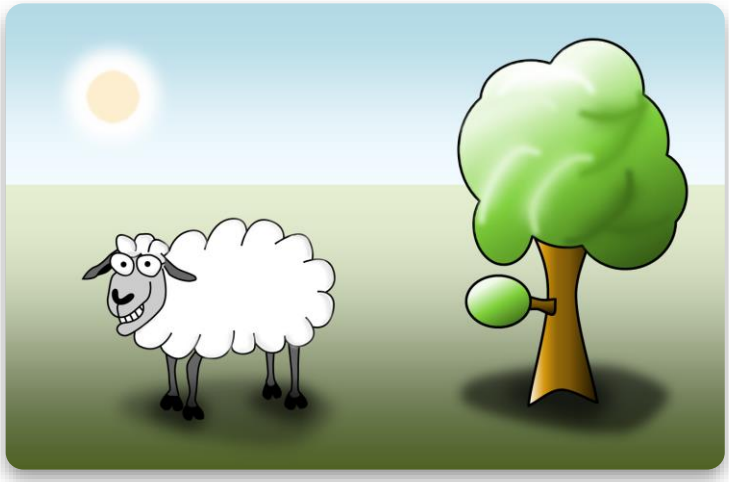
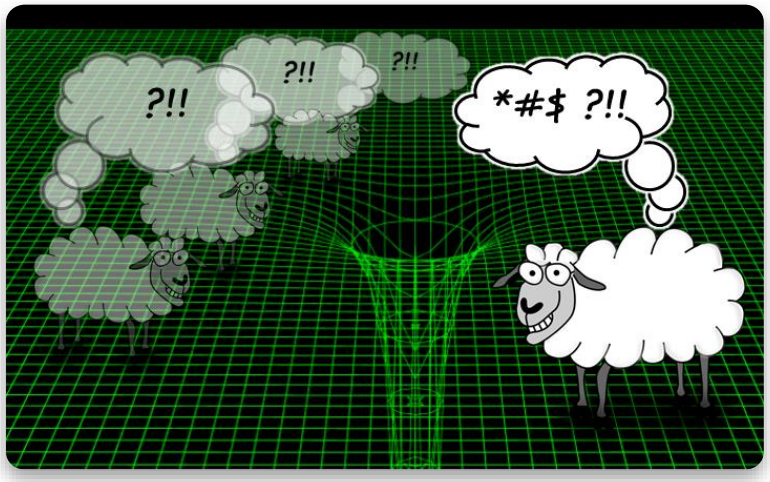
Modelling 1

WINTER TERM 2021/22





LECTURE 1

Introduction

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Agenda

First meeting

- What is the lecture about?
- How is it organized?
- Speed-run: The whole lecture

What is it about?

Lecture Topic

Modelling

- Natural phenomena
- Rebuild the outside world in the computer

Two Problems

- Forward: Simulation (Model → Data)
- Backward: Inverse Problems (Data → Model)

Technical Approach

- Mathematical modeling + numerical algorithms
- Mostly (applied) linear algebra

Topics

Modeling

- Modeling = Representation + Rules

Representations

- Mathematical representations
  - What kind of / how much information is there in a system/phenomenon
- Digital representations
  - Discretization
- Tools / theory for analysis
  - What is going on here?

Topics

Rules / Dynamics

- How does the system behave / evolve?
  - Space / time / both
  - Parameters?
- Modeling toolkit / examples
- Anecdotal / exemplary
  - More focus on representations

Analysis

- Understand our model
- Understand the data

The Answer to All Questions

Spoiler

- The answer will almost always be:

  Find a good coordinate system!

- (Because the questions will translate to

  What is the right coordinate system?)

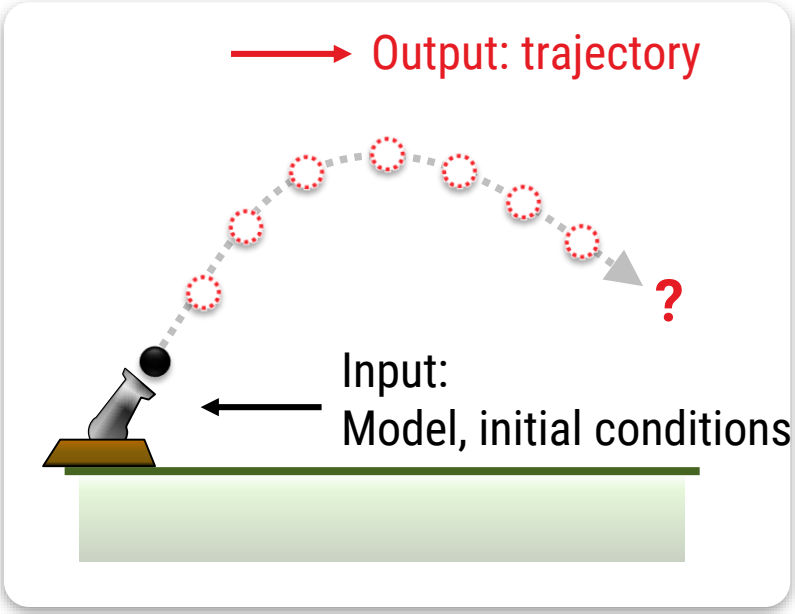
"You will only learn one trick, PCA.
But PCA is actually quite handy"

(do not take *too* seriously)

Topic: Simulation

Simulation

- „Forward“ simulation
- Predict system evolution



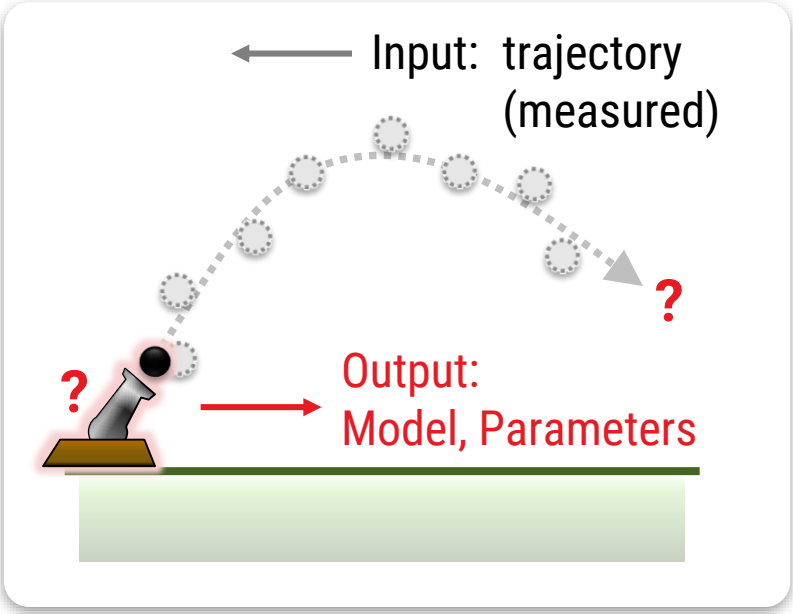
Inverse problems

- Estimate reality from data
  - Noisy (measured) data given
  - Model (assumptions) given
  - Fit model parameter for optimal explanation of data
- Variational modeling
- “Ill-posed problems”

Topics: Inverse Problems

Simulation

- „Forward“ simulation
- Predict system evolution



Inverse problems

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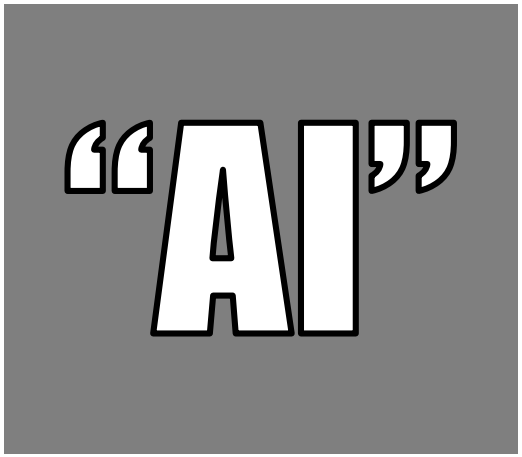
Relation to Machine Learning



AI today ≈ statistical machine learning

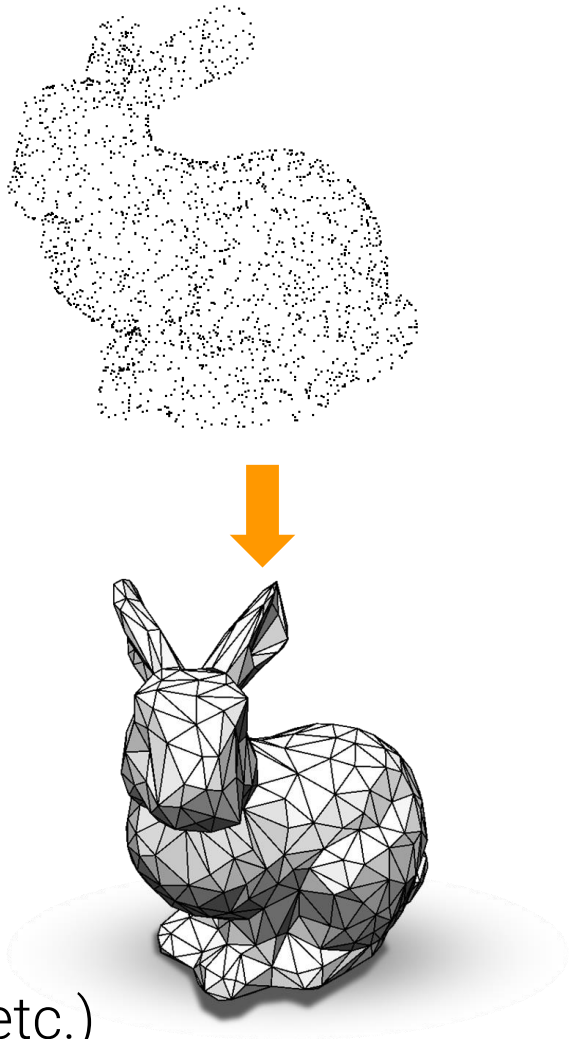
- ML is an inverse problem: Model from data
- Modelling-1 studies linear methods (least-squares)
  - Less attention to statistical properties
- Comprehensive ML approach in Modelling-2
  - “Statistical data modeling”

Style

Lecture Content

Topic

- Mathematical-numerical Modeling
- Application oriented
  - Focus on intuition
  - Less mathematical rigor / few proofs
  - „Getting things done“
- Examples focus on
  - Geometry
  - Dynamic systems
- Canonical examples
  - Reconstruction (from images, 3D scans etc.)



Background

Mathematical Modeling

- Tour through undergraduate engineering mathematics
- Connection to applications
- “Theoretical Computer Graphics”

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How is it organized?

Blended Learning

Lecture Format

Website

https://luna.informatik.uni-mainz.de/mod1-22-23/

Lectures

- Videos (in German, with English slides)
  - Completely available on the web right now
- Weekly meeting
  - Tuesdays 14-16h in room 04-432 (in-person)
- Tutorials
  - Wednesdays 14-16h in room 04-432 (in-person)
- Room / tutorial setup might change (~50 participants)

How-To

How to attend the course

- Watch a set of videos (usually one) each week
  - https://luna.informatik.uni-mainz.de/mod1-22-23/lehreinheiten.html
  - 13 units (“Lehreinheiten”) for 14 Weeks
- Attend weekly meeting
  - Tuesdays, 14-16h (c.t.)
  - We will discuss the videos you watched
  - Solve small theory problems together
- Formal rule: voluntarily participation
  - To benefit from the course:
    Proactive participation required

How to attend the course

Solve homework assignments

- Tutors: Jan Disselhoff, Christian Ali Mehmeti-Göpel
- Assignment sheets on the course webpage
- Includes quite a bit of practical problems

Tutorial Course

- Tutorials on Tuesday afternoon

How to attend the course

Schedule

- First assignment sheet next week
  - Will be published Mo, Oct 31 2022
- First tutorial course in third week
  - Wed Nov 9 2022

Handing-in solutions

- Assignments published Mondays
- Assignments to be handed-in Monday (evening: 23:59h)

Homework Assignments

Group work

- Form groups of 3 students
- Hand-in one solution per group
- Recommended: Discuss in group, solve yourself

Tutorial Details

“Active participation”

- You have to hand-in solutions (`gitlab.rlp.net`)
  - Skip at most two times without “good reasons”
- But no grading/corrections (resource limitation)
- Peer review
  - Solutions available to all, discuss together in tutorial
  - No formal process, rather information sharing
- Present your solutions
  - At least twice during the semester
- Exceptions: Discuss with tutor before they are needed
  - Except emergencies, of course

Assignments

This stuff is useful!

- Theory + Programming assignments
- We will consider applications “near to practice”
- Solve in any language / environment that does not nullify the assignment as such

Recommendations

1. Python & NumPy/SciPy & PySide2/Qt
   - “nice, but slow”
2. C++ & “Eigen” & Qt/Qt3D (GeoX if you like)
   - “painful, but fast” (add a bit of python to ease the pain)

Life-Pro-Tips

Formal requirements

- Are minimalistic, easy to meet
- Make sure to meet them,
  but do not make this your key objective

Effective studying

- Self-responsibility
- Be proactive
  - Participate
  - Interact
  - Engage with your peers

Exam

How will the exam look like?

- Unsure today
- Considering different options
  - On-site / take-home exam
  - Oral exams
  - Current plan:
    On-site exam on March 01 2023, 9-12h
- Depends on
  - Number of participants at the end of the semester
  - Maybe viruses & variants
    - let's hope not...

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Speed-run:
Everything in a few minutes

Modeling 1

Complete Lecture

- Models of natural phenomena: High-dim. coordinates
- World in the machine: Sampling
- Computing with coordinates: Linear Algebra
- What we can understand: Linear Maps
- Derivatives & Integrals are linear: ODEs, PDEs
- Understanding linear mappings: SVD (PCA, MDS, EVs)
- Santa-Claus Algorithms: (quaratic) variational models
- Analyzing data: PCA of data and learning Gaussians
- (Nonlinear stuff: local linearization)

Questions?

What should I do now/next?

Watch the first video

https://luna.informatik.uni-mainz.de/mod1-21-22/lehreinheiten.html