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SMARt COmmunities Skills Development in Europe

Urban Data Analytics

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HELLENIC OPEN UNIVERSITY

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Unit 1 – Taxonomy of Data Analytics' Techniques

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Module Aim and objectives

- This modules describes the key aspects of urban data analytics and techniques and tools to solve real-world problems. It includes being able to (i) explain the main sources and types of urban data (ii) discuss the different stages within the data lifecycle, (iii) describe big data characteristics, sources and types; (iv) present the big data analytics categories, (v) provide use cases for each category in the context of smart cities; (vi) use tools to perform big data analysis, (vii) demonstrate in detail how data analytics can enhance decision making through comprehensive real-world case studies.

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- Unit 1 – Taxonomy of Data Analytics' Techniques
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Unit 1 - Aim and objectives

- This unit introduces trainees to data analytics. Trainees will also become familiar with the taxonomy of data analytics' techniques.

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Unit 1 - Learning outcomes

- Describe the basic data analytics techniques.
- Present big data analytics applications to smart cities.

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Terms and keywords

- Data analytics
- Descriptive Analytics, Predictive Analytics, Clustering Analytics
- Anomaly/Outlier Detection Analytics
- Recommendation Analytics
- Text Analytics, Audio Analytics, Image/Video Analytics

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Descriptive Analytics techniques

- Descriptive statistics is a branch of statistics that involves summarizing and organizing data that has been collected.
- It involves the use of measures such as the mean, mode, median and range to describe the data.
- It also involves techniques such as graphical representation of the data using histograms and bar charts.
- Descriptive statistics are used to describe the data, make it easier to understand and interpret, and can provide useful information about the sample.

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Descriptive Analytics in smart cities

- Descriptive statistics can be used to analyze the number of connected devices in a city, the average energy consumption of connected buildings, and the number of transportation users. By looking at these metrics, city officials can gain insights into the performance of their city systems and plan for future upgrades and improvements.
- Descriptive statistics can be used to compare different smart cities to each other and see if there are certain factors that are more successful or efficient than others.

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Run Jupyter Online with Colab

- Google Colab is a cloud-based notebook environment that excels in collaborative work, data analysis, and machine learning tasks.
- Colab comes with many pre-installed Python libraries commonly used in data science and machine learning, such as NumPy, pandas, matplotlib. This saves time and effort in setting up the environment.
- Google Colab provides free access to Graphics Processing Units (GPUs) and Tensor Processing Units (TPUs). This is particularly advantageous for training machine learning models that require significant computational power.
- You can write and execute python code, save and share your analyses, and access powerful computing resources, all for free from your browser.
- To start working with Colab you first need to log in to your google/gmail account, then go to this link https://colab.research.google.com

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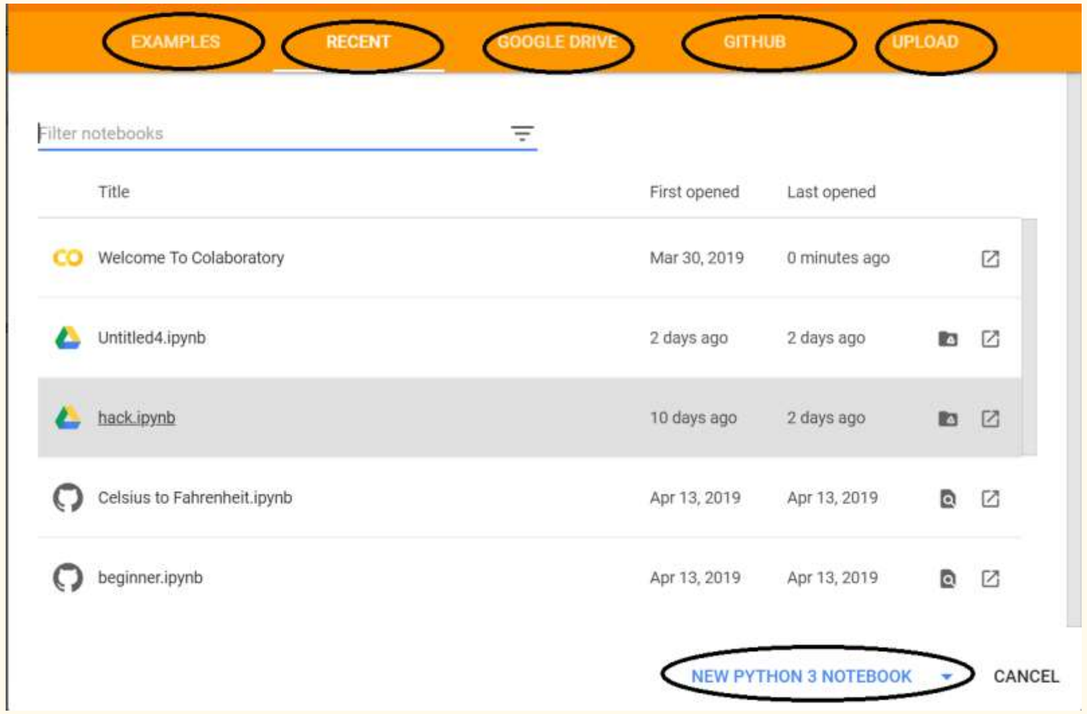
Opening Jupyter Notebooks in Colab

- EXAMPLES: Contain a number of Jupyter notebooks of various examples.
- RECENT: Jupyter notebook you have recently worked with.
- GOOGLE DRIVE: Jupyter notebook in your google drive.
- GITHUB: You can add Jupyter notebook from your GitHub but you first need to connect Colab with GitHub.
- UPLOAD: Upload from your local directory.



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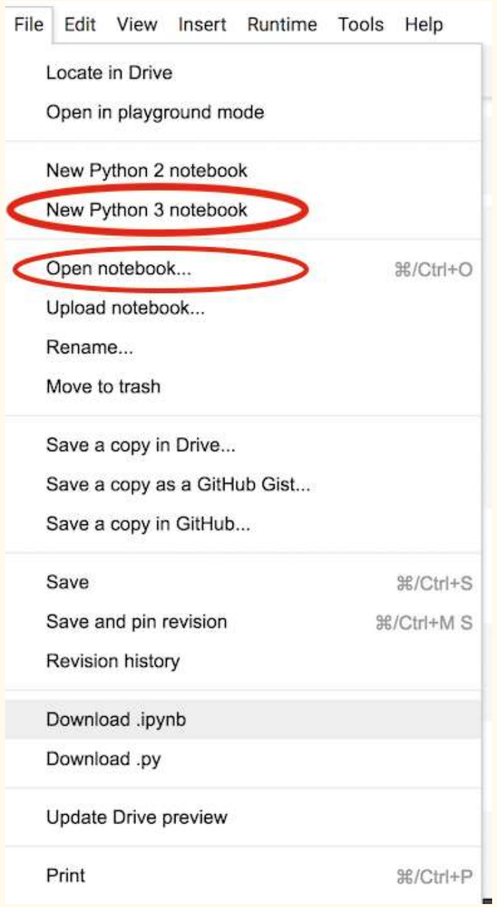
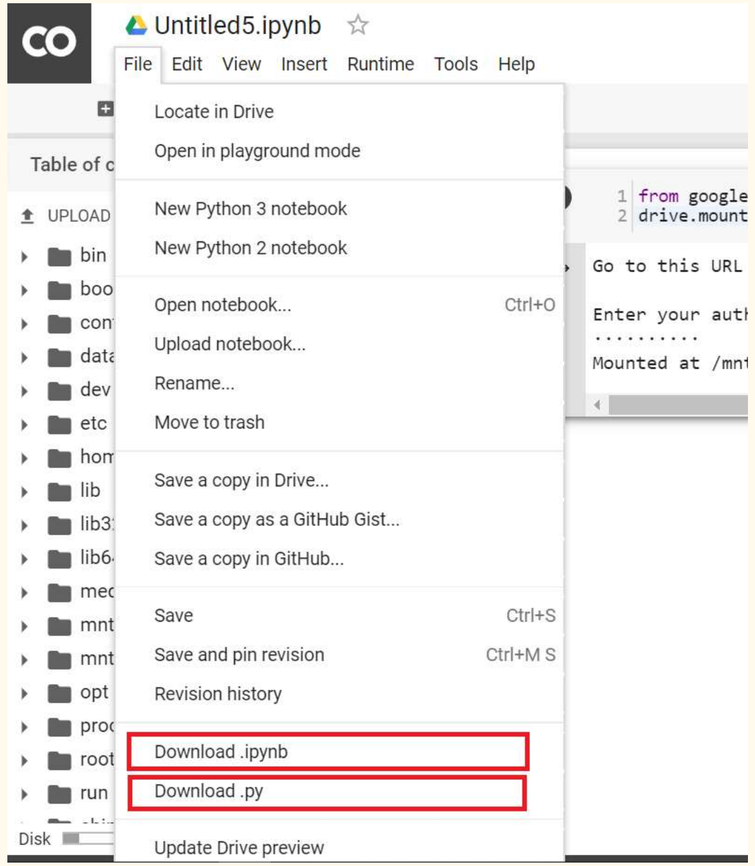
Create/Open/Download a Notebook

- If you want to open something specific, drop the “File” menu down to “Open Notebook…”





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CSV, basic sharing

- A basic approach to share data is the comma separated value (CSV) format
  - it is a text format, accessible to all apps
  - each line (even if blank) is a row
  - in each row, each value is separated from the others by a comma (even if it is blank)
  - cannot capture complex things like formula

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Reading an open dataset using python in google colab

- Dataset available at: https://www.kaggle.com/datasets/magdamonteiro/smart-cities-index-datasets/data

```
# Import the pandas library and alias it as pd for easier use
import pandas as pd
# Read the Smart City data from the provided CSV file URL and store it in the smart_cities DataFrame
!wget --no-check-certificate https://thalis.math.upatras.gr/~sotos/Smart_City.csv
smart_cities = pd.read_csv('Smart_City.csv')
# Display the contents of the smart_cities DataFrame
smart_cities
```

	City	Smart_Mobility	Smart_Environment	Smart_Government	Smart_Economy	Smart_People	Smart_Living	SmartCity_Index	SmartCity_Index_relative_Edmonton
0	Oslo	6480	6512	7516	4565	8618	9090	7138	666
1	Bergen	7097	6876	7350	4905	8050	9090	7296	823
2	Amsterdam	7540	5558	8528	8095	7098	7280	7311	839
3	Copenhagen	7490	7920	8726	5580	5780	7200	7171	698
4	Stockholm	6122	7692	8354	4330	6743	7730	6812	340
...	...	...	...	...	...	...	...	...	...

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Example of descriptive statistics

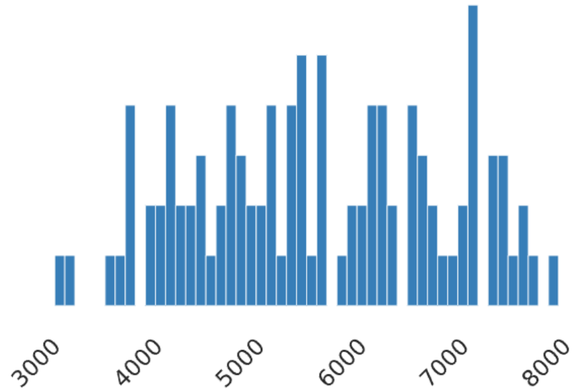
!pip install ydata-profiling #install the library

```
from ydata_profiling import ProfileReport
ProfileReport(smart_cities)
```

Smart_Mobility

Real number (ℝ)

Distinct	100	**Minimum**	3175
Distinct (%)	98.0%	**Maximum**	8110
Missing	0	**Zeros**	0
Missing (%)	0.0%	**Zeros (%)**	0.0%
Infinite	0	**Negative**	0
Infinite (%)	0.0%	**Negative (%)**	0.0%
Mean	5759.402	**Memory size**	944.0 B



- Live demo: https://colab.research.google.com/drive/1B9uDHHi049eZ2LszODpGYI43OpWsWKgD?usp=sharing

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Common terms to analyze the characteristics of a dataset

- **Distinct**: The number of unique values in a particular variable or column of a dataset.
- **Distinct** (%): The percentage of distinct values relative to the total number of values in a variable or column.
- **Missing**: The number of missing (null or undefined) values in a variable or column.
- **Missing** (%): The percentage of missing values relative to the total number of values in a variable or column.
- **Infinite**: The number of infinite values in a variable, which can occur in mathematical operations (e.g., division by zero).
- **Infinite** (%): The percentage of infinite values relative to the total number of values in a variable or column.
- **Zeros**: The number of zero values in a variable or column.
- **Zeros** (%): The percentage of zero values relative to the total number of values in a variable or column.

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Predictive Analytics techniques

- Regression Analysis: Regression analysis is a predictive analytics technique used to analyze relationships among different variables and determine a relationship in the form of an equation. It helps to predict the value of one variable (the dependent variable) based on the value of one or more other variables (the independent variables).
- Classification Analysis: Classification analysis is a popular supervised learning technique used to predict the categorical class of given data points. The classification process works by learning from previously labeled data and using it to classify new data points.
- Time Series Analysis: Time series analysis is a predictive analytics technique used to analyze the sequence of events over a period of time. It is used to understand how the values of a particular variable change over time. It helps to predict future values of the variable, by studying its past behavior.

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Applications of regression in smart cities data

- Transportation Planning: Regression techniques could be used to help better model traffic patterns or predict demand for public transportation.
- Land Use Mapping: Regression could be used to predict land use patterns, helping cities anticipate real estate development and urban density.
- Utility Resource Management: Regression could help urban planners anticipate and manage energy and water supply needs.
- Garbage Collection/Recycling: Regression could be used to calculate an area's trash collection needs and ensure efficient removal of waste.

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Example of regression analysis

- If you are interested in exploring the relationship between personal injuries and projected population using linear regression

- Use a linear regression model to fit the data. The model equation would be of the form:

  $$Y = \beta_0 + \beta_1 \cdot X + \epsilon$$

- Y is the dependent variable (personal injuries).
- X is the independent variable (projected population).
- β_0 is the intercept, representing the expected value of Y when X is 0.
- β_1 is the slope, indicating the change in Y for a one-unit change in X.
- ϵ represents the error term.

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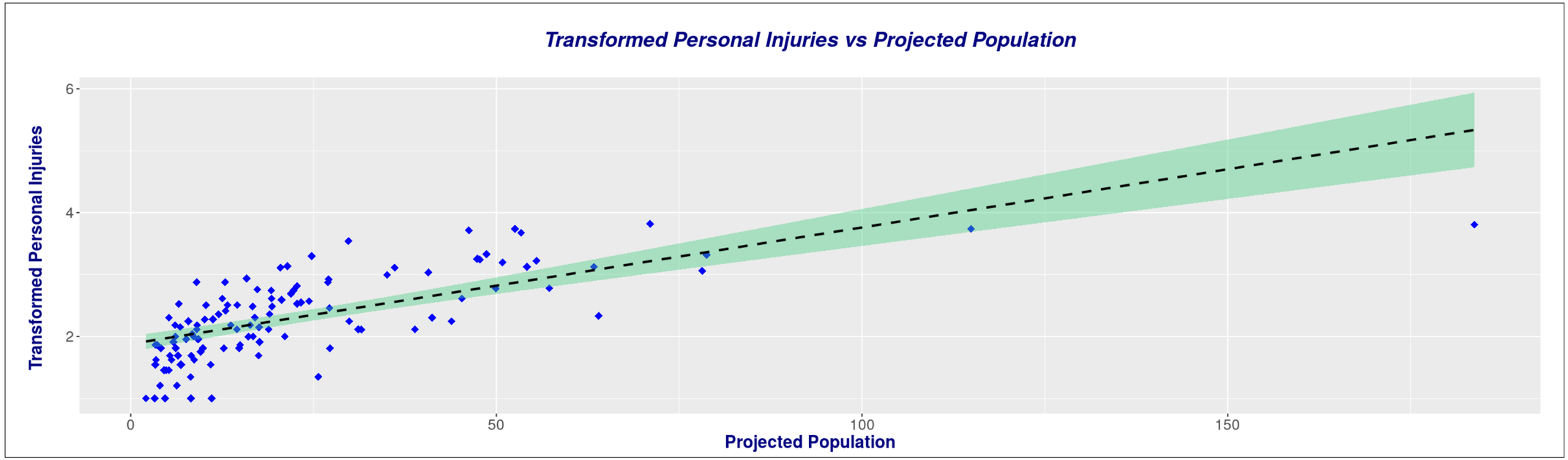
Example of regression analysis



Live demo: https://danielrivera1.shinyapps.io/Regression2/

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Applications of classification in smart cities data

- Automated Traffic Control: Smart cities use classification algorithms to automatically regulate traffic flow on different roads and intersections. The algorithms can detect patterns in traffic flow data and adjust traffic signals accordingly.
- Waste Management: Smart cities use classification algorithms to segment the waste coming from various sources such as households, factories, offices, etc. The algorithms can then be used to sort the waste into different categories so it can be processed and recycled more efficiently.
- Crime Detection and Prevention: Smart cities use classification algorithms to detect and prevent crime. The algorithms can be used to identify patterns in crime data such as location, time, type of crime, etc. This information can then be used to predict future crime hotspots and allow law enforcement to take steps to prevent them.

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Applications of time-series analytics in smart cities data

- Predictive Traffic Management: Smart city time-series data can be used to identify and predict potential traffic hot spots in order to better manage traffic flows. Real-time time series data can be gathered from traffic sensors to effectively manage traffic. This data can be used for everything from rerouting traffic to adjusting traffic signal timing.
- Environmental Monitoring: Smart city time-series data can be used to measure and monitor air quality. This data is essential for determining levels of air pollution and monitoring the effects of environmental policies, amongst other things.
- Energy Management and Conservation: Smart city time-series data can help cities to better manage energy use. This data can be used to identify energy hotspots where conservation efforts can be most effective and to improve the overall efficiency of energy systems.

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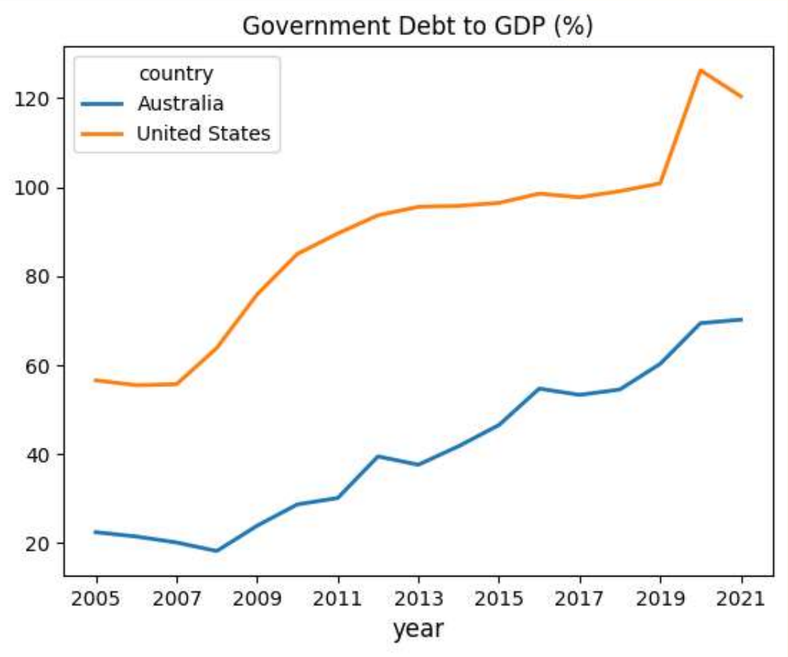
Example of time-series analysis

```python
# Import necessary libraries
from pandas_datareader import wb
import matplotlib.pyplot as plt
# Download government debt to GDP data from World Bank API for the US and Australia
govt_debt = wb.download(indicator='GC.DOD.TOTL.GD.ZS', country=['US', 'AU'], start=2005, end=2021).stack().unstack(0)
# Drop the top-level of the index to get a cleaner index
ind = govt_debt.index.droplevel(-1)
govt_debt.index = ind
# Plotting
ax = govt_debt.plot(lw=2)
ax.set_xlabel('Year', fontsize=12)
plt.title("Government Debt to GDP (%)")  # Add a title to the plot
plt.show()
```



Live demo:
https://colab.research.google.com/drive/1ua4HYjDDc_F4x54WDzJ40TWSgjLm7u1y?usp=sharing

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Clustering Analytics techniques

- Clustering analytics is a type of unsupervised machine learning technique used in data mining to group data points into segments, referred to as clusters. The goal of clustering is to identify patterns and relationships among the data points that share similarities. Clustering algorithms after finding patterns in the data then assigning each data point to a cluster based on those patterns. Well-know clustering algorithms:
  - Hierarchical Clustering: This technique creates a tree-like structure, also known as a dendrogram, to identify clusters of data points and to measure their similarity.
  - K-Means Clustering: This is an iterative technique that randomly assigns data points to clusters based on predetermined criteria. The algorithm measures the closeness of the data points to the cluster center. It then re-adjusts the cluster centers until the criterion is met.
  - Fuzzy C-Means Clustering: This clustering algorithm uses fuzzy logic to identify clusters of data points based on their similarity. It assigns fuzzy values to data points, which allows for more flexibility than other clustering techniques.

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Applications of clustering in smart cities data

- Crime Pattern Analysis: Clustering techniques can be used to detect patterns and trends in crime data collected from various urban sources. By analyzing crime data from a variety of sources, clusters can be identified that indicate areas with higher risk of crime.
- Urban Planning: Clustering algorithms can be used to develop plans for the development of new urban areas. Clusters of similar land use can be identified and used to inform decisions on building construction and land use policies.
- Resource Allocation: Clustering algorithms can be used to optimize the allocation of resources such as electricity, water, medical services and transportation. Clusters of areas with similar needs can be identified and used to ensure that resources are efficiently allocated.
- Waste Management: Clustering algorithms can be used to detect trends in the generation of waste in different areas and inform decisions on waste management. This can be used to ensure that resources are optimally utilized, reduce the environmental impact of waste management and improve overall sustainability.

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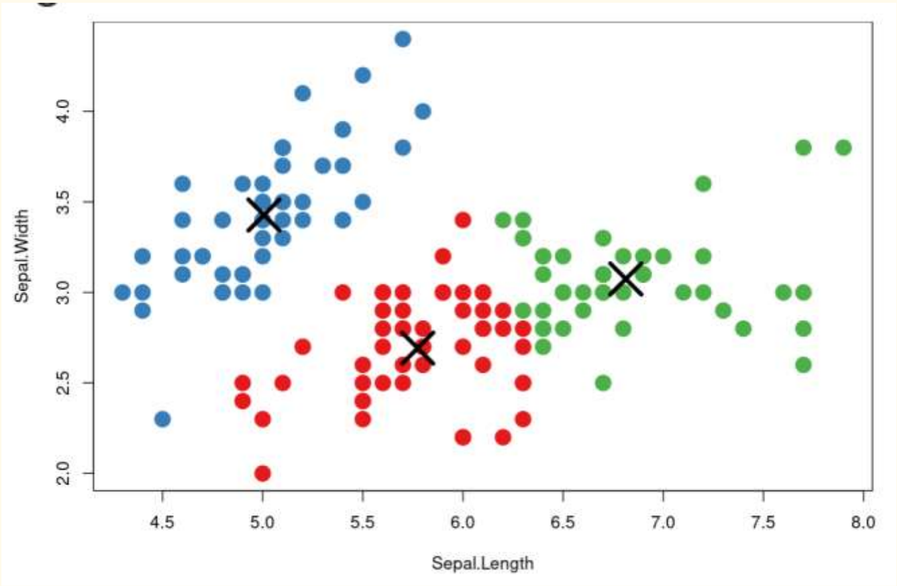
Example of clustering

- K-means algorithm works by randomly selecting k points in the data (which are called centroids) and assigning each data point in the dataset to the nearest cluster based on the distance between the point and the centroid.
- Then, the centroids are re-calculated and the points are re-assigned to the closest centroid.
- This process is repeated until convergence, which is when the centroids stop changing positions.



Live demo:
https://gallery.shinyapps.io/050-kmeans-example/

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Anomaly/Outlier Detection Analytics

- Anomaly/outlier detection analytics is a process used to identify potentially unusual patterns or behaviors in data sets.
- The outlying data points are the anomalies or outliers, which often indicate data entry errors, incorrect data recording, or unusual activities.
- Anomaly and outlier detection analytics typically involves algorithms or data visualization techniques to identify unusual data points, which can then be investigated further for accuracy or corrective action.
- These analytics are most often used in fraud detection and security monitoring.

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Applications of Anomaly/Outlier Detection in smart cities data

- Emergency Management: Anomaly/outlier detection can be used to detect unusual trends in environmental data, such as temperature, water purity, and air quality. This could help predict catastrophes such as floods or bushfires and enable city authorities to take actions to prevent such disasters.
- Energy Optimization: Anomaly/outlier detection can be used to detect anomalies in energy consumption data that may indicate inefficient energy usage or a malfunction in the energy system. This can help city authorities to identify and address energy-related issues in a timely manner.

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Recommendation Analytics

- Recommendation analytics is the process of leveraging data science techniques to analyze user preferences and make predictions about which items someone might like.
- The goal of recommendation analytics is to improve the user experience by recommending items to customers that are relevant and tailored to their individual tastes.
- These recommendations are made using a variety of types of algorithms, such as collaborative filtering or content-based filtering, as well as machine learning techniques.
- By taking into account factors such as user history, demographics, and past purchase behavior, machine learning algorithms can often make more accurate predictions about which items someone might like.

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Applications of Recommendation Analytics in smart cities data

- Smart Parking: Recommendation algorithms can be used to suggest the best available parking spots based on the historical data of at least the immediate past. This can help to identify the estimated occupancy level of individual parking spots in real-time, thereby reducing traffic congestion in areas where parking is limited.
- Smart Energy Usage: Recommendation algorithms can be used to help residents optimize their energy usage. This could involve suggesting the best time to turn on electricity for certain activities, or sending alerts when there is a need to reduce energy consumption.
- Smart Transportation: Recommendation algorithms can be used to suggest the most efficient public transport routes based on the current traffic conditions, helping reduce congestion and improve commuter experience.

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Text Analytics techniques

- Text analytics is a method of analyzing text data to identify trends, patterns, and insights that are not easily discernible from traditional sources of data.
- It uses natural language processing (NLP) algorithms and other analytic techniques to interpret text and generate meaningful data.
- Text analytics can be used in a variety of applications such as sentiment analysis, topic modelling, entity detection, and text classification.
- It can be used to identify patterns in large amounts of data and provide insights that would otherwise be difficult to uncover.

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Applications of text analytics in smart cities data

- Sentiment Analysis: Analyzing the sentiment of social media comments to understand the sentiment of residents toward urban services and development projects.
- Location-Based Analysis: Mining data from consumer reviews and GPS data to gain insights into the patterns of consumer behavior in the city.
- Natural Language Processing: Analyzing natural language in online news articles to better understand events in the city.
- Real-Time Decision Support: Using text mining to develop algorithms for analyzing data in real-time to allow governments to make better-informed decisions.

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Audio Analytics

- Audio Analytics is the process of analyzing sound for the purpose of detecting, extracting, and understanding meaningful patterns.
- It can be used to identify keywords and phrases that indicate person sentiment or sentiment trends across different locations.
- Additionally, audio analytics can be used to detect and recognize speech patterns to recognize human intent and provide speech recognition for smart home products.

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Applications of Audio Analytics in smart cities data

- Intelligent Traffic Management: Audio analytics can be used to detect and identify various types of sound, like traffic jams, road works and traffic accidents. The data gathered through audio analytics can be used to develop and improve traffic management strategies, which could lead to improved traffic flow and reduced congestion in cities.
- Intelligent Security System: Audio analytics can also be used to detect suspicious sounds, like gunshots, screams or other incidents that require immediate attention. The data gathered through audio analytics can be used to alert security officials in real time.

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Image/Video Analytics

- Image/Video analytics is a form of analytics that helps to extract meaningful information from images and videos.
- Depending on the applications, it can involve techniques such as facial recognition, object classification, motion estimation, and more.
- It can be used in a variety of scenarios including surveillance, healthcare, marketing and research, and security among others.

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Applications of Image/Video Analytics in smart cities data

- Traffic Monitoring: Smart cities use video analytics to monitor traffic congestion in real-time. This helps them understand where improvements can be made to improve traffic flow and reduce emissions.
- Security: Image/Video analytics can be used to analyse city cameras to identify suspicious activities and alert authorities of any potential threats.
- Public Safety: Video analytics can be used to identify potential hazards such as fire, overcrowding, and criminal activity. This allows for quicker response times and better protection of the public.
- Parking Management: Image/Video analytics can be used to monitor the availability of parking spaces in real-time. This helps cities optimize parking resources to maximize convenience and reduce traffic congestion.

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Video Analytics: car detection example

demo:
https://github.com/openvinotoolkit/openvino_notebooks/blob/latest/notebooks/vehicle-detection-and-recognition/vehicle-detection-and-recognition.ipynb?utm_source=chatgpt.com

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Further reading

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Unit completed - What's next?

- To consolidate your learning and reflect on the key concepts covered, please take a moment to complete this quiz.
- Your feedback and results will help you track your progress and support continuous improvement of the training experience.
- By completing this quiz, you will also become eligible to receive a certificate of successful training completion.
- Click this link to begin the quiz!

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