Inference & Causality
Week 1

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About Me

- Dr. Narges Chinichian
- PhD in Physics (Computational Neuroscience), with 8+ years experience in data science & machine learning.
- Hobby teacher, I also teach rope climbing at the neighboring gym Der Kegel!
- Fun fact about me: I’m a grand-grand-…-grand student of Gauss.

About You?

Please share briefly:

- 1. Your name & if you'd like: where you're from.
- 2. What languages you speak/read.
- 3. What is your educational background.
- 4. How would you rate your Python and Git skills?
- 5. What are your expectations for this course? What do you hope to learn?

- Bonus: If causality were a person, how would they look and what would they be like?

Course Overview

- 6 weeks | 2 day per week (12 sessions)| 4 × 45min units
- Hands-on, project-based learning

- Check the course hub on Notion for up-to-date information:
  https://tinyurl.com/mrcjp79s

The course will be covering:

- Statistical inference
- Introduction to causality
- Interventions
- Do-calculus
- Fallacies

Outline of Week 1

- Set up the infrastructure (GitHub).
- Explain the difference between frequentist and Bayesian inference
- Apply Bayes' theorem to simple problems
- Update beliefs with new evidence

Setting Up Your GitHub

- Please all add your GitHub handle and name here: https://tinyurl.com/4xxzhphf

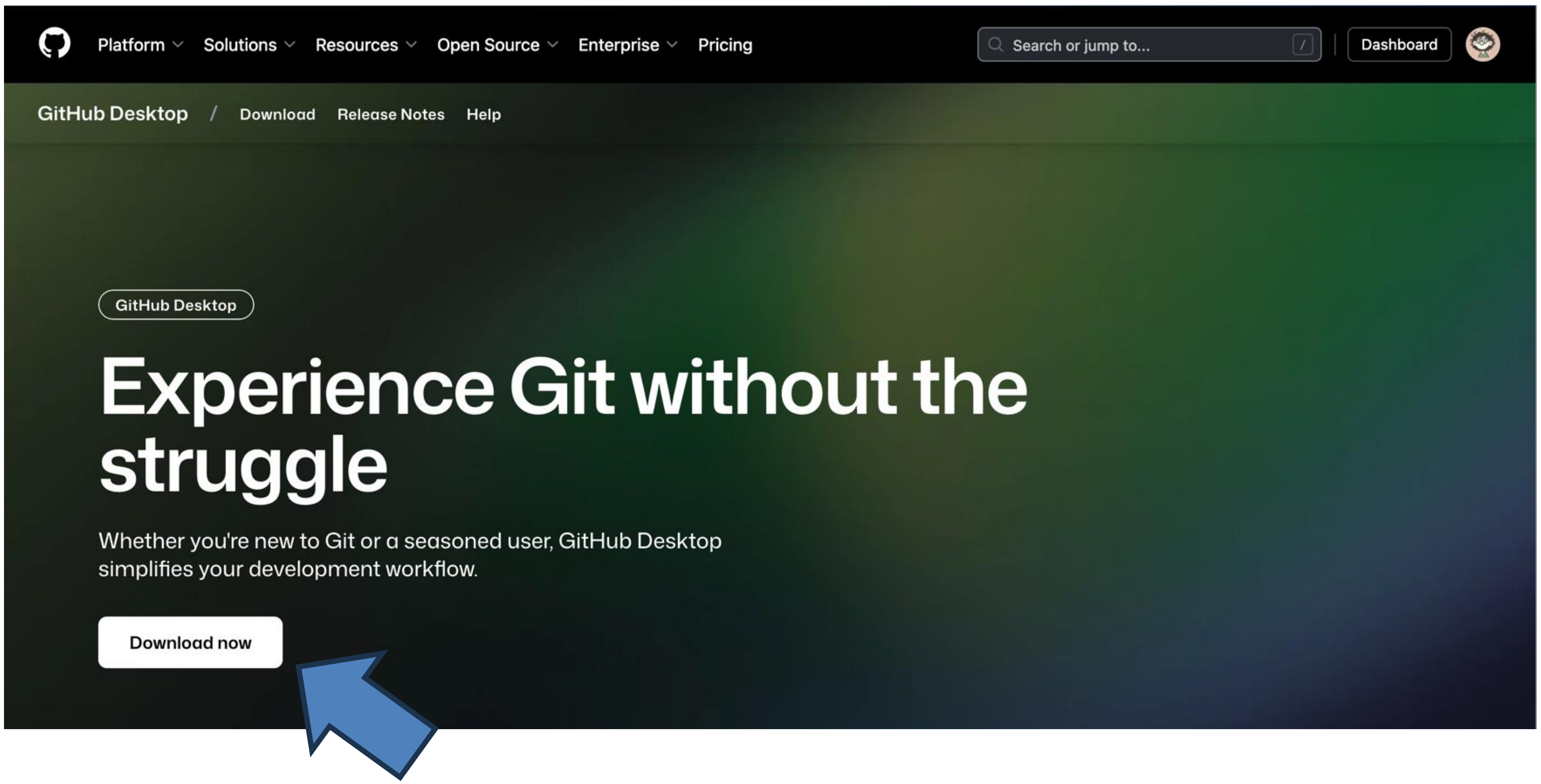
- You handle is what you get in your url when you are on your profile page:

- So if you see:
- https://github.com/NoCh-Git

- Your handle is NoCh-Git.

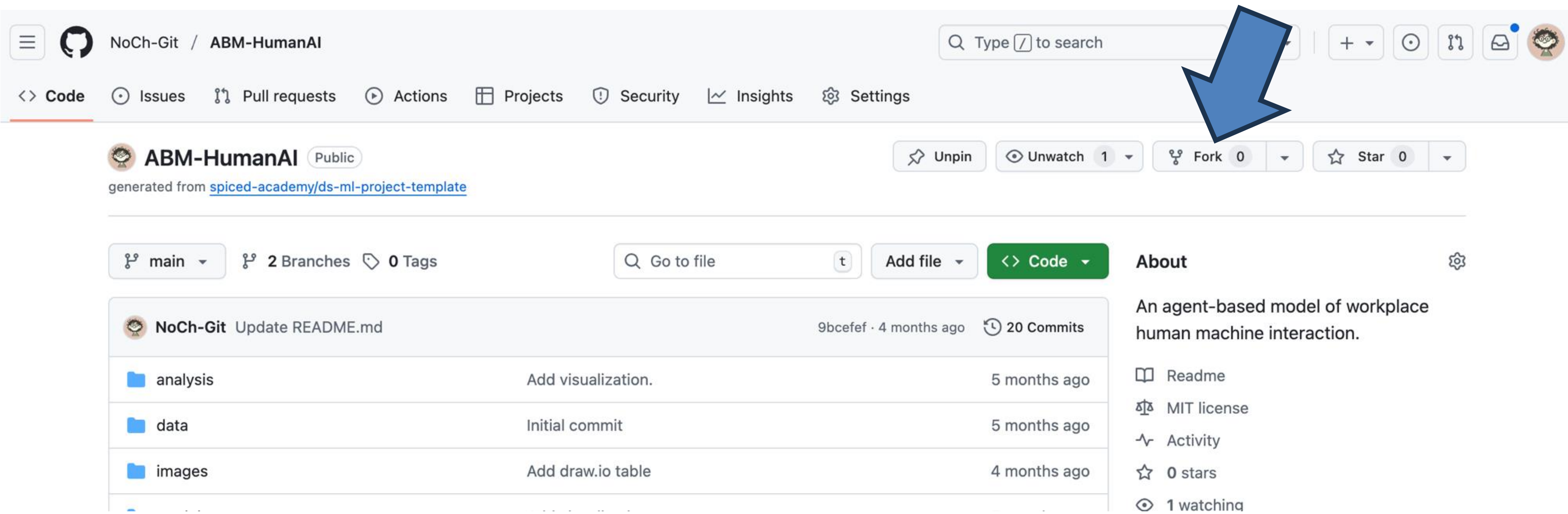
Install GitHub Desktop (Optional)

https://github.com/apps/desktop



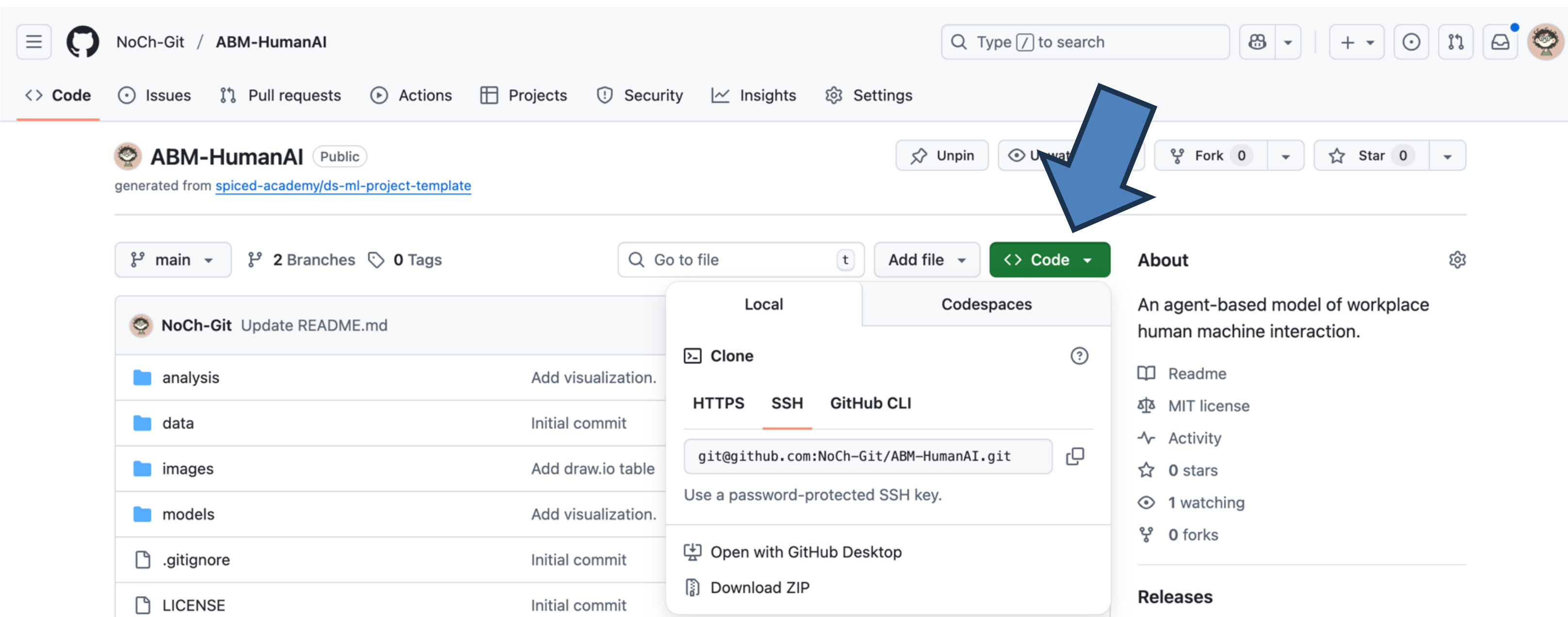
Fork Repo of Today

- Forking a repo would create a copy of that repo for you that you can play with.
- Choose yourself as the owner and untick the “Copy the main branch only” box.



Clone the Forked Repo to Your Machine Using GitHub Desktop or CLT

- You need to have a local copy of the Python notebooks.



Ready?

Notebook 1

Notebook 1 of week 1 in your "notebooks" folder.

What is Statistical Inference?

- Drawing conclusions about unknowns from data
- Two paradigms:
  - Frequentist: parameters fixed, data random
  - Bayesian: parameters uncertain, updated via evidence
- Both appear throughout this module; today we compare and practice

Want to play a quick game?

Two Paradigms:

Frequentist

- Probability = long-run frequency
- Parameters are fixed (unknown), data is random
- Confidence intervals, hypothesis tests

Bayesian

- Probability = degree of belief
- Parameters have distributions (prior → posterior)
- Bayes’ theorem combines prior and likelihood

Bayes' Theorem

$$P(\mathrm{H}|\mathrm{D}) = \frac{P(\mathrm{D}|\mathrm{H})}{P(\mathrm{D})} P(\mathrm{H})$$

- Where:
- H = Hypothesis for example some "disease"
- D = Data for example a "positive test"
- $P(\mathrm{H})$ is the probability of the hypothesis before we see the data, called the **prior** probability, or just prior.
- $P(\mathrm{H}|\mathrm{D})$ is the probability of the hypothesis after we see the data, called the **posterior**.
- $P(\mathrm{D}|\mathrm{H})$ is the probability of the data under the hypothesis, called the **likelihood**.
- $P(\mathrm{D})$ is the **total probability** of the data, under any hypothesis.

Cookie Problem

From Allen Downey's version of Um problem

- Suppose there are two bowls of cookies.
- Bowl 1 contains 30 vanilla cookies and 10 chocolate cookies.
- Bowl 2 contains 20 vanilla cookies and 20 chocolate cookies.
- Now suppose you choose **one of the bowls at random** and, without looking, choose **a cookie at random**. If the cookie is **vanilla**, what is the probability that it came from **Bowl 1**?

$$P(B_1|V) = \frac{P(B_1)P(V|B_1)}{P(V)}$$

$$\left.\begin{array}{l} P(V|\mathrm{B}_1) = \frac{3}{4} \text{ and } P(\mathrm{B}_1) = \frac{1}{2} \\ P(V) = P(\mathrm{B}_1)P(V|\mathrm{B}_1) + P(\mathrm{B}_2)P(V|\mathrm{B}_2) \\ P(V) = \frac{1}{2} \times \frac{3}{4} + \frac{1}{2} \times \frac{1}{2} = \frac{5}{8} \end{array}\right\} \quad P(\mathrm{B}_1|V) = \frac{\frac{1}{2} \times \frac{3}{4}}{\frac{5}{8}} = \frac{3}{5}$$

Bayes Tables

Useful tools to calculate Bayesian probabilities.

Normalized multiplication of prior and likelihood = Posterior

	prior	likelihood	unnorm	posterior
Bowl 1	0.5	0.75	0.375	0.6
Bowl 2	0.5	0.50	0.250	0.4

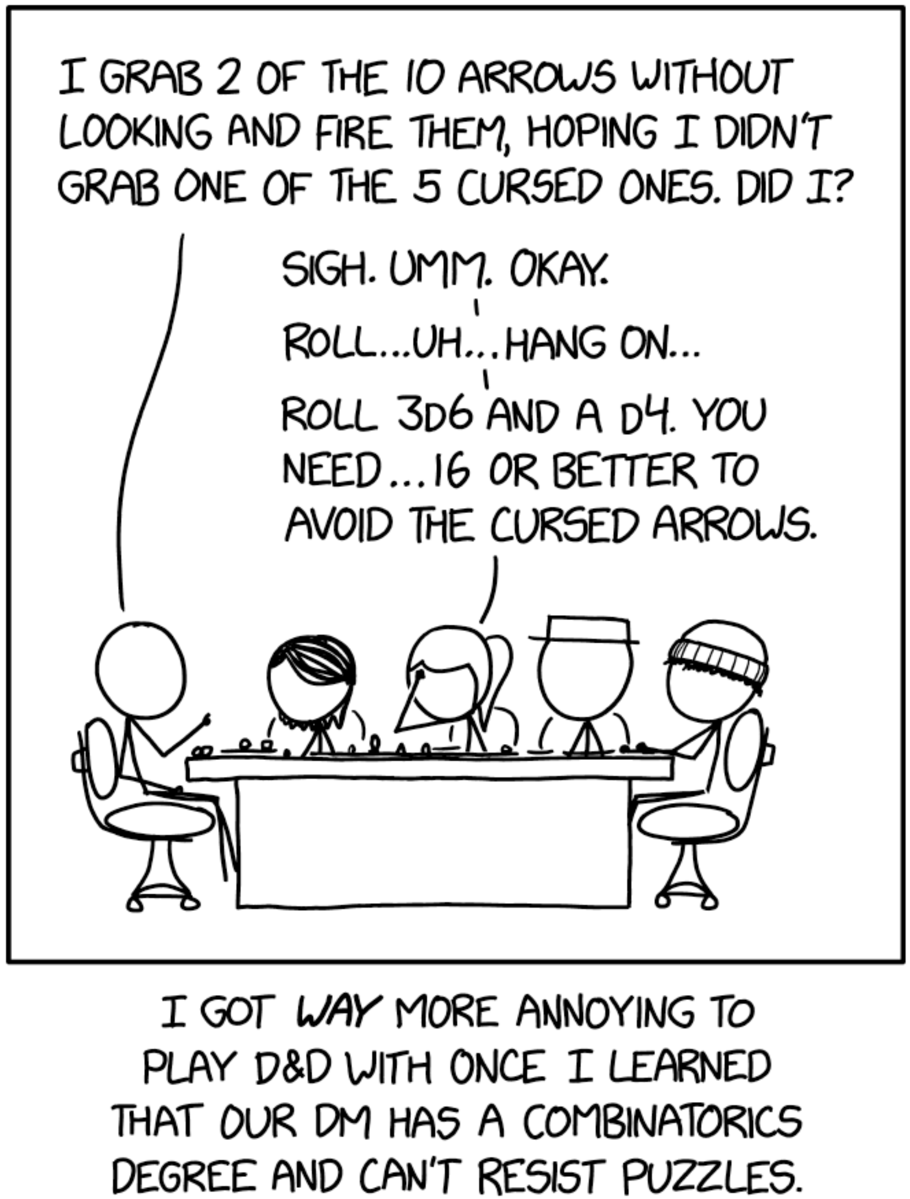
Unnormalized multiplication of prior and likelihood

Dice Problem (more than two distributions)

From Allen Downey's book, Think Bayes

- Suppose there are three dice:
- A 6 sided, an 8 sided and a 12 sided.
- We choose one of the dice at random, roll it, and report that the outcome is a 1.
- What is the probability that I chose the 6-sided die?

	prior	likelihood	unnorm	posterior
6	1/3	1/6	1/18	4/9
8	1/3	1/8	1/24	1/3
12	1/3	1/12	1/36	2/9



Source: https://www.explainxkcd.com/wiki/index.php/3015:_D%26D_Combinatorics

Monty Hall Problem

Selvin, S. (1975)

- Based on a show called “Let’s Make a Deal”.
- You are on a game show and have to choose one of three doors:
- Behind one door is a car, and behind the other two are goats.
- You pick a door (say, Door 1).
- The host, who knows what’s behind each door, opens another door (say, Door 3) revealing a goat.
- You are then asked:

“Do you want to stick with your choice, or switch to the other unopened door?”

What should you do to maximize your chance of winning the car?

- If the car is behind Door 1, Monty chooses Door 2 or 3 at random, so the probability he opens Door 3 is .
- If the car is behind Door 2, Monty has to open Door 3, so the probability of the data under this hypothesis is 1.
- If the car is behind Door 3, Monty does not open it, so the probability of the data under this hypothesis is 0.

	prior	likelihood	unnorm	posterior
Door 1	1/3	1/2	1/6	1/3
Door 2	1/3	1	1/3	2/3
Door 3	1/3	0	0	0

Notebook 2

Let’s get some hands-on experience with Python.

Recap

- Two views: frequentist vs Bayesian (both useful)
- Bayes' theorem links prior, evidence, posterior
- Next: Bayesian networks & probabilistic modelling

Homework

- Exercise: Fill out the excercises on Jupyter notebooks 1 and 2 for this week, commit your answers and submit .
- Optional: Come up with a new example of where Frequentist/Bayesian approaches are the best.