An Introduction To Bayesian Statistics

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How do we estimate the probability?

- Classical: By considering equal outcomes
- Frequentist: Relative Frequency over time
- Bayesian: By updating our beliefs for each obs.

Coin Toss: Classical Est.

```
   Coin
    |
 -------
 |     |
 H     T

0.5   0.5
```

Dice: Classical Est.

```
                 Dice
                   |
   -----------------------------
   |     |     |     |     |     |
   1     2     3     4     5     6

 0.16  0.16  0.16  0.16  0.16  0.16
```

Classical Stats

- Requirements
  - All Outcomes are known
  - Outcomes are assumed to be equally likely
- Advantages
  - Fast Estimation
  - Easy to understand
- Disadvantages
  - High Bias
  - Outcomes must be known
  - Cannot create sophisticated (high variance) models

How do we estimate the probability?

- ~~Classical~~
- Frequentist
- Bayesian

Thermometer Calibration: Frequentist Est.

- Calibrating Thermometer to show accurate values
- Follows a Normal Distribution

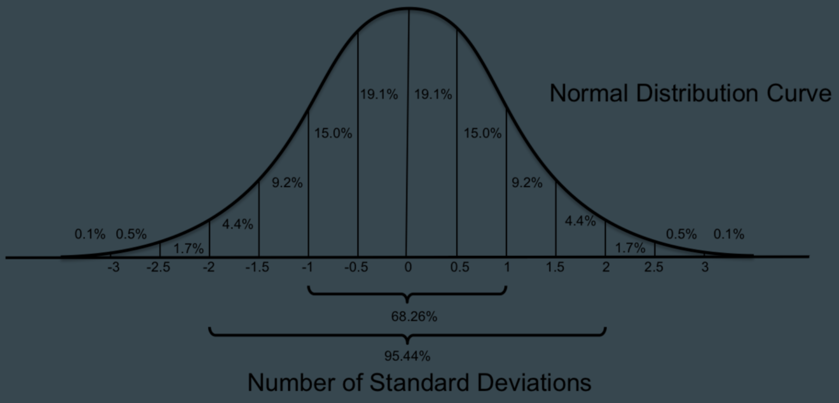
Frequentist Approach:

Take many readings and use the expectation value (mean) to find value over time.

Thermometer Calibration: Frequentist Est.

<u>Confidence Interval</u>:

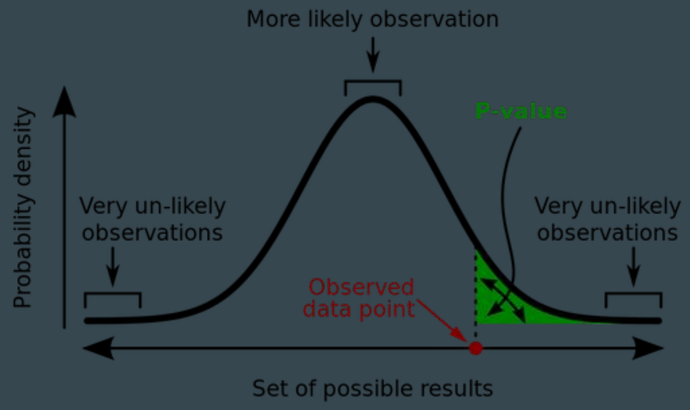
- From sample mean and standard deviation, calculate an interval
- "Interval that contains the true parameter some percent of the time"



Probability of Rain: Frequentist Est.

P-value:

- Probability of data given a parameter
- “The probability that outcome is due to random chance given that there is no difference between experimental groups”
- $P(X \mid \mu)$



Thermometer Calibration: Test

1. Mean thermometer temp is higher than assumed param,
   P-value = 0.001 (highly significant),

   Does this mean that the probability of mean thermometer temp is 0.999? ❌

2. 95% Confidence interval is [98°C, 102 °C] and mean = 100°C,

   Does this mean that 100°C will fall inside this interval 95% of the time? ❌

Thermometer Calibration: Test

1. Mean thermometer temp is higher than assumed param,
   P-value = 0.001 (highly significant),

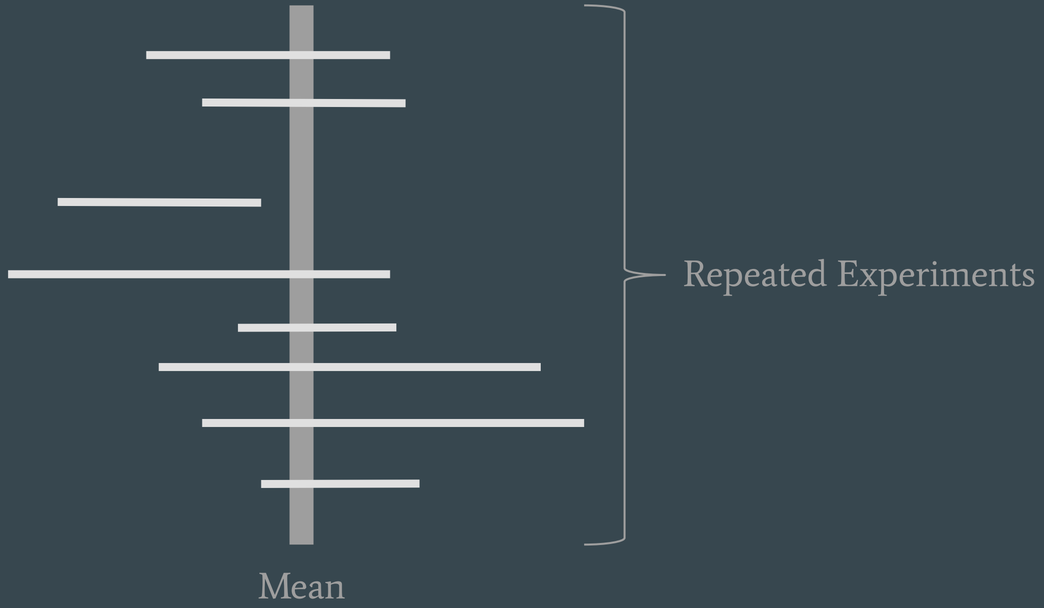
   Probability of getting this result given no difference in experimental groups is 0.001

2. 95% Confidence interval is [98°C, 102 °C] and mean = 100°C,

   Interval will contain the parameter 95% of the time

Thermometer Calibration: Test Learnings

Frequentism expects that parameters exist and are fixed, the probabilities are the likelihood of our data given these expectations



Thermometer Calibration: Test Learnings

Child doesn't move, but you will only take a picture of them 95% of the time

Frequentist Stats

- Requirements
  - Possibility to perform experiments indefinitely
  - Parameters are assumed to be specific values
  - Able to estimate params given enough experiments
- Advantages
  - Works well for simulations
  - “Objective”
- Disadvantages
  - Requires large sample size
  - Does not allow for integration of domain knowledge
  - P-values and confidence intervals are unintuitive
  - Difficult to communicate

Frequentist Stats Disav. Cont.

What if?

- Amount of data you have is limited? ✓
- You have relevant and applicable prior information ✓
- “Infinite” experiments are not possible? (Cost, feasibility) ✓
- Stakeholders have a hard time understanding frequentist logic? ✓
- Children never stay still and assuming they don’t is blasphemy ✓

How do we estimate the probability?

- ~~Classical~~
- ~~Frequentist~~
- Bayesian

Bayes Theorem

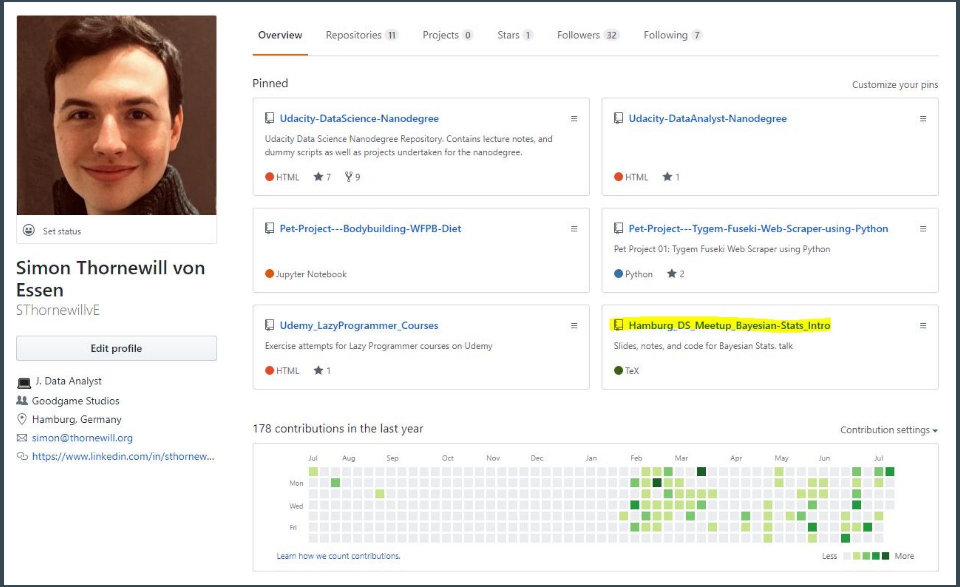
How

Foreshadow MCMC

Conclusion and “Call to Action”

Find Slides on Github

https://cutt.ly/zGqux9



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