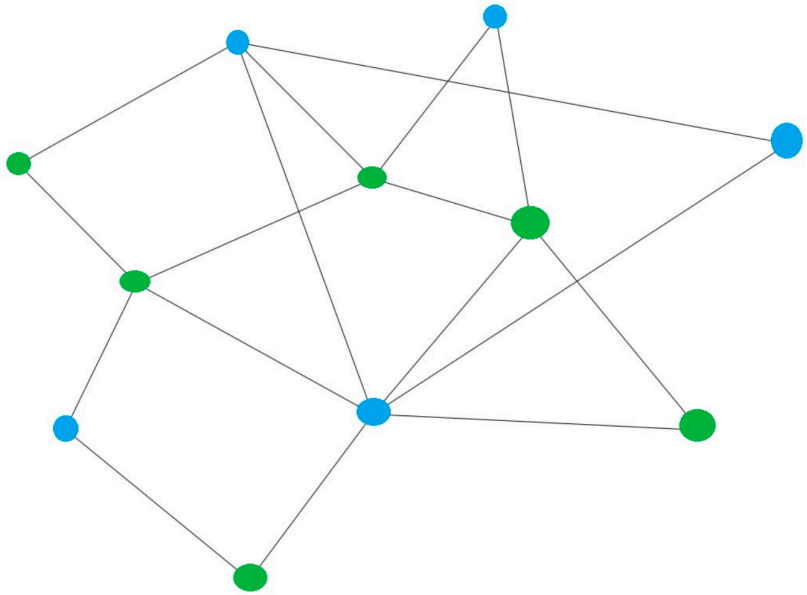


- Separating groups of points



Challenge: ML on networks

- How do we do machine learning when the data is not in space, but in a network?
  - What does clustering mean?
  - What does separation mean?



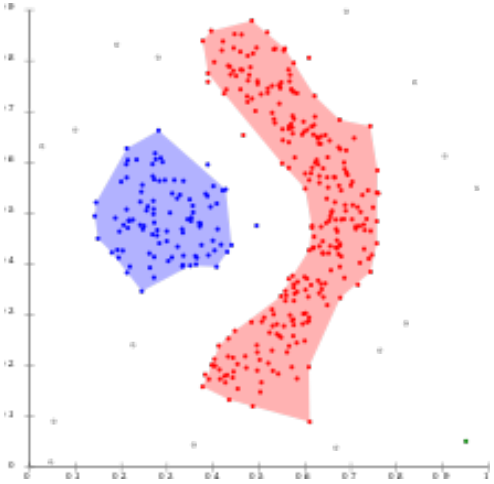
Challenge: ML on networks

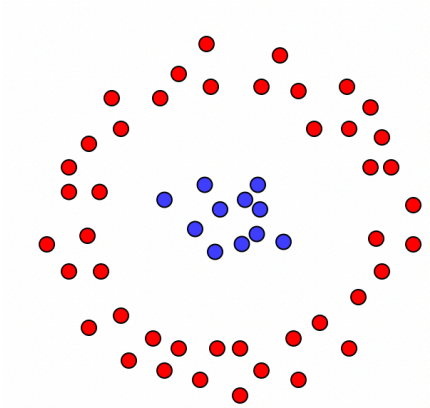
- Network data shows up everywhere
- We need to generalise ML to work on networks for more advanced operations

- The maths that works in Euclidean (R^D) space has to be modified to work on graphs.

Networks for ML

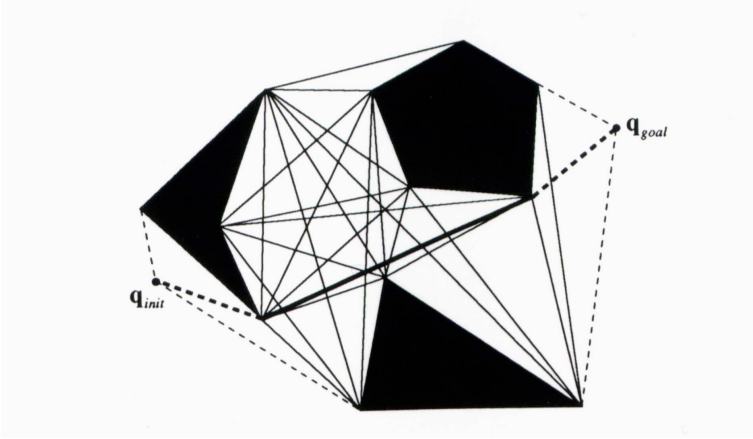
- Another perspective:
  - Networks are useful for ML
- Example
  - Clustering with DBSCAN
    - Connect points that are close to each other to make graph
    - Take connected components to get clusters
  - Easily finds oddly shaped clusters
- Networks are good for determining the *shape* of data

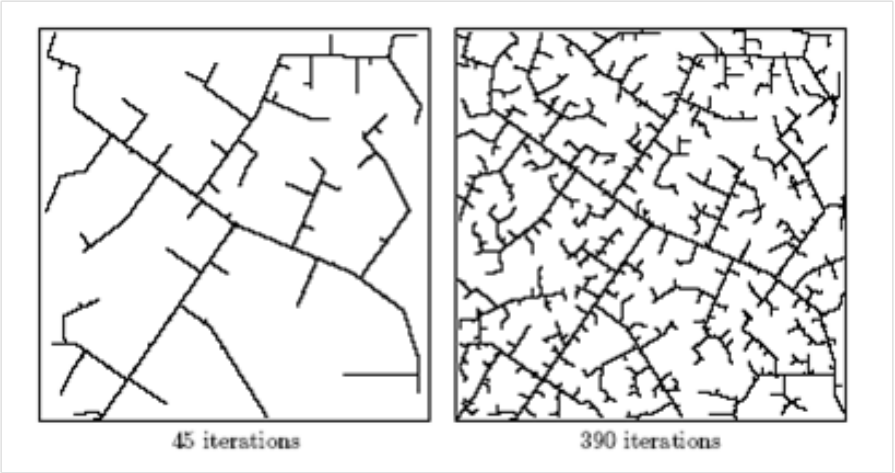




Networks for ML

- Used in
  - Clustering
  - Robotics
  - Motion planning
  - ….





Topics

- Networks, ML and algorithms
  - Community detection (clustering)
  - Predicting unknown values at nodes (classification)
  - Kernel methods
    - Graph kernels
  - Influence maximisation
    - Finding representative items and sampling
- Properties of common networks and models
  - Power law networks
  - Small world graphs (six degrees of separation etc)
  - Web graphs
  - Epidemics and cascades
- Theory, maths, statistics
  - Properties of random graphs and other common types of graphs
  - Metric spaces
  - Expansion, growth etc

- This is an advanced course to help research and innovation. We will try to balance between covering a range of interesting topics and studying them in depth

Web page

- Web page
  - http://www.inf.ed.ac.uk/teaching/courses/stn/
- Lookout for announcements on the web page
- Reading materials, slides, exercise sets will be uploaded to the web page.

Note and exercises

- Some material will be covered in lectures, other materials will be given as notes and exercises
- Please follow along as these are uploaded
  - Solutions to some exercises to be uploaded 1-2 week afterward
- Suggestion: Create your own study groups of 3 – 5 people and discuss
  - Try to write the solutions, proofs as cleanly and logically as possible

Lectures

- Please attend the lectures
- Bring notebook and pen

Coursework Project

- You will be given option of 10-12 projects
  - Pick one to do
- Topics expected in areas of:
  - Machine learning and optimisation
  - Algorithms and data structures
  - Data mining
  - Recommendation systems
  - Social networks
  - Linguistic networks and analysis of stories
  - Road networks or maps
  - Self driving cars (possibly)

  - Find your own topic!

Coursework Project

- You will be given a general topic area
- Your job is to:
  - Understand the domain and identify a question to answer. Determine its motivations.
  - Formulate the problem precisely, mathematically.
  - Find good solutions
    - Show that your solution works well
    - Can be theoretical or experimental (or both)
    - Either way, you need to be rigorous – be able say exactly where it works or does not work, and why
  - Write a good report that explains all of the above nicely

Project

- 1 project. 40% of marks
- Given: Around Oct 10 to 15.
- Due: Around Nov 15.
- **Objective: Try something new in network science.**
- Submit code and ≈3 page report
- The usual project consists of motivation, problem formulation, some mathematical/algorithmic ideas and verification by experiments

- We assume that you can program and run common algorithm and ML libraries
- Marked on
  - Rigor of work
  - Originality in problem and solution
  - Clarity of presentation

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

Programming and python

- We will occasioanlly use python with jupyter notebooks in class
- Setup instructions on web page
- Sample notebook with lecture slides. Try it out!

Theory Exam

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

Pre-requisites

- See Topic 0: Background at
  - http://www.inf.ed.ac.uk/teaching/courses/stn/files1920/lectures.html
- Probability, distributions, set theory
- Basic graph theory and algorithms
  - Graphs, trees, DFS, BFS, minimum spanning trees, sorting etc
- Asymptotic notations
- Linear algebra
- Read up on all these materials and notations
- Do exercise 0

- Make sure you know this material
- And can do exercises 0 without help, and can explain your answers

- From next class, I will assume that you know this material.

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!