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.

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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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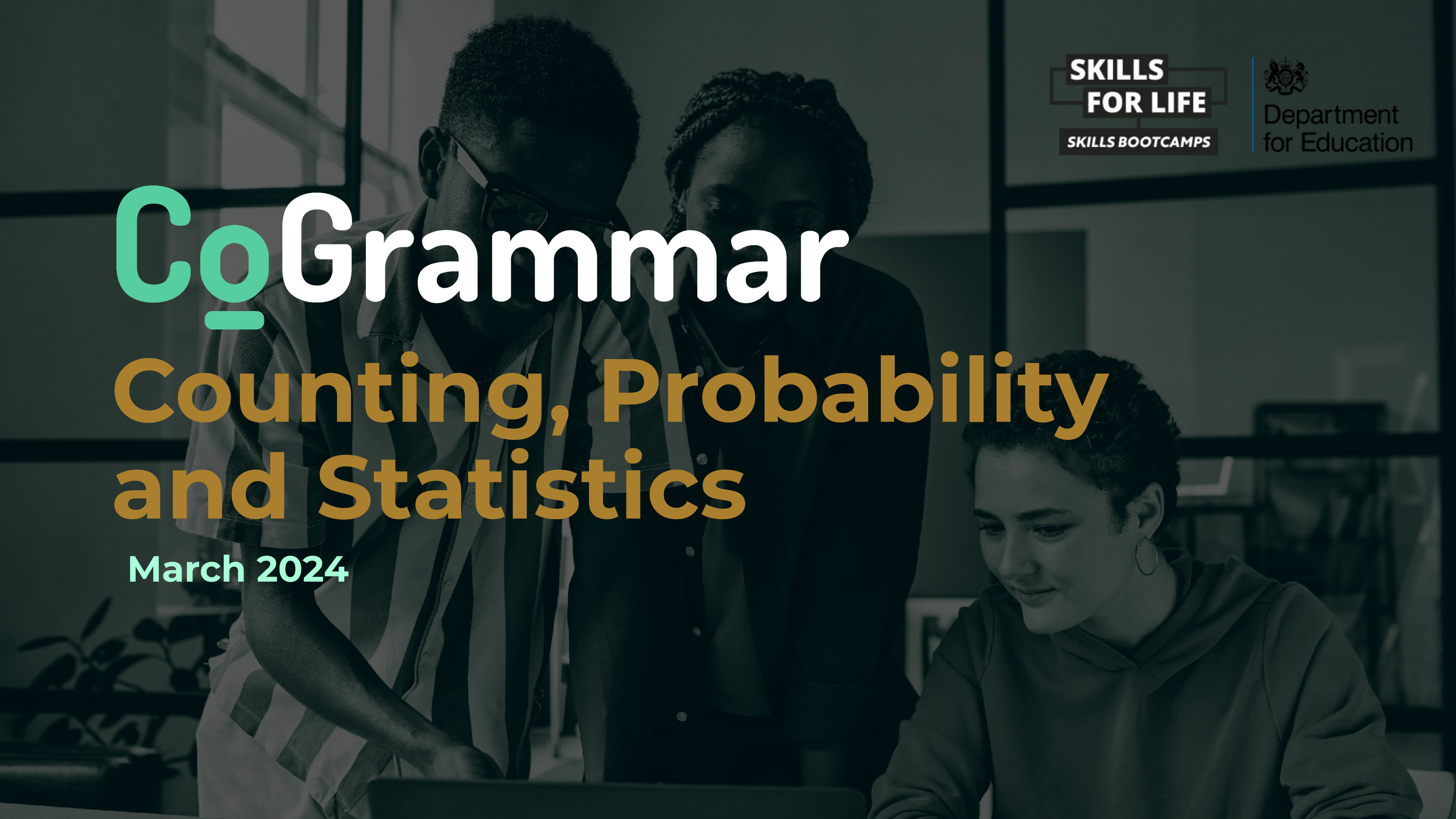

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Counting, Probability and Statistics

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:

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

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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. 4/13

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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:

$$P(heart\ or\ king) = \frac{13}{52} + \frac{4}{52} - \frac{1}{52} = \frac{16}{52} = \frac{4}{13}$$

- ❖ 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)!

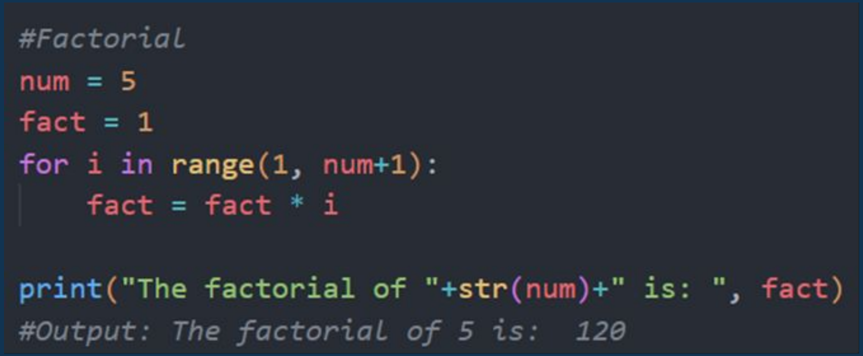
  = n(n-1)(n-2)!

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

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

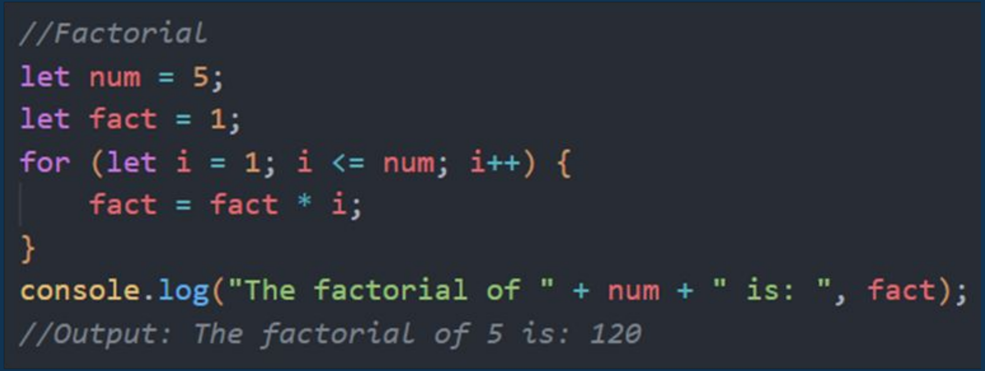
- For example 3! = 3 x 2 x 1 x 0! = 3 x 2 = 6. Usually 0! is simply omitted.

Detour: What is a factorial?

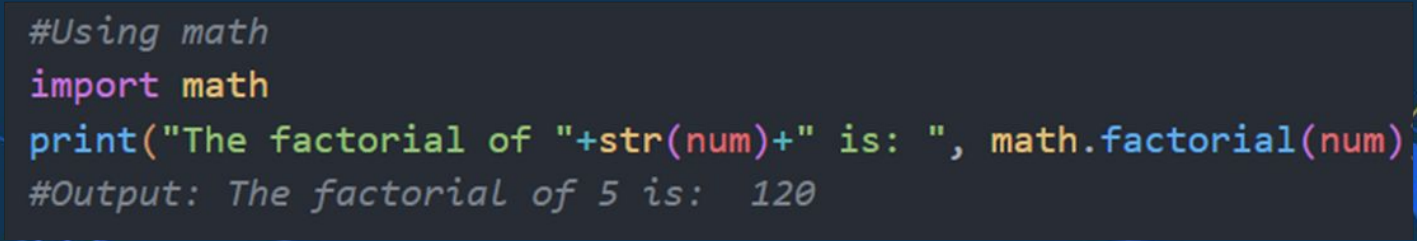


```python
#Factorial
num = 5
fact = 1
for i in range(1, num+1):
    fact = fact * i

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
```

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:

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

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Combinations Application

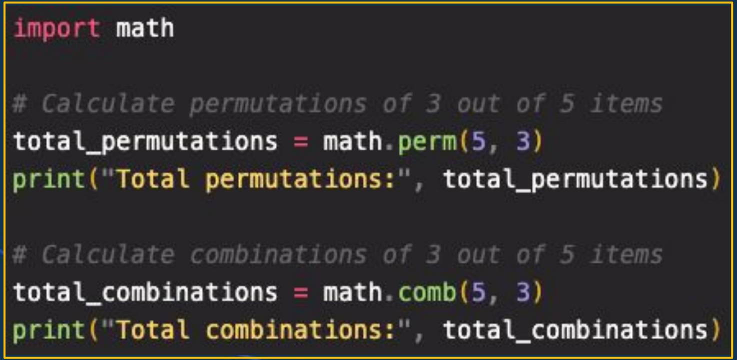
In Data Science, combinations are used in feature selection algorithms to choose the best subset of features for a machine learning model.

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

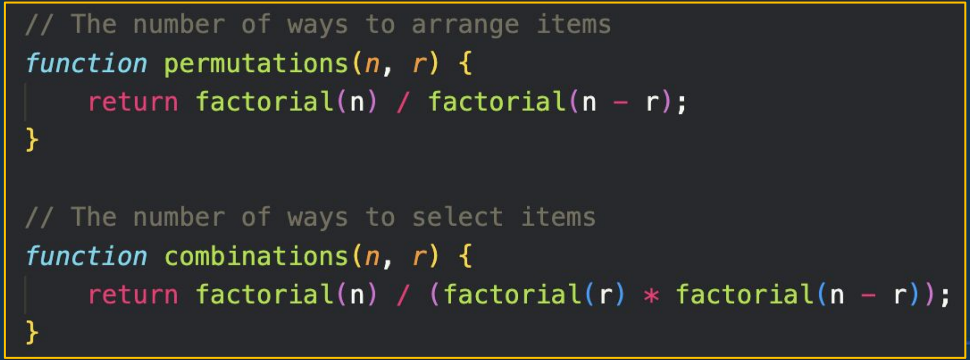
- ❖ We can use the built-in Math library in Python and in JavaScript, the functions need to be created from scratch.



```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**.

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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,

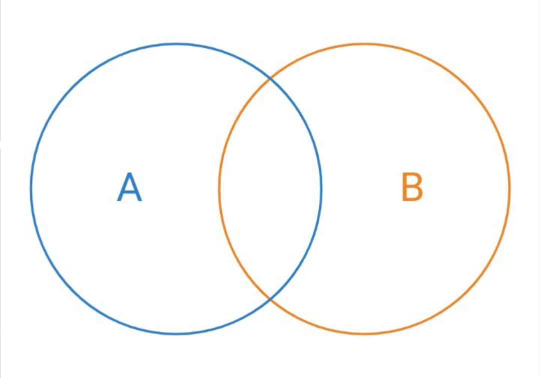
$$\boxed{P(A\ or\ B) = P(A) + P(B)}$$

This cannot exceed 1.

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

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

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:

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

- **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.

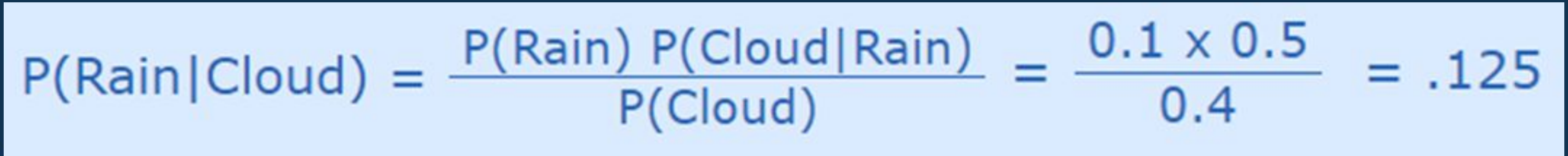
$$\boxed{P(A|B) = \frac{P(B|A) \cdot P(A)}{P(B)}}$$

- **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.

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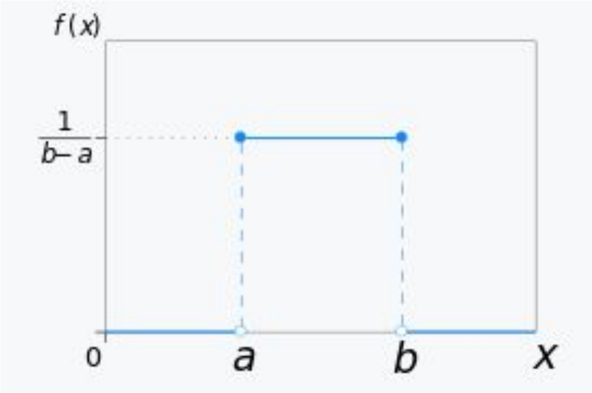
Uniform Distribution

- In a uniform distribution all outcomes are equally likely.



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

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

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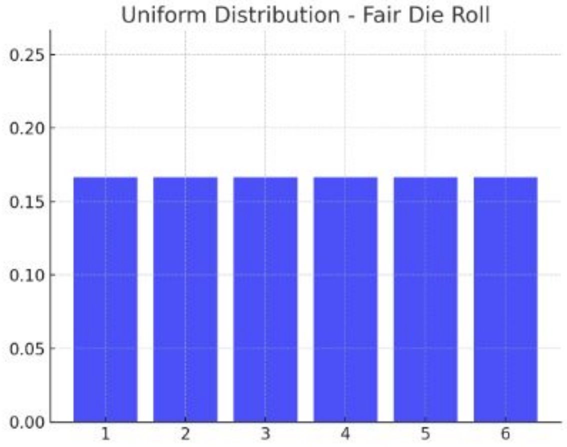
Uniform Distribution

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



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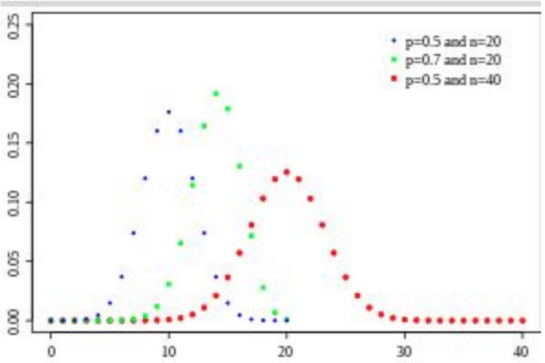
Binomial Distribution

- ❖ Number of successes in a fixed number of trials



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

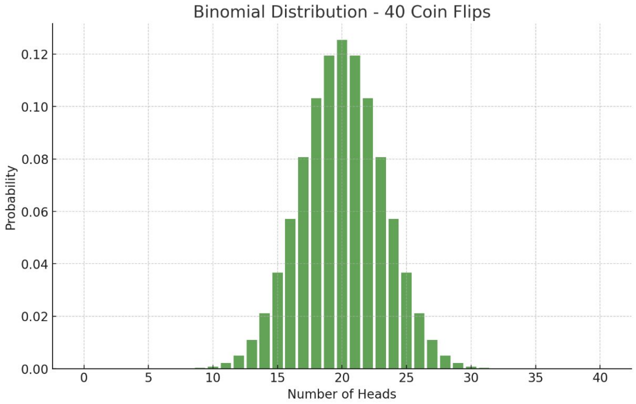
for $k = 0, 1, 2, ..., n$, where

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

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



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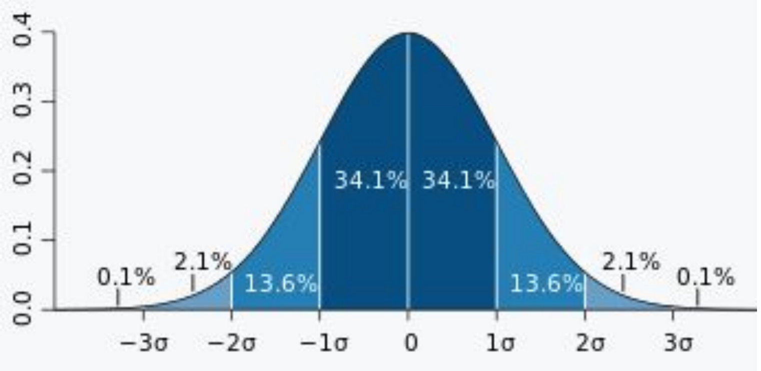
Normal Distribution

- 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

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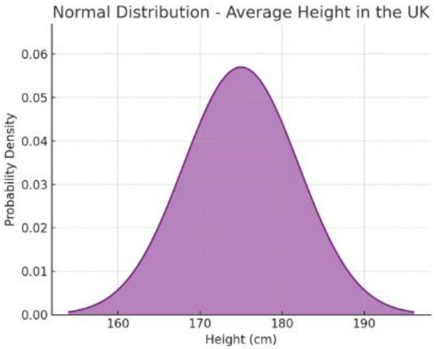
Normal Distribution

- 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.



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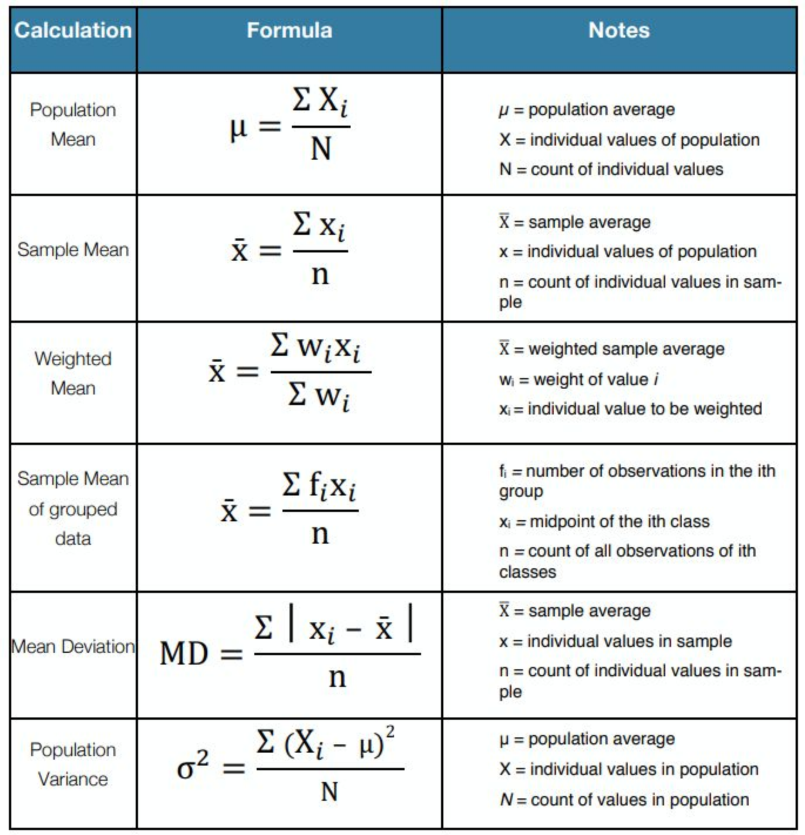
Descriptive Statistics

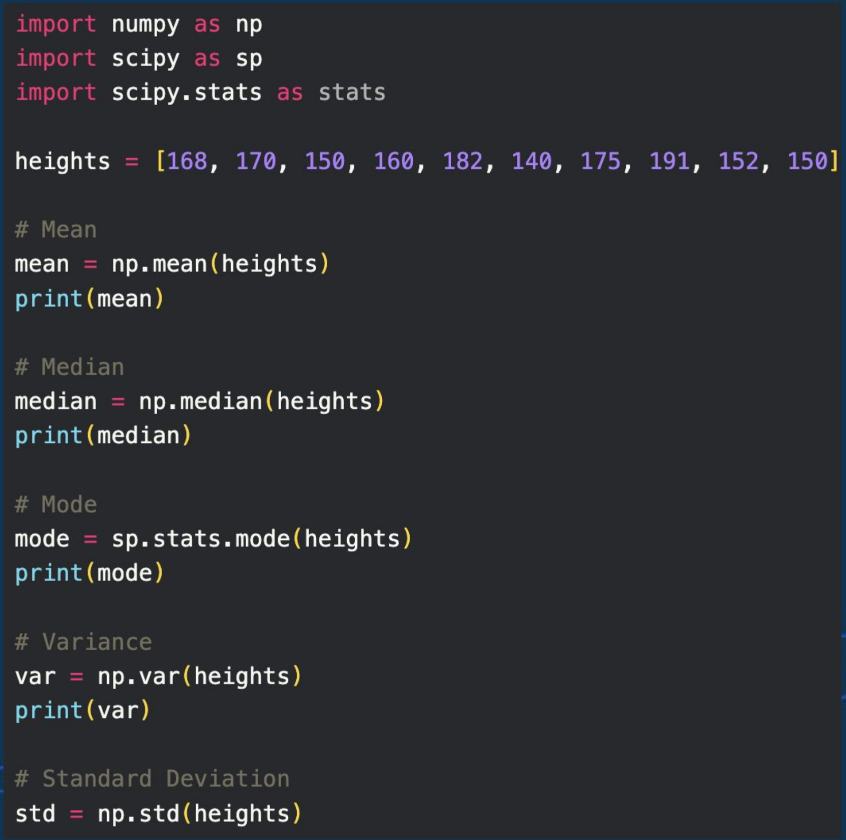
A set of methods for organising, summarising and presenting data.

- 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	$MD = \frac{\Sigma \mid x_i - \bar{x} \mid}{n}$	$\bar{X}$ = 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



```python
import numpy as np
import scipy as sp
import scipy.stats as stats

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

# Mean
mean = np.mean(heights)
print(mean)

# Median
median = np.median(heights)
print(median)

# Mode
mode = sp.stats.mode(heights)
print(mode)

# Variance
var = np.var(heights)
print(var)

# Standard Deviation
std = np.std(heights)
```

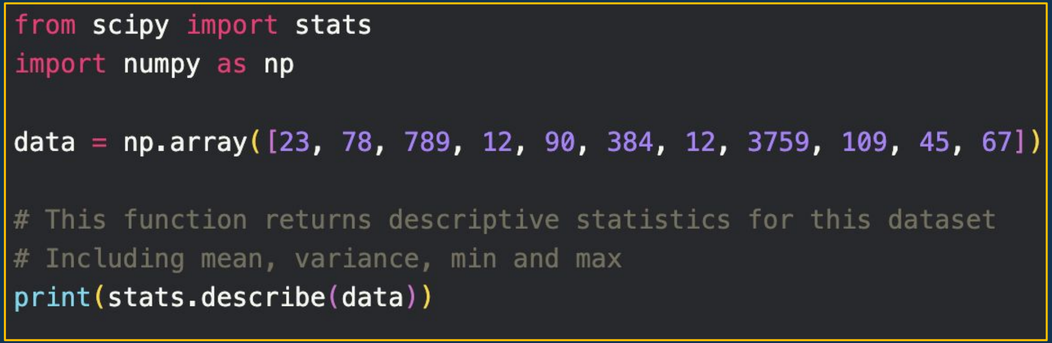
Inferential Statistics

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 and numpy** 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 cannot be used for calculating basic statistical measures such as mean, median, and standard deviation?

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

Correct Answer: A

- 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, but can be used to calculate basic statistics.
- The **numpy** library also provides statistical functions but in it’s documentation it is said to be less efficient than SciPy. It is best used for descriptive statistics an basic statistical functions.

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.

Summary

Variables

- ➢ Represent unspecified values in algebraic expressions and equations.

Sets

- ➢ Store a collection of distinct objects known as elements.

Functions

- ➢ Relations between a set of inputs and a set of permissible outputs.
- ➢ Each input of a function is related to at most one output.

Summary

Asymptotes

- ➢ A line that a curve approaches as it heads towards infinity.

Complexity Analysis

- ➢ A measure of the amount of resources, such as time and/or space, required by an algorithm to solve a problem as a function of the size of the input.

- ➢ Measured by Big O Notation, which measures the worst-case complexity and allows comparison of algorithms.

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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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