# Advanced Algorithms

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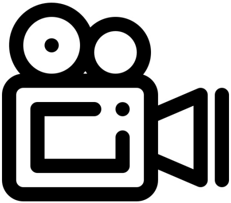
# Recap and Outlook

Lecture 14

# Recording of this Lecture

## This lecture will be recorded

- Recording only of the lecturers by themselves.
- If there are questions from the audience, please make a clear signal if the microphone shall be muted.
- Our goal is to record the lecture, but it is no guarantee that each lecture will be recorded.



# Recap

# Topics

- Matchings: maximum weighted matching, stable matchings, faster bipartite matching
- Max flows: blocking flows, push relabel
- Min-cost flows: cycle canceling
- Scheduling on unrelated machines, with and without release dates
- Linear programming: modelling, poly-time algorithms
- Linear programming: duality and total unimodularity
- Matroids and the Greedy algorithm

# Oral Exam

Oral exam: individual appointments, each around 30-35 minutes.

**Structure:**

- Prepare a topic of your choice! We will let you start with that (around 5-10 minutes).
  - Explain the problem and give details about algorithms and proofs.
  - Examples: min-cost flow, matroids, etc.
- We start asking questions about other topics.
- You can use a whiteboard to present your answers.

# How to prepare?

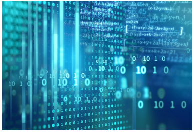
- Read and unterstand the material.
- Exercise answering questions with a sheet of paper and a pen.
- Try to think about possible questions, e.g.,
  - "What are matroids and why are they useful?"
  - "What is a blocking flow and where does it appear?"
  - "Model the matching problem as an ILP. Can we solve it in poly-time? Why?"
  - ...

# Outlook:
# Algorithms & Uncertainty

# Uncertainty in problem data is one of the main challenges in modern planning processes.

- Travel times change
- Jobs must be rescheduled or cancelled
- Material, subproducts are delivered late/early
- Data-driven applications (BigData, Industry 4.0) ...





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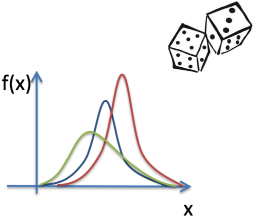
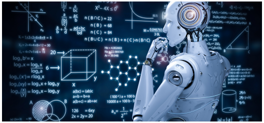
# Modeling Uncertainty in Input Data

| Online Models (incremental) | Stochastic Information | Predictions (e.g. ML-based) |
| --- | --- | --- |

**Different branches** of optimization: stochastic and online optimization, robust optimization, and learning-based algorithm design

# Routing under Uncertainty

Unforeseen requests must be integrated into planned tours.

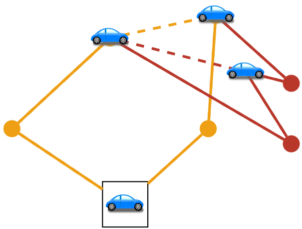

Patient transport


Roadside assistance

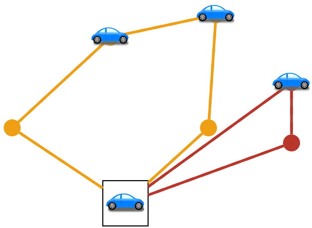
# Online Routing Problems

**Online**: Recompute (ReOpt) or waiting strategy (Ignore)?

ReOpt



Ignore



**Theorem**

ReOpt and Ignore compute tours at most a factor of 2.5 longer than the best tour.

Suppose you had an idea where new jobs would appear.

# Online Algorithms & ML

## Online Algorithms

- \+ robust, strong worst-case guarantees
- − possibly poor for simple real-world instances

## ML-based Algorithms

- \+ good for many real-world instances
- − possibly arbitrarily bad for individual instances

Combine the best of both worlds

## Learning-Augmented Online Algorithms

- \+ very good for many real-world instances
- \+ robust against ML prediction errors, strong worst-case guarantees

# New: Learning-Augmented Online Algorithms

- Online algorithm has access to predictions (e.g. ML)
- No assumption about the quality of the prediction

Online Algorithm plus 

## Requirements for an Algorithm

1. Consistency: (nearly) optimal solution with perfect prediction
2. Robustness: even with arbitrarily bad prediction, a worst-case guarantee holds (ideally comparable to the online algorithm)
3. Smoothness: Solution quality decreases as prediction error increases

...more on this in "Algorithms and Uncertainty"

# Further Courses

- **Optimization Bootcamp** (block course, 14.-18.07.2025)
  - Modeling and practical implementation in Python
- **Approximation Algorithms** (Master, summer term)
- **Algorithms and Uncertainty** (Master)