Introduction

Statistical Methods for Data Science

Yinan Yu

Department of Computer Science and Engineering

October 31, 2022

- What is *data*?
- Why do we need to do *data science*?
- Why *statistical methods*?

What is data?

What is data?

Images of you...

image from `https://en.wikipedia.org/wiki/Pedestrian`

What is data?

Movies you have watched...

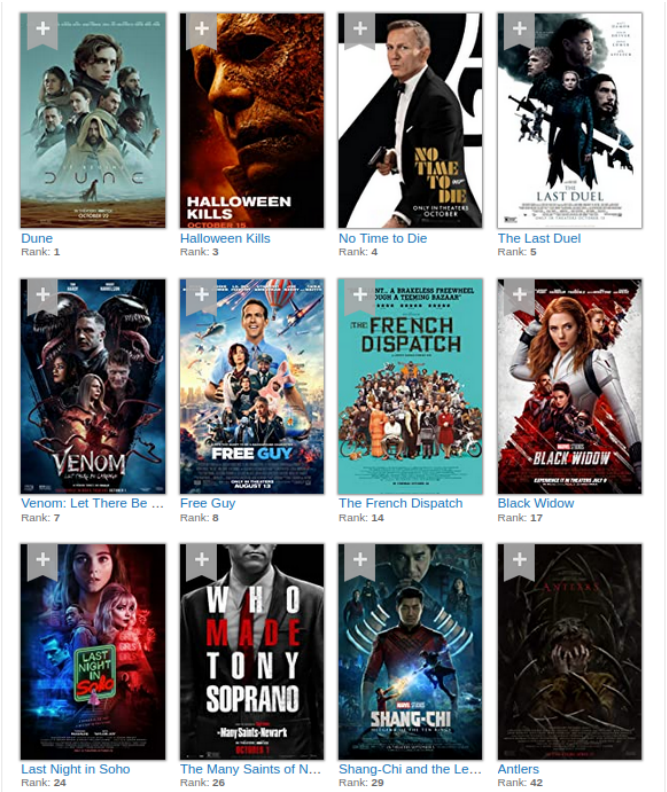


image from `https://www.imdb.com`

What is data?

Places you have been...

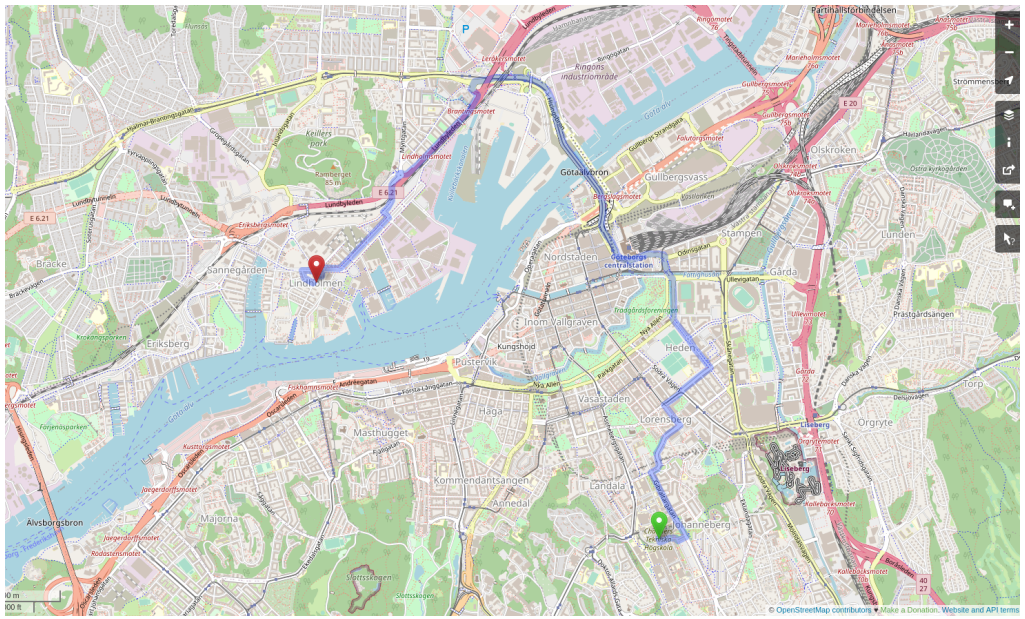


image from `https://www.openstreetmap.org`

What is data?

- Data is everywhere

What is data?

- Data is everywhere
- Our personal data is being collected as we speak

What is data?

- Data is everywhere
- Our personal data is being collected as we speak
- Our behaviors are being **explored**, **modeled** and **predicted** using data

What is data?

- Data is everywhere
- Our personal data is being collected as we speak
- Our behaviors are being **explored**, **modeled** and **predicted** using data
- We are constantly refreshing our social media feed

What is data?

- Data is everywhere
- Our personal data is being collected as we speak
- Our behaviors are being **explored**, **modeled** and **predicted** using data
- We are constantly refreshing our social media feed
- We are not in control anymore

What is data?

- Data is everywhere
- Our personal data is being collected as we speak
- Our behaviors are being **explored**, **modeled** and **predicted** using data
- We are constantly refreshing our social media feed
- We are not in control anymore
- Your phone knows you better than yourself

Why do we need to do data science?

- Learning what to do with data is to empower yourself

Why do we need to do data science?

- Learning what to do with data is to empower yourself
- Taking back control

Why do we need to do data science?

- Learning what to do with data is to empower yourself
- Taking back control
- Controlling others

Why do we need to do data science?

- Learning what to do with data is to empower yourself
- Taking back control
- Controlling others - don't do that

Why do we need to do data science?

- Learning what to do with data is to empower yourself
- Taking back control
- Controlling others - don't do that
- Using data for good

Why do we need to do data science?

- Learning what to do with data is to empower yourself
- Taking back control
- Controlling others - don't do that
- Using data for good

Is it even optional?

Why statistical methods?

- Data is random
- We are bad at keeping track of random things

Why statistical methods?

- Data is random
- We are bad at keeping track of random things
  - What was the temperature *every day* in 2022? 

Why statistical methods?

- Data is random
- We are bad at keeping track of random things
  - What was the temperature *every day* in 2022? 
- We use summaries instead

Why statistical methods?

- Data is random
- We are bad at keeping track of random things
  - What was the temperature *every day* in 2022? 
- We use summaries instead
  - What was the *average* temperature in 2022? 

Why statistical methods?

- Data is random
- We are bad at keeping track of random things
  - What was the temperature *every day* in 2022? 
- We use summaries instead
  - What was the *average* temperature in 2022? 

Statistical methods

What is this course NOT about?

What is this course NOT about?

- Hardcore probability theory course

What is σ-algebra?

Definition 1.2 (σ-algebra) A class of sets $\mathcal{A} \subset 2^{\Omega}$ is called a *σ-algebra* if it fulfills the following three conditions:

(i) $\Omega \in \mathcal{A}$.
(ii) $\mathcal{A}$ is closed under complements.
(iii) $\mathcal{A}$ is closed under countable unions.

Source: Klenke, Achim. Probability theory: a comprehensive course. Springer Science & Business Media, 2013.

What is this course NOT about?

- Hardcore probability theory course

  What is σ-algebra?

  Definition 1.2 (σ-algebra) A class of sets $\mathcal{A} \subset 2^{\Omega}$ is called a *σ-algebra* if it fulfills the following three conditions:

  (i) $\Omega \in \mathcal{A}$.
  (ii) $\mathcal{A}$ is closed under complements.
  (iii) $\mathcal{A}$ is closed under countable unions.

  Source: Klenke, Achim. Probability theory: a comprehensive course. Springer Science & Business Media, 2013.

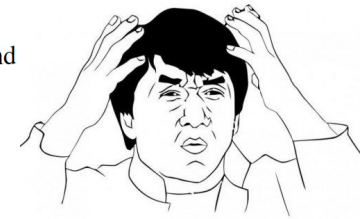
- Introductory statistics course

  2. A box contains four black pieces of cloth, two striped pieces, and six dotted pieces. A piece is selected randomly and then placed back in the box. A second piece is selected randomly. What is the probability that:

     a. both pieces are dotted?

     b. the first piece is black and the second piece is dotted?

     c. one piece is black and one piece is striped?



  Source: Lee, Yong-Gu, and Sam-Yong Kim. Introduction to statistics. Yulgokbooks, Korea (2008): 342-351.

What is this course NOT about?

- Hardcore probability theory course

  What is σ-algebra?

  Definition 1.2 (σ-algebra) A class of sets $\mathcal{A} \subset 2^{\Omega}$ is called a *σ-algebra* if it fulfills the following three conditions:

  (i) $\Omega \in \mathcal{A}$.
  (ii) $\mathcal{A}$ is closed under complements.
  (iii) $\mathcal{A}$ is closed under countable unions.

  Source: Klenke, Achim. Probability theory: a comprehensive course. Springer Science & Business Media, 2013.

- Introductory statistics course

  2. A box contains four black pieces of cloth, two striped pieces, and six dotted pieces. A piece is selected randomly and then placed back in the box. A second piece is selected randomly. What is the probability that:

     a. both pieces are dotted?

     b. the first piece is black and the second piece is dotted?

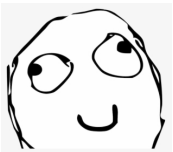
     c. one piece is black and one piece is striped?

  Source: Lee, Yong-Gu, and Sam-Yong Kim. Introduction to statistics. Yulgokbooks, Korea (2008): 342-351.

- Pure machine learning course

  Support Vector Machines, Decision Trees,

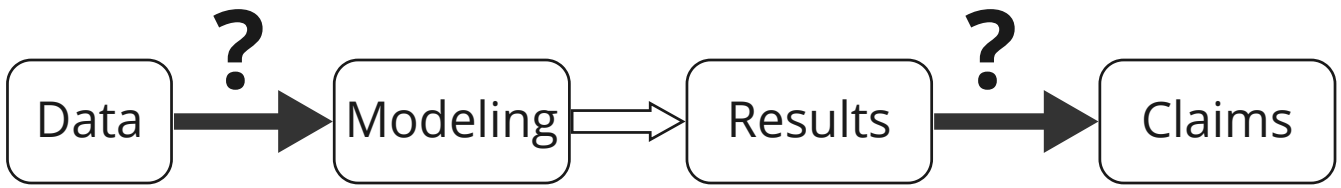
  Convolutional Neural Networks, Transformers

Our focus

Our focus

Two foci:

- What to do with data
- How to regulate your data-related claims



In practice, this course is a mixture of probability, statistics and machine learning

Regulate your data-related claims

Regulate your data-related claims

- You have 3 ducks at home and they weigh 2kg, 5kg, 0.5kg each

Regulate your data-related claims

- You have 3 ducks at home and they weigh 2kg, 5kg, 0.5kg each
- Oof, absolute units

Regulate your data-related claims

- You have 3 ducks at home and they weigh 2kg, 5kg, 0.5kg each
- Oof, absolute units
- You feed them a weight loss drug called "duckiphanamin" for a month and now they weigh 1.2kg, 6kg, 0.48kg each

Regulate your data-related claims

- You have 3 ducks at home and they weigh 2kg, 5kg, 0.5kg each
- Oof, absolute units
- You feed them a weight loss drug called "duckiphanamin" for a month and now they weigh 1.2kg, 6kg, 0.48kg each

Question! Can you claim that duckiphanamin works?

Regulate your data-related claims

- You have 3 ducks at home and they weigh 2kg, 5kg, 0.5kg each
- Oof, absolute units
- You feed them a weight loss drug called "duckiphanamin" for a month and now they weigh 1.2kg, 6kg, 0.48kg each

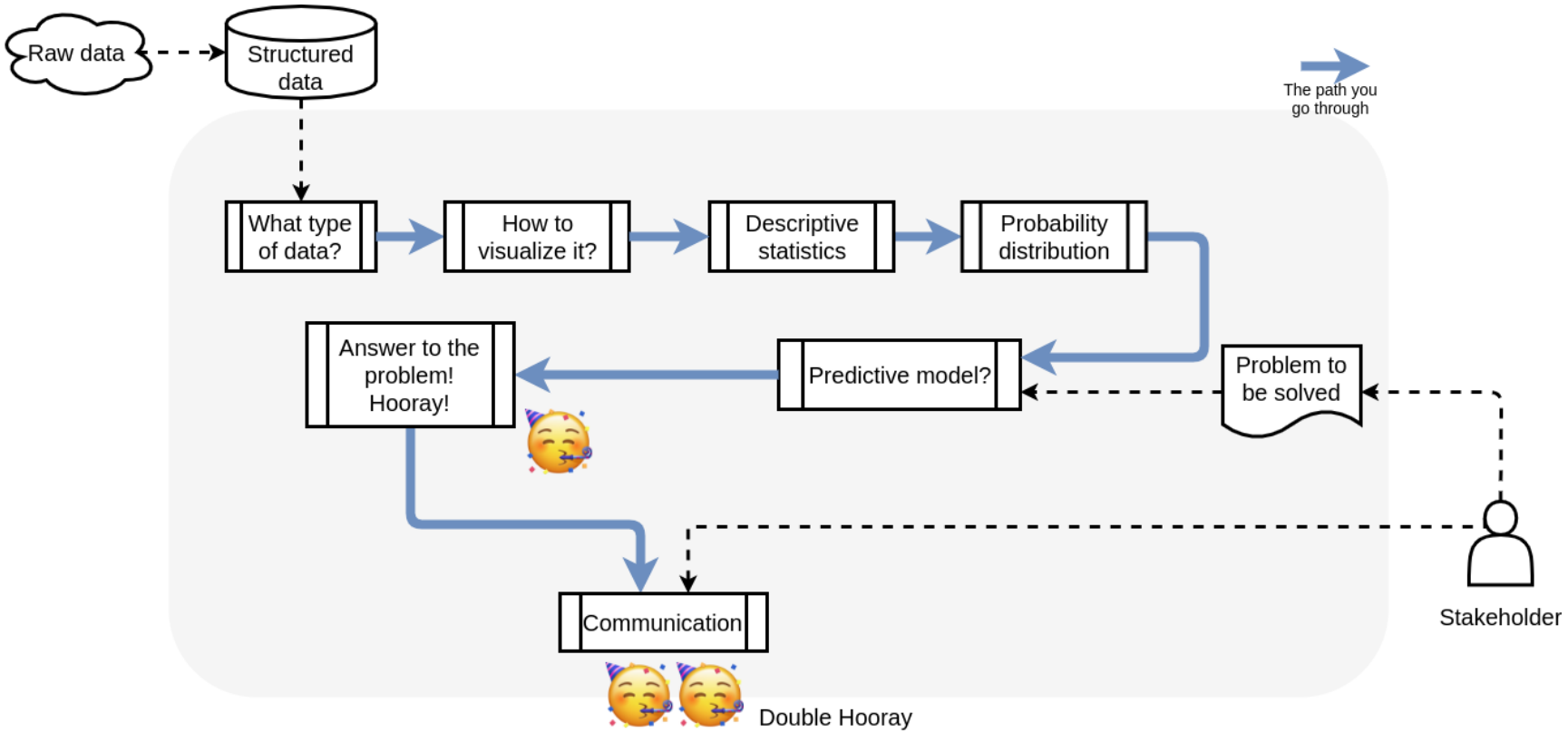
Question! Can you claim that duckiphanamin works?

- How about feeding duckiphanamin to your other 100 ducks? If they all lose 0.5kg each, can you claim duckiphanamin works then?

Course outcome

How do you know if you will pass the course?

Course outcome



You should be able to walk through this map and achieve double hooray without supervision.

Some notes

Some notes

- Data collection and management
  - Not to be underestimated!
  - Not covered in the course - we work with structured data!

Some notes

- Data collection and management
  - Not to be underestimated!
  - Not covered in the course - we work with structured data!
- Communication is important!
  - You never develop in isolation
  - Learn how to communicate efficiently

Some notes

- Data collection and management
  - Not to be underestimated!
  - Not covered in the course - we work with structured data!
- Communication is important!
  - You never develop in isolation
  - Learn how to communicate efficiently
- Be patient
  - There is a lot to learn
  - Learning can be painful. Hang in there!

Some notes

- Data collection and management
  - Not to be underestimated!
  - Not covered in the course - we work with structured data!
- Communication is important!
  - You never develop in isolation
  - Learn how to communicate efficiently
- Be patient
  - There is a lot to learn
  - Learning can be painful. Hang in there!
- **Do not hesitate to ask questions!!!**

Practicalities and logistics

- Information: Canvas
- Lecturer & TAs: can be found on Canvas
- Communication:
  - Email me
  - Ping me on Slack
- Student representatives:
  - Please send me an email this week if you are interested!
  - Otherwise they will be randomly selected
  - Read more about student representatives here

Grading

- Fail, pass (G), pass with distinction (VG)
- 3 assignments (10 pts each), 1 project (20 pts + bonus pts), 1 exam (50 pts)
  - fail: < 50 pts
  - pass: ≥ 50 pts
  - pass with distinction: ≥ 80 pts
    - Assignments + project: ≥ 40 pts
    - Exam: ≥ 40 pts
- Submission: Canvas

Grading

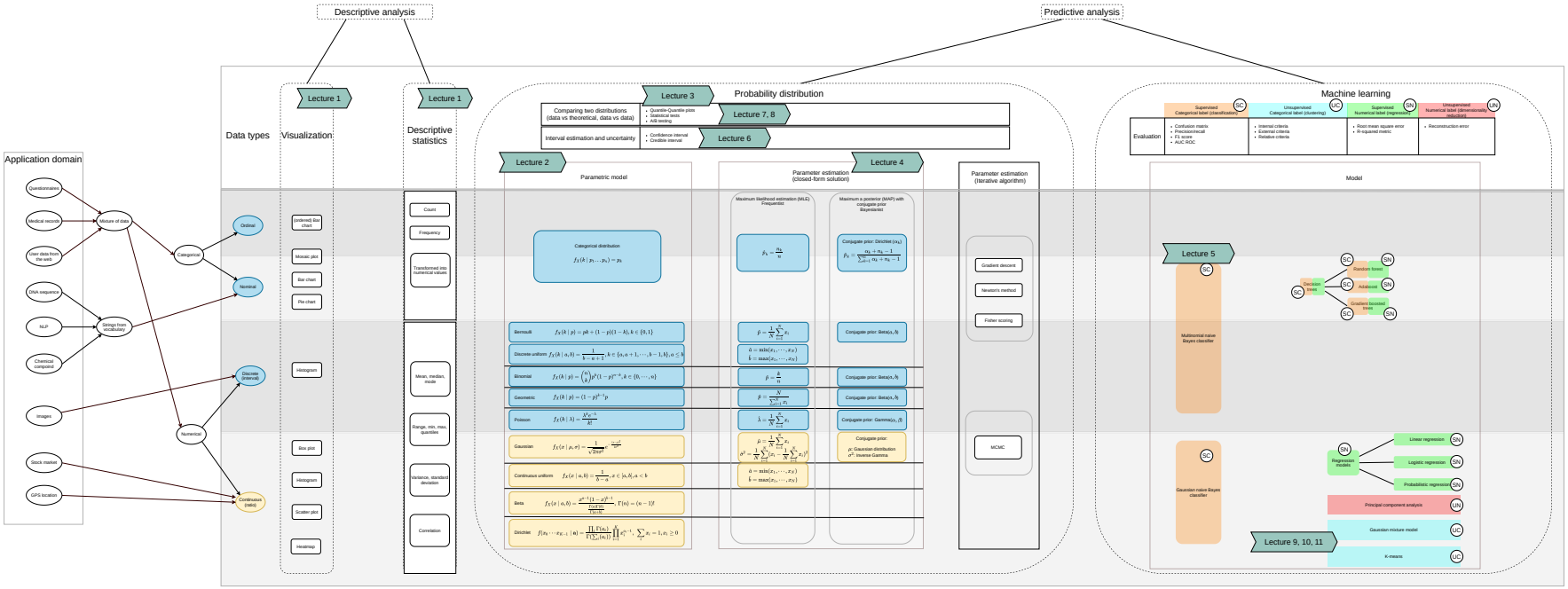
- Assignments (3*10 pts, group of 1-3 students)
- Project (20 pts, group of 1-3 students):
  - Self-defined subject
  - A report, Python code and a presentation
  - Find an opponent group
- Take-home exam (50 pts, individual)
- Late policy:
  - Assignments: 25% penalty for 0-24 hours
  - Project and exam: strict
- About grouping: try to team up with someone with complementary knowledge and skill sets

Content

- Data types, descriptive statistics, visualization
- Probability distributions
- Modeling, parameter estimation, point estimation, interval estimation
- Hypothesis testing
- Application 1: classification, Naive Bayes classifier
- Application 2: clustering, K-means, Gaussian mixture model

Content

Lecture map to help you keep track of where we are



Feedback and questions are welcome at
yinan.yu@asymptotic.ai or yinan@chalmers.se

Programming language and tools

- Programming language: Python
- Interactive environment: Jupyter Notebook

Programming language and tools

- Libraries
  - Data handling and processing
    - NumPy: efficient mathematical functions
    - Pandas: structured data processing
  - Visualization
    - Matplotlib: plotting library
    - Seaborn: additional statistical plotting functions
  - Statistics
    - SciPy: a Python library for statistics and math in general
    - StatsModels: some more advanced statistical models
  - Machine learning
    - scikit-learn: predictive models and clustering

Literature

- Text book: *The Data Science Design Manual*
- Online materials posted throughout the course

Final notes

Have fun!

See you on the other s(l)ide!