Welcome to the CoGrammar Counting, Probability and Statistics Lecture

The session will start shortly...

Questions? Drop them in the chat. We'll have dedicated moderators answering questions.

Coding Interview Workshop Housekeeping

- The use of disrespectful language is prohibited in the questions, this is a supportive, learning environment for all - please engage accordingly. **(Fundamental British Values: Mutual Respect and Tolerance)**
- No question is daft or silly - **ask them!**
- There are **Q&A sessions** midway and at the end of the session, should you wish to ask any follow-up questions. Moderators are going to be answering questions as the session progresses as well.
- If you have any questions outside of this lecture, or that are not answered during this lecture, please do submit these for upcoming Academic Sessions. You can submit these questions here: **Questions**

Coding Interview Workshop Housekeeping cont.

- For all **non-academic questions**, please submit a query: **www.hyperiondev.com/support**
- Report a **safeguarding** incident: **www.hyperiondev.com/safeguardreporting**
- We would love your **feedback** on lectures: **Feedback on Lectures**

Skills Bootcamp
8-Week Progression Overview

Fulfil 4 Criteria to Graduation

✅ Criterion 1: Initial Requirements

Timeframe: First 2 Weeks
Guided Learning Hours (GLH): Minimum of 15 hours
Task Completion: First four tasks

Due Date: 24 March 2024

✅ Criterion 2: Mid-Course Progress

60 Guided Learning Hours

Data Science - **13 tasks**
Software Engineering - **13 tasks**
Web Development - **13 tasks**

Due Date: 28 April 2024

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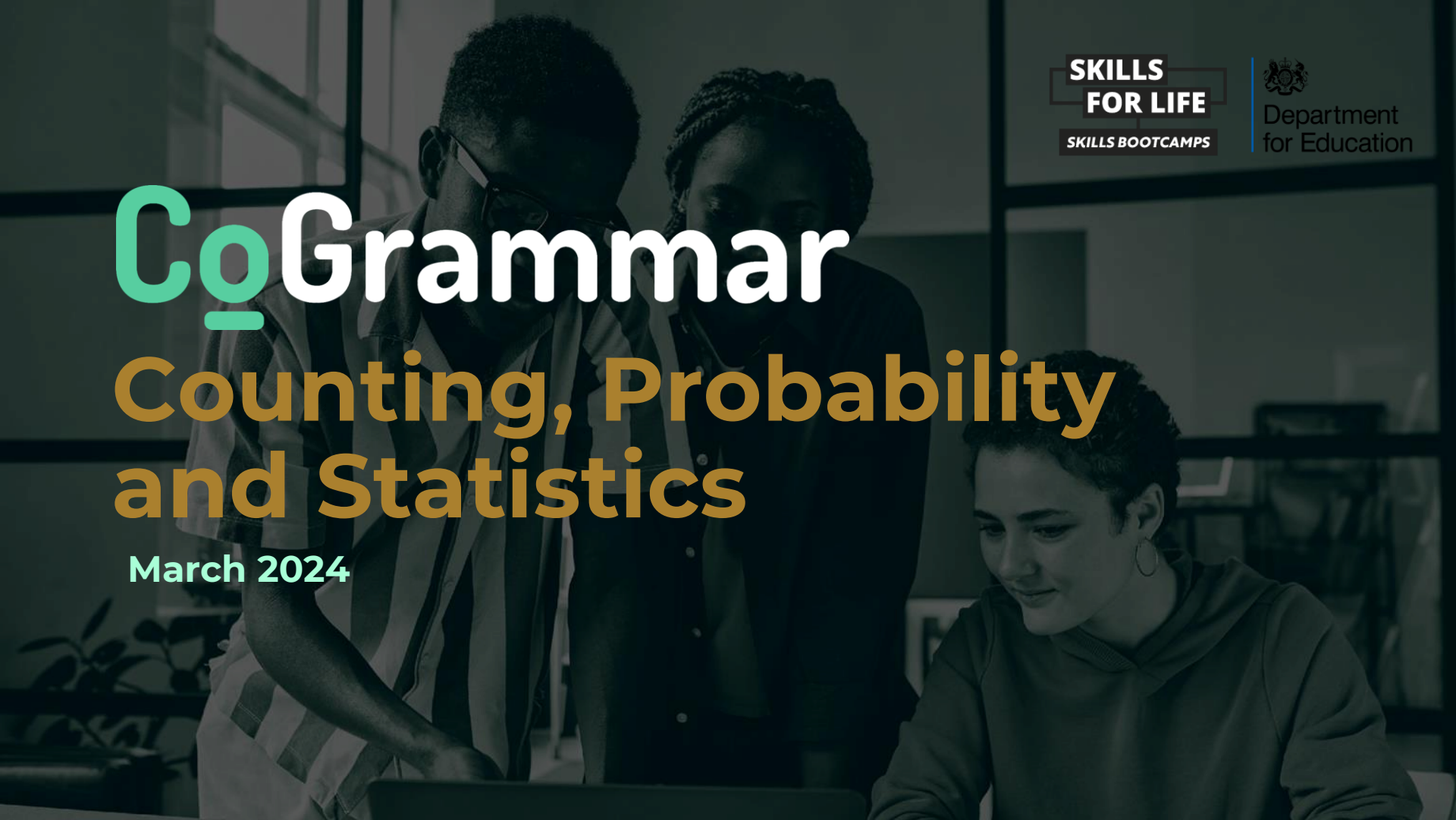
Skills Bootcamp Progression Overview

✅ Criterion 3: Course Progress

Completion: All mandatory tasks, including Build Your Brand and resubmissions by study period end
Interview Invitation: Within 4 weeks post-course
Guided Learning Hours: Minimum of 112 hours by support end date (10.5 hours average, each week)

✅ Criterion 4: Demonstrating Employability

Final Job or Apprenticeship Outcome: Document within 12 weeks post-graduation
Relevance: Progression to employment or related opportunity



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Counting, Probability and Statistics

March 2024

Portfolio Assignment Reviews

Submit you solutions here!

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Learning Objectives

- Apply **basic counting principles** and calculate **permutations** and **combinations** for solving practical problems.
- Utilize **fundamental probability concepts** and **Bayes' theorem** to model and solve real-world scenarios.
- Compute and interpret **descriptive statistics** to analyze and summarize data sets.

Learning Objectives

- Identify and apply appropriate **distributions** and understand **sampling techniques** for data modelling.
- Introduce basic **inferential statistics**, including **hypothesis testing** and calculating **confidence intervals** to make data-driven decisions.

What is the total number of ways to arrange the letters in the word "PYTHON"?

A. 120
B. 720
C. 5040
D. 363880

Correct Answer: B

- We use the following formula to calculate the number of ways to **arrange** a set of items:

$$P(n,r) = \frac{n!}{(n-r)!}$$

Where n is the number of items we have to **choose** from and r is the number of items we want to **arrange**. P is the number of **permutations**.

- In our case, n = r:

$$P(n,r) = n!$$
$$P(6,6) = 6! = 720$$

Correct Answer: B

- This should not be confused with the number of way to **choose** or **select** a set of items.
- This is known as the number of **combinations**.
- In this case, the order does not matter i.e. if you select 3 items 1, 2, 3 and then select 3 items 2, 3, 1; this would be considered to be the **same** selection.
- When order doesn't matter, we have less options compared to when order does matter.

In a standard deck of playing cards, what is the probability of drawing a heart or a king?

A. 1/2
B. 1/4
C. 1/13
D. 1/4 + 1/13

Correct Answer: D

- There are **52 cards** in a standard playing card deck.
- The cards are divided into **4 suites** with **13 cards** in each.
- The 13 cards consist of numbered cards from 1-10, a jack, a queen and a king.
- The **probability of an outcome** is:

$$P(E) = \frac{number\ of\ favourable\ outcomes}{total\ number\ of\ outcomes}$$

Correct Answer: D

- When we want to combine probabilities and determine the likelihood of Event A **or** Event B, we use:

$$P(A\ or\ B) = P(A) + P(B)$$

- Thus to calculate the probability of drawing a heart or a king:

$$P(heart\ or\ king) = \frac{13}{52} + \frac{4}{52} = \frac{1}{4} + \frac{1}{13}$$

- Based on this answer, how many cards would you expect to draw before you draw a heart or king?

What is the mean of the following set of numbers: [2, 4, 6, 8, 10]?

A. 4
B. 6
C. 8
D. 10

Correct Answer: B

- The **mean** of a set of numbers is also known as the **average**.
- The mean gives us an indication of the **central tendency** of a distribution.
- The other common measures of central tendency are: **mode** and **median**.

Detour: What is a factorial?

- A factorial, denoted by an exclamation point (**!**), is **the product of all positive integers up to a given number**. So n! = n(n-1)!

  = n(n-1)(n-2)!

  = n(n-1)(n-2)...(n-n)!

  Where (n-n)! = 0! = 1.

- For example 3! = 3 x 2 x 1 x 0! = 3 x 2 = 6. Usually 0! is simply omitted.

Detour: What is a factorial?

```python
#Factorial
num = 5
fact = 1
for i in range(1, num+1):
    fact = fact * i

print("The factorial of "+str(num)+" is: ", fact)
#Output: The factorial of 5 is:  120
```

```javascript
//Factorial
let num = 5;
let fact = 1;
for (let i = 1; i <= num; i++) {
    fact = fact * i;
}
console.log("The factorial of " + num + " is: ", fact);
//Output: The factorial of 5 is: 120
```

```python
#Using math
import math
print("The factorial of "+str(num)+" is: ", math.factorial(num))
#Output: The factorial of 5 is:  120
```

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Permutations

Arrangement of objects where order is important.

- To calculate permutations, we use the following formula

$$P(n,r) = \frac{n!}{(n-r)!}$$

n is the number of items to choose from
r is the number of items chosen to be arranged

- For example, if we have 5 books and we want to arrange 3 on a bookshelf, we would use the following calculation to calculate the number of possible arrangements:

$$P(5,3) = \frac{5!}{(5-3)!} = \frac{120}{2} = 60$$

Permutations Application

In Software Engineering and Web Development, permutations are used in algorithms that require generating all possible arrangements of a set of items.

For example, permutations can be used to generate all possible combinations of a password.

Let's have a look at this in Python :)

Combinations

Selection where order doesn't matter.

- To calculate combinations, we use the following formula

$$C(n,r) = \frac{n!}{r!\,(n-r)!}$$

n is the number of items to choose from
r is the number of items chosen to be chosen

- For example, if we have 10 flowers and we want to choose 3 for a bouquet, we would use the following calculation to calculate the number of possible bouquets:

$$C(10,3) = \frac{10!}{3!\,(10-3)!} = \frac{10 \times 9 \times 8}{6} = 120$$

Combinations Application

In Data Science, combinations are used in feature selection algorithms to choose the best subset of features for a machine learning model.

For example, when building a recommendation system, combinations can be used to select the most relevant features for predicting user preferences.

Let's have a look at this in Python :)

Applications in JS and Python

- We can use the built-in Math library in Python and in JavaScript, the functions need to be created from scratch.

```python
import math

# Calculate permutations of 3 out of 5 items
total_permutations = math.perm(5, 3)
print("Total permutations:", total_permutations)

# Calculate combinations of 3 out of 5 items
total_combinations = math.comb(5, 3)
print("Total combinations:", total_combinations)
```

```javascript
// The number of ways to arrange items
function permutations(n, r) {
    return factorial(n) / factorial(n - r);
}

// The number of ways to select items
function combinations(n, r) {
    return factorial(n) / (factorial(r) * factorial(n - r));
}
```

Probability

- **Sample Space:** The set of all possible outcomes.
- **Events:** Specific outcomes or sets of outcomes from the sample space.

For example, if {2.2, 2.6, 2.8, 2.9} is the **sample space**, then {2.2, 2.6} is one of the **events.**

In the case of flipping one coin, {Heads, Tails} is the **sample space** and {Heads} is one **event**.

Probability

The likelihood of the occurrence of a specific event in a sample space.

- To calculate the probability of an event (E), we use the following formula

$$P(E) = \frac{number\ of\ favourable\ outcomes}{total\ number\ of\ outcomes}$$

- The total number of outcomes is the same as the number of outcomes in the **sample space**.
- We can use this definition to calculate the **probability of certain permutations or combinations**.

Probability Rules

- **Addition Rule:** For mutually exclusive events A and B,

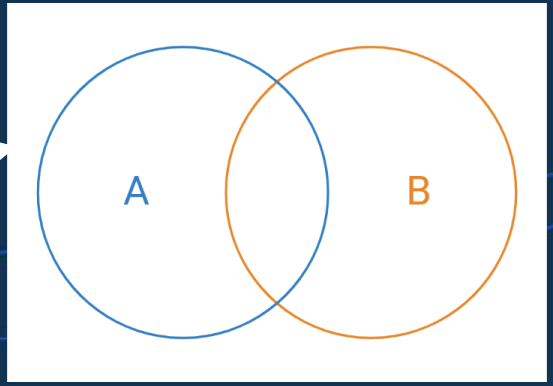
$$P(A \text{ or } B) = P(A) + P(B)$$

This cannot exceed 1.

- **Multiplication Rule:** For independent events A and B,

$$P(A \text{ and } B) = P(A) \times P(B)$$

This is a Venn Diagram, we can use it to visualise these rules :)



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Conditional Probability

- **Conditional Probability:** This is used to calculate the probability of an event A, given that another event B has already happened:

$$P(A|B) = \frac{P(A \text{ and } B)}{P(B)}$$

- **Independence:** Events A and B are independent if their occurrence do not influence each other i.e.

$$P(A|B) = P(A) \quad \text{and} \quad P(B|A) = P(B)$$

Bayes Theorem

- **Bayes Theorem:** A formula for conditional probability which provides a way to revise existing predictions or theories (update probabilities) given new or additional evidence.

$$P(A|B) = \frac{P(B|A) \cdot P(A)}{P(B)}$$

- **Applications:**
  - Calculation of Financial Risk
  - Accuracy of Medical Tests
  - Bayesian Inference and Statistics
  - Machine Learning and Artificial Intelligence
  - Weather Forecasting

Bayes Theorem example

- You are planning a barbeque (braai) today, but the morning is cloudy
  - Oh no! 50% of all rainy days start off cloudy! -> P(Cloud | Rain)
  - But cloudy mornings are common (about 40% of days start cloudy) -> P(Cloud)
  - And this is usually a dry month (only 3 of 30 days tend to be rainy, or P(Rain) = 10%)

What is the chance of rain during the day?

$$P(\text{Rain}|\text{Cloud}) = \frac{P(\text{Rain})\,P(\text{Cloud}|\text{Rain})}{P(\text{Cloud})} = \frac{0.1 \times 0.5}{0.4} = .125$$

Or a **12.5%** chance of rain. Not too bad, let's have a braai!

Let’s Breathe!

Let’s take a small break before moving on to the next topic.

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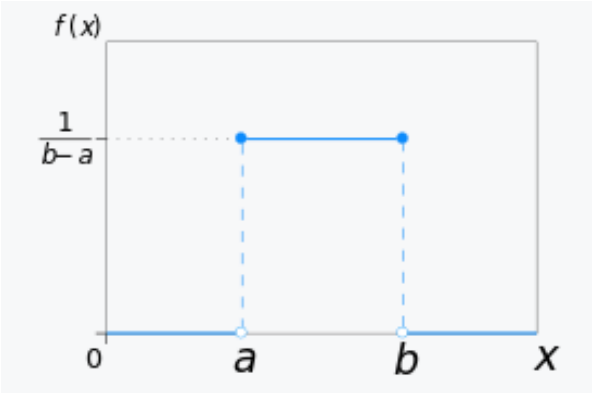
Distributions

- **Random variables:** Numerical description of the outcome of an experiment.
- So far we have looked at experiments with a **finite** number of outcomes. These are known as **discrete random variables**.
- A random variable that can take on **any value** on an **interval** of a **real number line** is called a **continuous random variable**.
- **Probability Distributions:** Describes how the probabilities are distributed over the values of the random variable.
  - In the case of continuous random variables, this is a function f(x).
  - This is a fun tool to help visualise distributions: Probability distribution explorer.

Uniform Distribution

- In a uniform distribution all outcomes are equally likely.

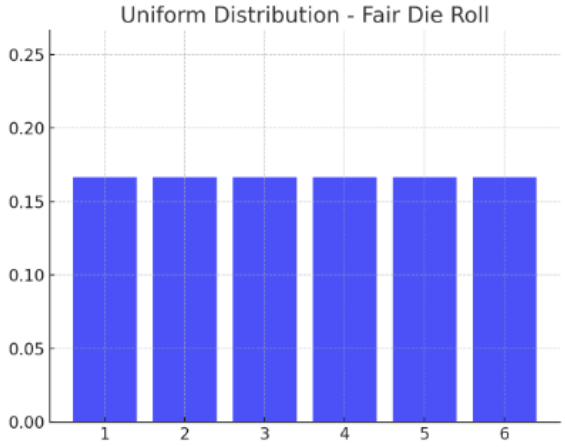


$$f(x) = \begin{cases} \frac{1}{b-a} & \text{for } a \leq x \leq b, \\ 0 & \text{for } x < a \text{ or } x > b. \end{cases}$$

Source: https://en.wikipedia.org/wiki/Continuous_uniform_distribution

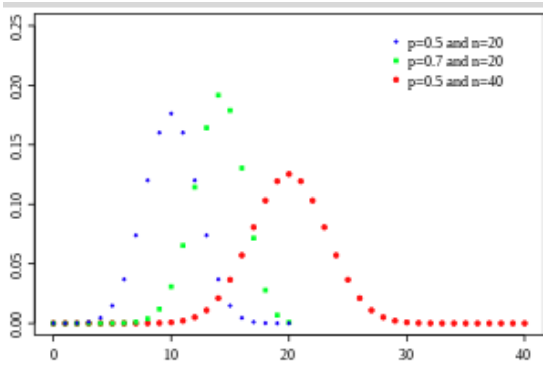
Uniform Distribution

- An example is a fair 6-sided die, which has P(x)=⅙ for all sides.



Binomial Distribution

- Number of successes in a fixed number of trials



$$f(k,n,p) = \Pr(k;n,p) = \Pr(X=k) = \binom{n}{k} p^k (1-p)^{n-k}$$

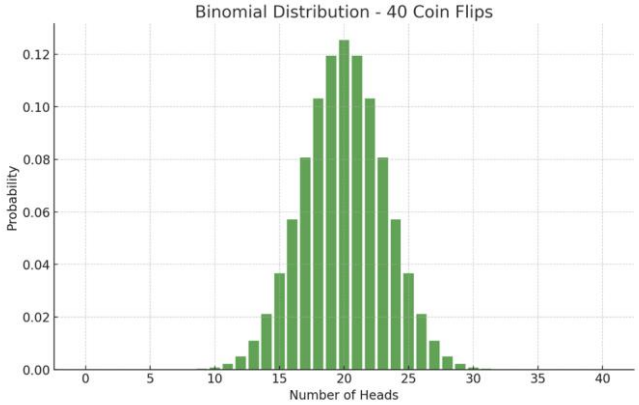
for $k = 0, 1, 2, \ldots, n$, where

$$\binom{n}{k} = \frac{n!}{k!(n-k)!}$$

Source: https://en.wikipedia.org/wiki/Binomial_distribution

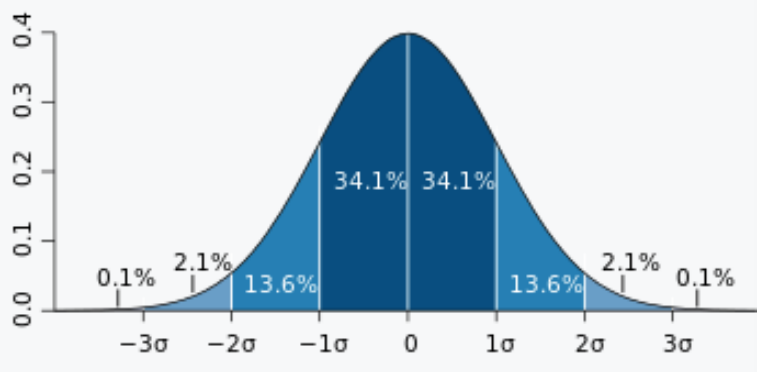
Binomial Distribution

- To get the probability of getting 20 heads in a coin toss when doing 40 trials, substitute in p=½ , n=40, k=20, to get P(40,20,½) = 0.125



Normal Distribution

- Describes data in clusters around a mean. It is the most common distribution in statistics since it tends to represent natural phenomena more accurately than most other distributions most of the time.

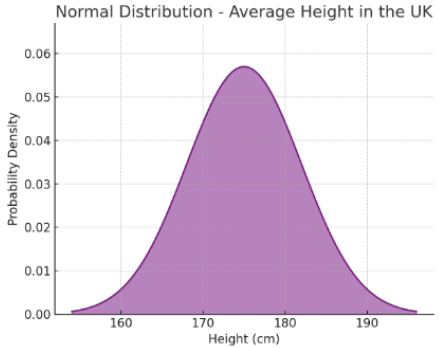


$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}$$

Source:
https://en.wikipedia.org/wiki/Normal_distribution

Normal Distribution

- An example is the height of people. The probability of a male in the UK being between 168 cm (one standard deviation below the mean) and 182 cm (one standard deviation above the mean) is approximately 0.683.
- We get this by calculating the area underneath the curve with P(182)-P(168) where the mean is 175 cm and the standard deviation is 7 cm.



Descriptive Statistics

A set of methods for organising, summarising and presenting data.

- These measures can help us **summarise the features** of a dataset.
- The most commonly used descriptive statistics are:
  - **Mean:** Measure of central tendency, also known as the **average**. It is equal to the sum of the dataset divided by the number of elements.
  - **Median:** Measure of central tendency. The middle value when the dataset is sorted in ascending or descending order.
  - **Mode:** Measure of central tendency. The value which has the highest frequency in the data.
  - **Variance:** Measure the spread of data around the mean.
  - **Standard Deviation:** Square root of the variance, measures dispersion about the mean.

Descriptive Statistics

Calculation	Formula	Notes
Population Mean	$\mu = \frac{\Sigma X_i}{N}$	μ = population average X = individual values of population N = count of individual values
Sample Mean	$\bar{x} = \frac{\Sigma x_i}{n}$	$\bar{x}$ = sample average x = individual values of population n = count of individual values in sample
Weighted Mean	$\bar{x} = \frac{\Sigma w_i x_i}{\Sigma w_i}$	$\bar{x}$ = weighted sample average w_i = weight of value *i* x_i = individual value to be weighted
Sample Mean of grouped data	$\bar{x} = \frac{\Sigma f_i x_i}{n}$	f_i = number of observations in the ith group x_i = midpoint of the ith class n = count of all observations of ith classes
Mean Deviation	$MD = \frac{\Sigma \lvert x_i - \bar{x} \rvert}{n}$	$\bar{x}$ = sample average x = individual values in sample n = count of individual values in sample
Population Variance	$\sigma^2 = \frac{\Sigma (X_i - \mu)^2}{N}$	μ = population average X = individual values in population *N* = count of values in population

heights=[168,170,150,160,182,140,175,191,152,150]

mean = np.mean(heights) -> **Mean** = 163.8

Median
heights.sort()
median = np.median(heights) -> **Median** = 164.0

Mode
import statistics as stats
stats.mode(heights) -> **Mode** = 150

Variance
np.var(heights) -> **Variance** = 235.359

Standard deviation
np.std(heights) - > **Standard deviation** = 15.341

Inferential Statistics

Use of data from a sample to make inferences or predictions about a population

- Inferential statistics help us **make estimates and predictions** about our population and **test hypotheses** made about our population.
- Inferential Statistics allow us to use the sample to make reasonable estimates about the population as a whole.
- **Hypothesis testing:** Involves setting up a **null hypothesis** and an **alternative hypothesis** and then conducting a **statistical test of significance**. Conclusions are drawn based on the **test statistic**, the **critical value** and the **confidence interval**.
- **Confidence Interval:** Helps us estimate the parameters of a population. It allows us to **quantify the accuracy** of our estimates.

Statistics in Code

- JavaScript is usually **not** used to perform extensive statistical calculations and analyses.
- In Python, the **scipy** library provides extensive statistical functions and tools to help us analysis data sets and make predictions.

```python
from scipy import stats
import numpy as np

data = np.array([23, 78, 789, 12, 90, 384, 12, 3759, 109, 45, 67])

# This function returns descriptive statistics for this dataset
# Including mean, variance, min and max
print(stats.describe(data))
```

Which of the following is an example of a continuous random variable?

A. Number of heads in 10 coin flips
B. Temperature in degrees Celsius
C. Number of students in a class
D. Number of cars passing a toll booth in an hour

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Correct Answer: B

- A continuous random variable **cannot be counted** and its value falls within a certain interval.
- It's value is dependent on a possible outcome of an experiment, thus *"Temperature in degrees Celsius"* is the best answer to this question.
- All the other options, despite being possible outcomes of an experiment, are all countable variables. Thus they would be **discrete random variables**.

In Python, which library can be used for calculating basic statistical measures such as mean, median, and standard deviation?

A. math
B. statistics
C. numpy
D. scipy

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Correct Answer: D

- The **scipy** Python module is the best choice for calculating statistics of a dataset.
- The built-in Python **statistics** module was not intended for use with large datasets and complex statistics.
- The **numpy** library also provides statistically functions but in it's documentation it is said to be less efficient than SciPy.

Portfolio Assignment: SE

Event Probability Simulator

Objective: Build a Python application that simulates the probability of different outcomes for given scenarios. The tool should allow users to define a scenario, including the number of trials and the specific events to simulate, and then output the probability of each event occurring.

Portfolio Assignment: SE

Requirements:

- Develop the application in Python, using libraries like numpy or scipy for mathematical operations.
- Allow users to input parameters for simulations, such as the number of trials and event probabilities.
- Implement functionality to calculate permutations and combinations where needed to simulate scenarios (e.g. drawing cards from a deck, dice rolls).
- Utilize Bayes' theorem to update probabilities based on new information for certain scenarios.
- Include a README file that explains how to use the application, with examples of different scenarios and how to interpret output.

Portfolio Assignment: DS

Descriptive Statistics and Data Visualization Tool

Objective: Create a Python script that computes descriptive statistics for a given dataset and visualizes these statistics through various charts and graphs. The tool should help in understanding the distribution, central tendency, and variability of data.

Portfolio Assignment: DS

Requirements:

- Utilize pandas for data manipulation and matplotlib or seaborn for creating visualizations.
- Compute basic descriptive statistics (mean, median, mode, standard deviation, quartiles) and display them in a user-friendly format.
- Create visualizations such as histograms, box plots, and scatter plots to represent the data distribution and statistical summaries.
- Implement functionality to apply basic inferential statistics techniques, like calculating confidence intervals for sample means.
- Provide a README file detailing the tool's functionality, how to run it, and examples of output given sample datasets.

Portfolio Assignment: WD

Interactive Hypothesis Testing Tool

Objective: Develop a web application that allows users to perform hypothesis testing on data they input. The application should guide users through selecting a hypothesis, choosing a significance level, and then inputting or uploading data to test against the hypothesis.

Portfolio Assignment: WD

Requirements:

- Build the application using HTML/CSS for the frontend and JavaScript for the backend logic.
- Design an intuitive UI for users to input their hypothesis, select a significance level (e.g., 0.05, 0.01), and input or upload their data.
- Calculate and display the result of the hypothesis test, including the p-value and whether the hypothesis is accepted or rejected at the chosen significance level.
- Offer brief explanations or tooltips about the hypothesis testing process and the significance of the p-value and confidence intervals.
- Include a README file with instructions on setting up and using the application, along with a simple example to demonstration.

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Q & A SECTION

Please use this time to ask any questions relating to the topic, should you have any.

Thank you for attending

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