Algorithms II
2025

Michael Kapralov

Welcome!

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As Master students, you know that algorithms are central for

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- **computer science**

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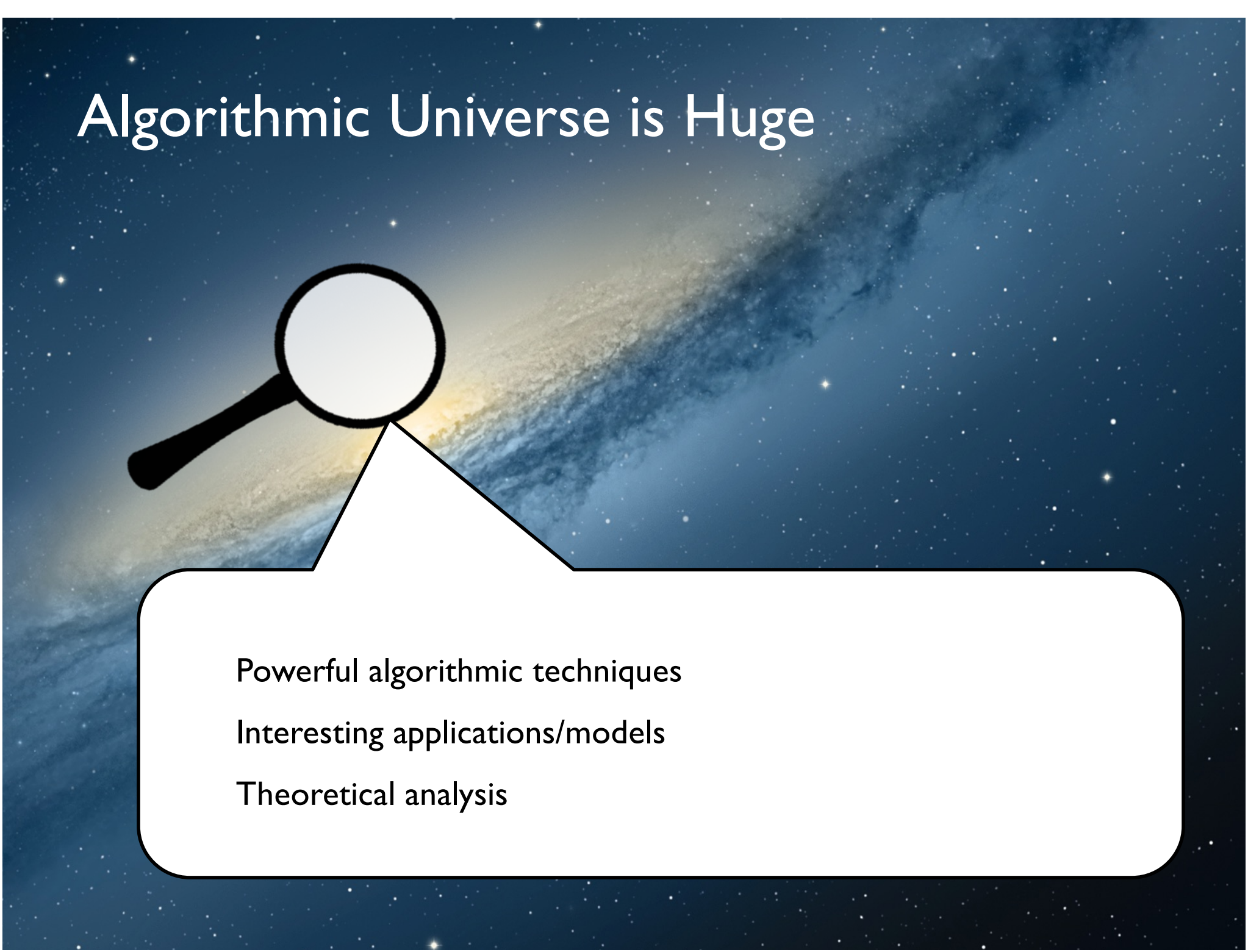
As Master students, you know that algorithms are central for

- ~~computer science~~ **ALL SCIENCES**
- **getting a job**
- **having fun**

Algorithmic Universe is Huge



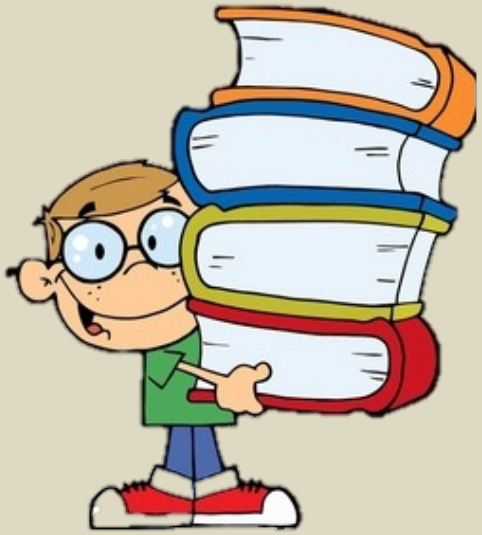
Powerful algorithmic techniques

Interesting applications/models

Theoretical analysis

To enjoy this course (prerequisites)

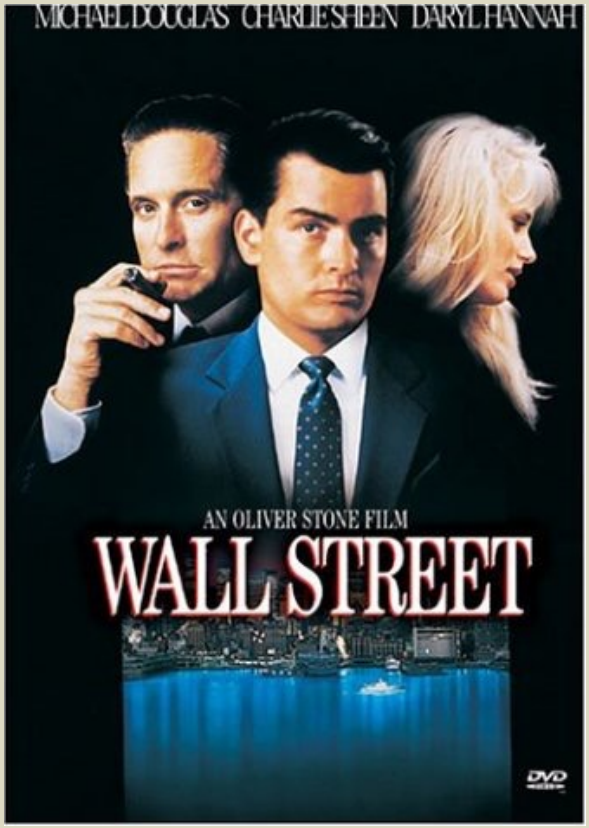
- You have taken and enjoyed basic algorithms
  - Basic datastructures (lists, queues, stacks, binary search trees, heaps…)
  - Basic algorithms (divide-and-conquer, dynamic programming, greedy, shortest path, spanning trees, flows)
  - Asymptotic analysis



- You have good basic knowledge of (discrete) math and probabilities

- I'll assume that you are now comfortable doing basic proofs

LIST OF (POTENTIAL) TOPICS



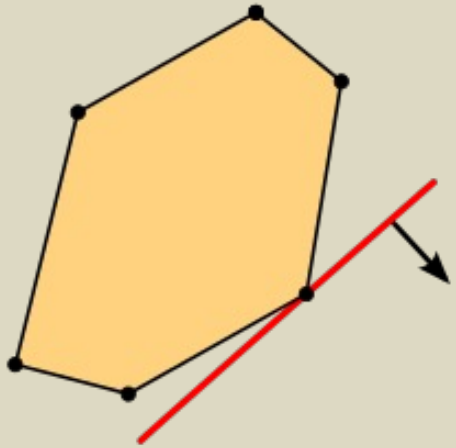
"Greed is good. Greed is right. Greed works. Greed clarifies, cuts through and captures the essence of the evolutionary spirit."

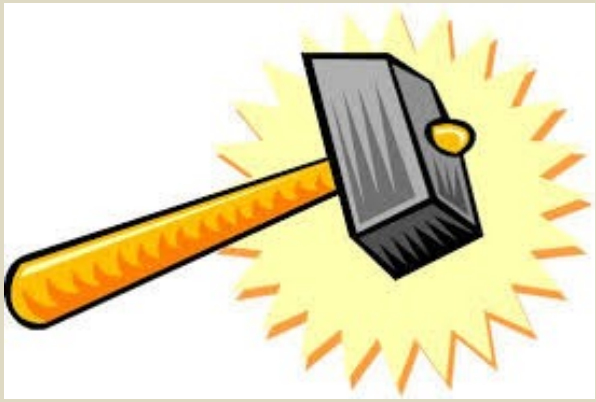
- Gordon Gecko

When does basic greedy work? The answer is matroids

Also matroid intersection

Linear Programming

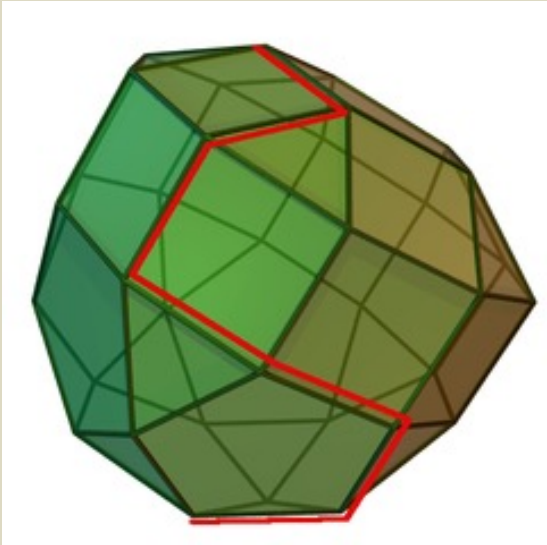




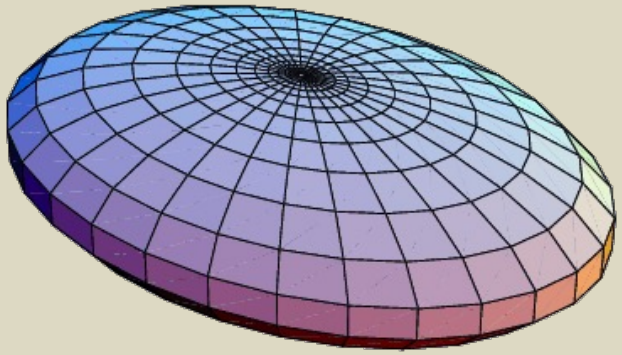
- Important big hammer
- Leonid Kantorovich - “founder of linear programming” Nobel prize in economics’1975

- Solution structure, duality
- Their use in the design of algorithms
- How to solve them?

Optimization

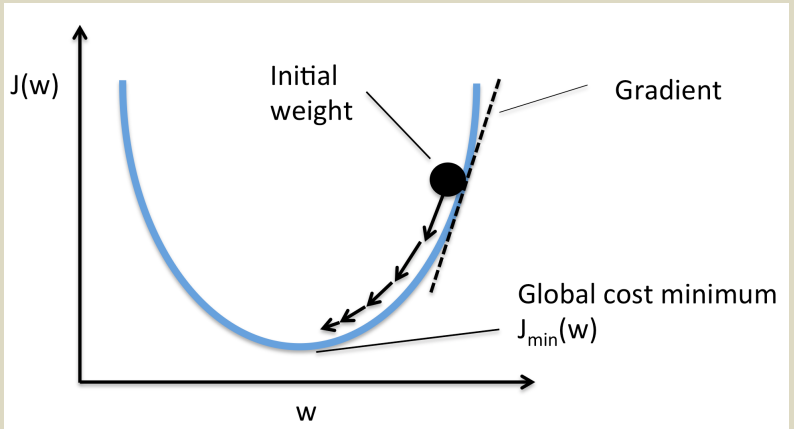


Simplex method



Ellipsoid method

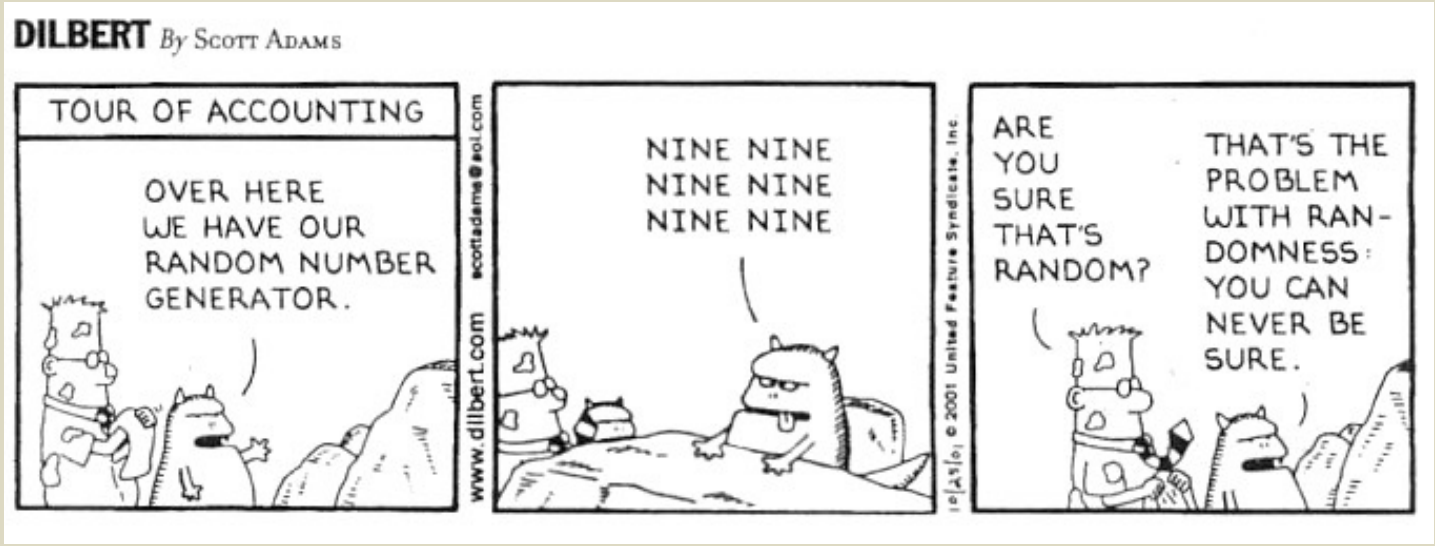
Multiplicative Weight Update



Gradient Descent

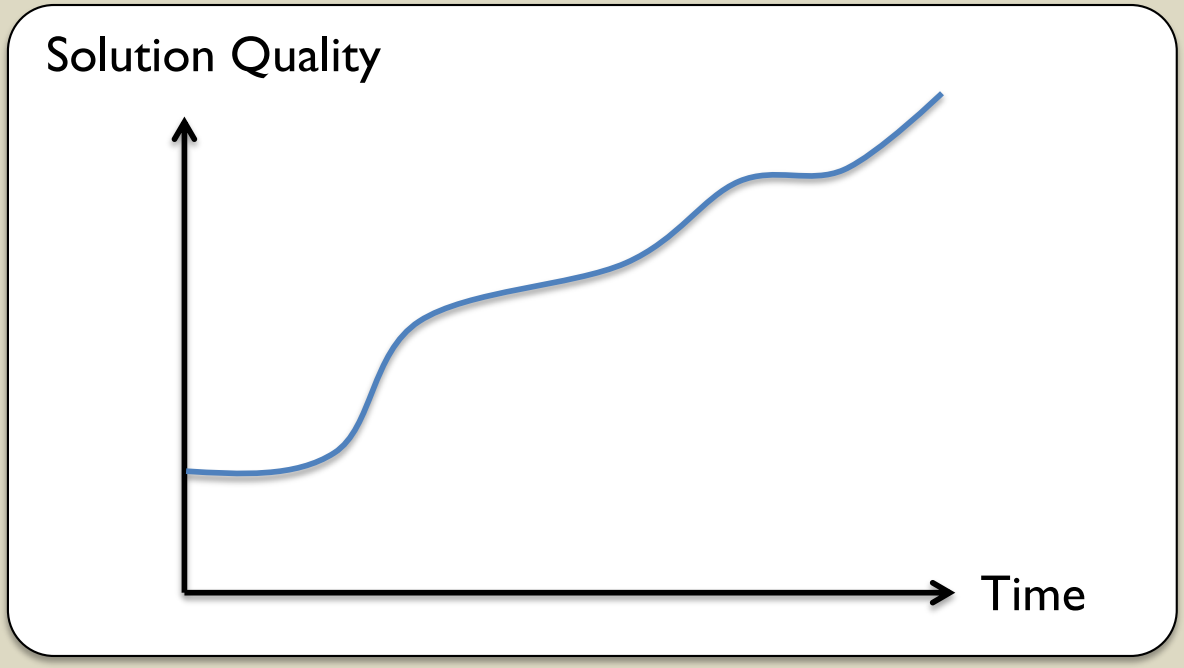
Randomized Algorithms

How to use  **to design better algorithms**



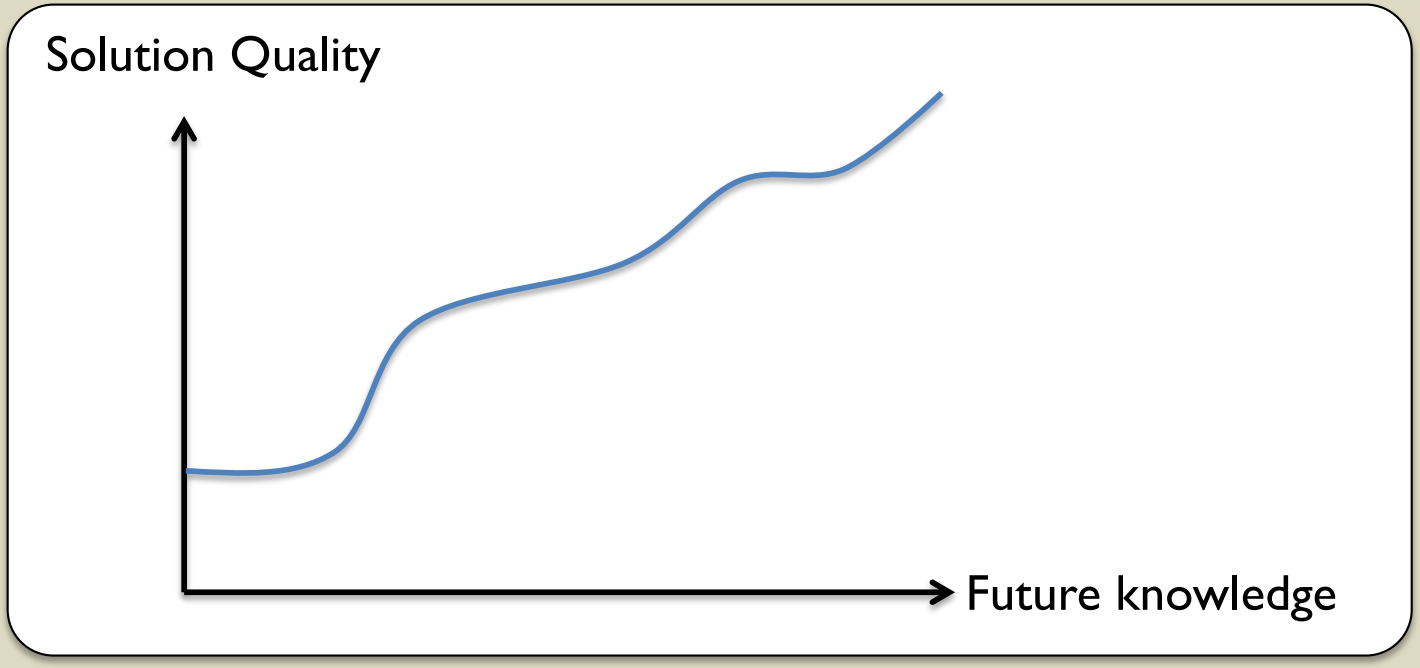
Approximation Algorithms

The study of tradeoff between solution quality and time



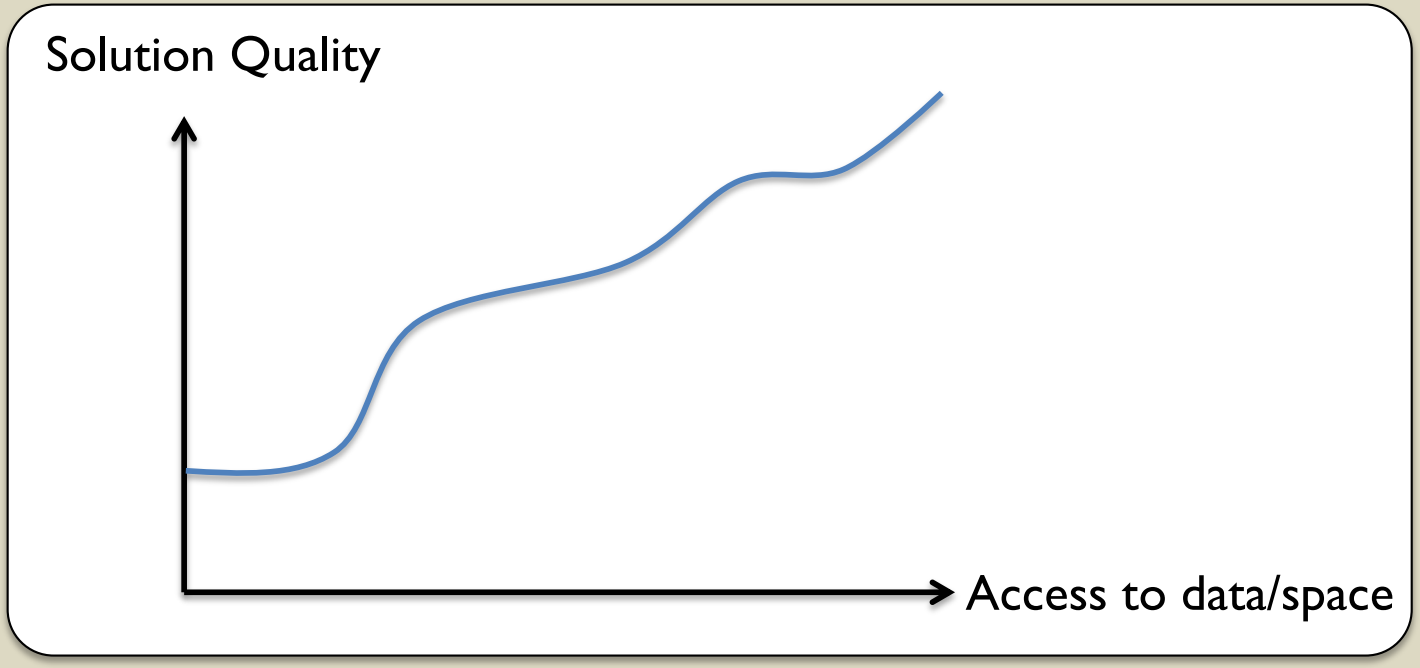
Online Algorithms

The study of tradeoff between solution quality and knowledge about future



Streaming Algorithms

The study of tradeoff between solution quality and massive data (so limited space and access)

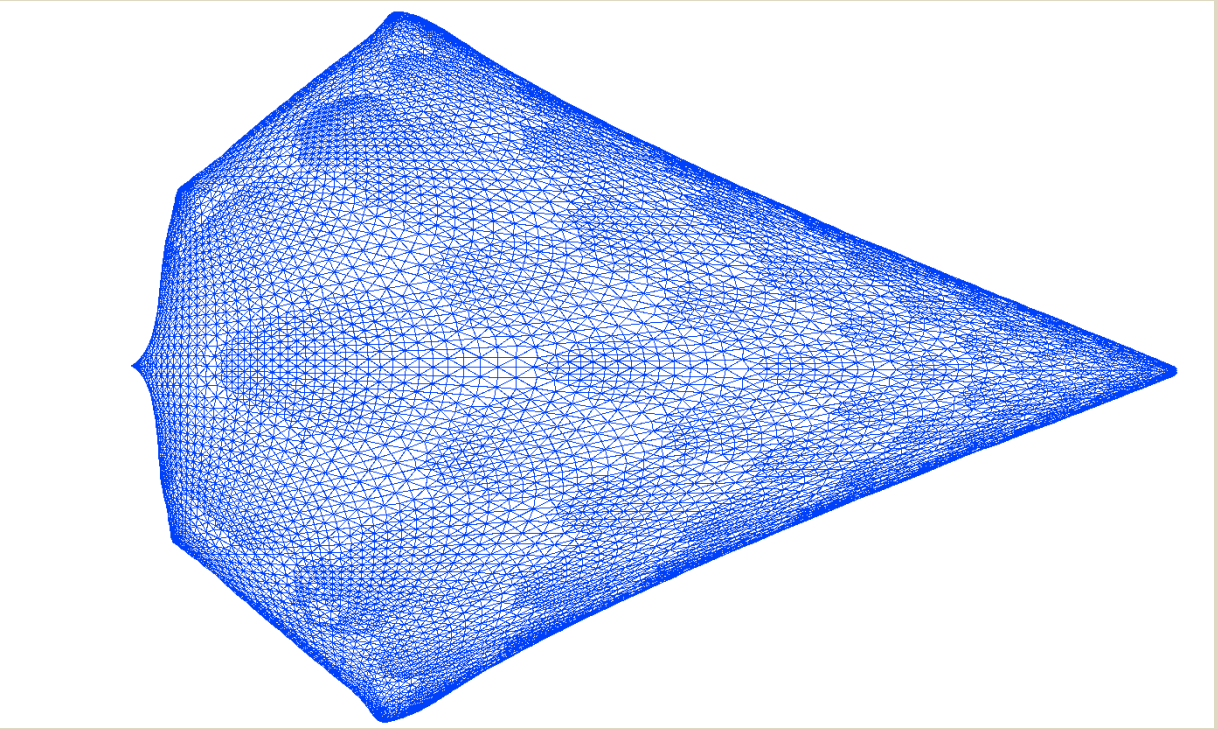


A better illustration…

How much information must flow in a system to perform a given task?

Spectral Graph Theory

- Study properties of graph using the eigenvalues/eigenvectors of adjacency matric



BASIC INFORMATION ABOUT COURSE

Who is he (the course responsible)?

- Michael Kapralov
  - michael.kapralov@epfl.ch
  - http://theory.epfl.ch/kapralov
- Faculty of computer science
  - Research on algorithms
- Office: INJ 113
- Happy to get feedback and to answer questions!

Dream team of TAs

Alberts

James

Jan

Polina

Davide

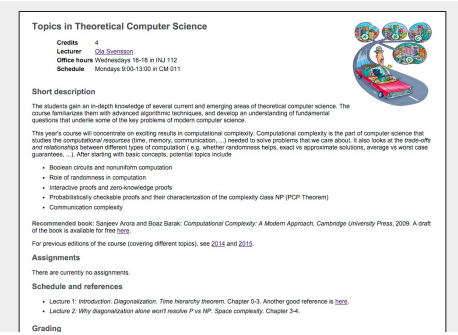
Lukas

Ekaterina

Weronika

The Course Essentials

Course homepage: *http://theory.epfl.ch/courses/AdvAlg/*


Topics in Theoretical Computer Science

Credits 4
Lecturer Ola Svensson
Office hours Wednesdays 16-18 in INJ 112
Schedule Mondays 9:00-13:00 in CM 011

Short description

The students gain an in-depth knowledge of several current and emerging areas of theoretical computer science. The course familiarizes them with advanced algorithmic techniques, and develop an understanding of fundamental questions that underlie some of the key problems of modern computer science.

This year's course will concentrate on exciting results in computational complexity. Computational complexity is the part of computer science that studies the computational resources (time, memory, communication, ...) needed to solve problems that we care about. It also looks at the *trade-offs* and relationships between different types of computation (e.g. whether randomness helps, exact vs approximate solutions, average vs worst case guarantees, ...). After starting with basic concepts, potential topics include

- Boolean circuits and nonuniform computation
- Role of randomness in computation
- Interactive proofs and zero-knowledge proofs
- Probabilistically checkable proofs and their characterization of the complexity class NP (PCP Theorem)
- Communication complexity

Recommended book: Sanjeev Arora and Boaz Barak: *Computational Complexity: A Modern Approach, Cambridge University Press, 2009.* A draft of the book is available for free here.

For previous editions of the course (covering different topics), see 2014 and 2015.

Assignments

There are currently no assignments.

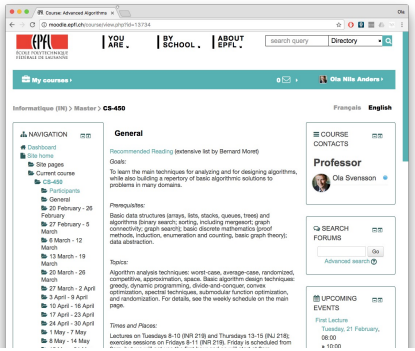
Schedule and references

- Lecture 1: *Introduction. Diagonalization. Time hierarchy theorem.* Chapter 0-3. Another good reference is here.
- Lecture 2: *Why diagonalization alone won't resolve P vs NP. Space complexity.* Chapter 3-4.

Grading

Links, material, information, topics, …

MOODLE



Lecture notes, detailed schedule, forum, all dynamic information, videos of last year's lectures

In short, the place to be

Grading: 30% homeworks (will be 2 assignments can be made in a group of up to 3 students), 30% midterm exam, 40% final exam

Comparison to Bachelor Algorithms

- Not only algorithms for solving problems in 20 minutes (more advanced techniques for more complex problems)
- Assume more mathematical maturity

> Taking as granted that it would be like most courses, where one can spend a week working on the material during the exam session. **Emphasizing that this is not the case during the presentation of the course seems important to me.**
>
> --- Comment on a previous instalment of the course