SMARCO

SMARt COmmunities Skills Development in Europe

Artificial Intelligence

Dr. Assoc. Prof. Sotiris Kotsiantis

HELLENIC OPEN UNIVERSITY

Co-funded by the European Union

smarco

Project 101186291 — SMARCO
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

SMARCO

SMARt COmmunities Skills Development in Europe

Unit 3 – Unsupervised Learning and Recommendation methods

Co-funded by the European Union

smarco

Project 101186291 — SMARCO
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

Unit 3 - Aim and objectives

- This unit introduces trainees to unsupervised learning and forecasting. Trainees will also understand how to handle clustering and recommendation problems related to smart cities.

Co-funded by
the European Union

smarco

Project 101186291 — SMARCO
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

Unit 3 - Learning outcomes

- Present the basic unsupervised learning techniques.
- Demonstrate a clustering algorithm in a smart city related problem.
- Demonstrate a recommendation algorithm in a smart city related problem.

Co-funded by the European Union

smarco

Project 101186291 — SMARCO
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

Table of contents

Co-funded by the European Union

smarco

Project 101186291 — SMARCO
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

Terms and keywords

- Unsupervised machine learning
- Clustering algorithm, clusterer
- Recommendation algorithms, recommendation system

Co-funded by the European Union

smarco

Project 101186291 — SMARCO
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

Unsupervised learning

- Unsupervised learning is a type of machine learning that searches for previously undetected patterns in a data set.
- This type of learning is used to draw inferences from datasets without the presence of any labeled data.
- Examples of unsupervised learning include clustering, which groups data based on similarities, and associative analysis, which finds relationships among variables in the data.

Project 101186291 — SMARCO
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

An example of smart city clustering problem

- A smart city clustering problem could involve the grouping of different cities according to various criteria such as population density, infrastructure, economic potential, educational quality, environmental conditions, public services, etc.
- The goal would likely be to identify cities that share similar characteristics, which could then be used to improve urban planning.
- The results of the clustering process would provide a better understanding of the different cities' needs and help to create better policies, strategies, and resources for each of them.

Co-funded by the European Union

smarco

Project 101186291 — SMARCO
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

Application of a clustering algorithm

- The application of a classification algorithm to a dataset begins with understanding the data and the type of clustering algorithm that is best suitable for the problem.
- After selecting the algorithm and preprocessing the data, the next step is to train the model using the dataset.
- After training the model, it is important to analyze the performance of the clustering model using various evaluation metrics.

Co-funded by the European Union

smarco

Project 101186291 — SMARCO
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

Clustering algorithms

- K-Means Clustering: A popular clustering algorithm that partitions a given dataset into k clusters by iteratively assigning data points to the nearest cluster.
- Hierarchical Clustering: A clustering algorithm that builds a hierarchy of clusters by creating nested clusters that are successively split or merged.
- DBSCAN: A clustering algorithm that uses a density-based approach to detect different clusters in the dataset.
- Mean-Shift Clustering: A clustering algorithm that clusters the data points by shifting points towards the highest density region.
- Affinity Propagation Clustering: A clustering algorithm that uses a “message passing" idea in order to cluster data points into meaningful clusters.

Co-funded by the European Union

smarco

Project 101186291 — SMARCO
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

Well known evaluation metrics (1)

- Silhouette Score: The silhouette score is calculated based on the average distance between each data point within a cluster and the average distance between each data point and the points in the neighboring clusters.

For each sample, the Silhouette Score is calculated as:

$$S_i = \frac{b_i - a_i}{\max(b_i, a_i)}$$

where:

- S_i is the Silhouette Score for the ith sample.
- a_i is the average distance from the ith sample to the other samples in the same cluster.
- b_i is the average distance from the ith sample to the samples in the nearest cluster (different from the one to which the sample belongs).

Co-funded by the European Union

smarco

Project 101186291 — SMARCO
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

Well known evaluation metrics (2)

- Calinski-Harabasz evaluation metric (also known as Variance Ratio Criterion) metric measures the ratio between the sum of squared within-group dispersion and the sum of squares between-groups dispersion.

$$CH = \frac{B}{W} \times \frac{N-k}{k-1}$$

where:

- B is the between-cluster variance.
- W is the within-cluster variance.
- N is the total number of data points.
- k is the number of clusters.

Co-funded by the European Union

smarco

Project 101186291 — SMARCO
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

Well known evaluation metrics (3)

- The Davies-Bouldin homogeneity evaluation metric is calculated based on the similarity between clusters, and it measures the compactness of cluster centers within a cluster, as well as the separation between clusters.

$$DB = \frac{1}{k}\sum_{i=1}^{k} \max_{j \neq i}\left(\frac{\sigma_i + \sigma_j}{d(c_i, c_j)}\right)$$

where:

- σ_i is the average distance from the points in cluster i to the centroid of cluster i

  .
- $d(c_i, c_j)$ is the distance between the centroids of clusters i and j.

Co-funded by
the European Union

smarco

Project 101186291 — SMARCO
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

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

Co-funded by the European Union

smarco

Project 101186291 — SMARCO
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

Training a clustering algorithm in Google Colab

```
import pandas as pd
!wget --no-check-certificate https://thalis.math.upatras.gr/~sotos/Smart_City_index_headers.csv
data = pd.read_csv('Smart_City_index_headers.csv')
data
```

	Id	City	Country	Smart_Mobility	Smart_Environment	Smart_Government	Smart_Economy	Smart_People	Smart_Living	SmartCity_Index	SmartCity_Index_relative_Edmonton
0	1	Oslo	Norway	6480	6512	7516	4565	8618	9090	7138	666
1	2	Bergen	Norway	7097	6876	7350	4905	8050	9090	7296	823
2	3	Amsterdam	Netherlands	7540	5558	8528	8095	7098	7280	7311	839
3	4	Copenhagen	Denmark	7490	7920	8726	5580	5780	7200	7171	698
4	5	Stockholm	Sweden	6122	7692	8354	4330	6743	7730	6812	340
...	...	...	...	...	...	...	...	...	...	...	...

- Press Shift+Enter to execute the cell in colab cell

Co-funded by the European Union

smarco

Project 101186291 — SMARCO
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

Dataset columns description

- Smart Mobility refers to the use of technology and data to improve transportation systems within a city.
- Smart Environment focuses on leveraging technology and data to monitor, manage, and improve environmental sustainability within a city.
- Smart Government involves the application of technology to enhance the efficiency, transparency, and responsiveness of government services.
- Smart Economy refers to the use of technology and innovation to drive economic development within a city.
- Smart People focus on initiatives that empower and engage citizens through technology.
- Smart Living involves using technology to enhance the overall quality of life for residents.
- A Smart City Index is a comprehensive assessment tool that evaluates and ranks cities based on various criteria related to their smart city initiatives. These indices typically cover multiple aspects, including technology, sustainability, governance, innovation, and quality of life.
- Smart City Index relative to Edmonton involve evaluating how well Edmonton performs compared to other cities in terms of its smart city initiatives across different categories.

Co-funded by the European Union

smarco

Project 101186291 — SMARCO
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

Train k-means with 3 clusters

```
# Install PyCaret library using pip
!pip install git+https://github.com/pycaret/pycaret.git
# Import necessary functions from PyCaret's clustering module
from pycaret.clustering import *
# Set up the clustering experiment using PyCaret's setup function
# 'data' is the DataFrame containing the dataset, and 'session_id' is set for reproducibility
cluster = setup(data, session_id=7652)
# Create a K-Means clustering model using PyCaret's create_model function
# 'num_clusters=3' specifies the number of clusters to create (in this case, 3 clusters)
kmeans = create_model('kmeans', num_clusters=3)  # Train K-Means with 3 clusters
```

	Silhouette	Calinski-Harabasz	Davies-Bouldin	Homogeneity	Rand Index	Completeness
0	0.2621	39.6339	1.2989	0	0	0

Co-funded by the European Union

smarco

Project 101186291 — SMARCO
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

The assigned clusters in the last column

```
kmeans_cluster = assign_model(kmeans)
kmeans_cluster
```

	Id	City	Country	Smart_Mobility	Smart_Environment	Smart_Government	Smart_Economy	Smart_People	Smart_Living	SmartCity_Index	SmartCity_Index_relative_Edmonton	Cluster
0	1	Oslo	Norway	6480	6512	7516	4565	8618	9090	7138	666	Cluster 1
1	2	Bergen	Norway	7097	6876	7350	4905	8050	9090	7296	823	Cluster 1
2	3	Amsterdam	Netherlands	7540	5558	8528	8095	7098	7280	7311	839	Cluster 0
3	4	Copenhagen	Denmark	7490	7920	8726	5580	5780	7200	7171	698	Cluster 0
4	5	Stockholm	Sweden	6122	7692	8354	4330	6743	7730	6812	340	Cluster 1
...	...	...	...	...	...	...	...	...	...	...	...	...
97	98	Riga	Latvia	4152	4584	4616	7380	3745	4330	4712	-1760	Cluster 2
98	99	Beijing	China	7610	2998	2806	4905	5183	1980	4449	-2023	Cluster 2
99	100	St Petersburg	Russia	4588	2908	3622	4515	5390	4100	4191	-2281	Cluster 2
100	101	Calgary	Canada	6675	4052	5946	8022	6424	8657	6678	206	Cluster 0
101	102	Edmonton	Canada	5801	4499	6396	8022	6200	8141	6472	0	Cluster 0

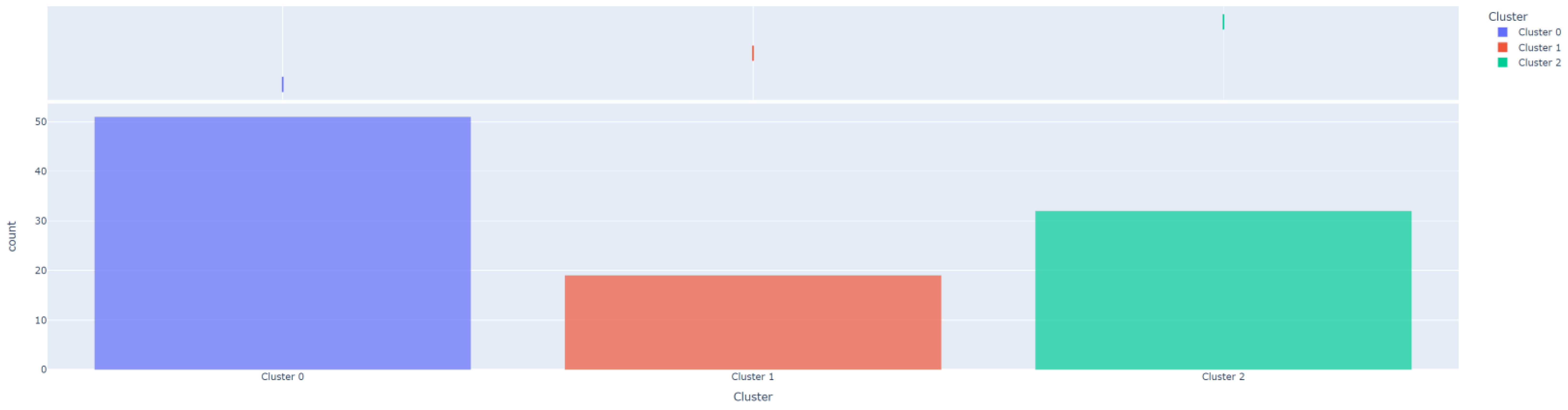
Co-funded by the European Union

smarco

Project 101186291 — SMARCO
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

Clusters distribution

```
plot_model(kmeans, plot = 'distribution')
```



Co-funded by the European Union

smarco

Project 101186291 — SMARCO
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

You can run the full example code

https://colab.research.google.com/drive/1W81wKG8ltxiT8CVNljpnhn3Mw6OPgrq8?usp=sharing

Co-funded by the European Union

smarco

Project 101186291 — SMARCO
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

Other applications of clustering in a smart city

- Smart Mobility: Clustering algorithms can be used to analyze and segment transport data. This can be used to better understand urban mobility patterns and better manage urban traffic.
- Smart Waste Management: Clustering algorithms can be used to analyze patterns in garbage collection and recycling in order to optimize service delivery.
- Citizen Segmentation: Clustering algorithms can be used to create citizen profiles and segment citizens to understand their needs better and customize services accordingly.
- Crime Monitoring and Prevention: Clustering algorithms can be used to identify crime hot spots and predict criminal activities, enabling authorities to take preventive measures promptly.

Co-funded by the European Union

smarco

Project 101186291 — SMARCO
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

Recommendation

- Trying to **predict** the opinion the user will have on the different items and be able to recommend the "best" items to each user based on: **the user's previous likings** and the **opinions of other like minded ("Similar") users**

Co-funded by the European Union

smarco

Project 101186291 — SMARCO
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

Rating Matrix

- The ratings of users and items are represented in a matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
a			1		4	5			4		3					2			4		2				
b			4							3							5	1		3					
c		5		4			4						3		5					4		5			
d								3				5				3			4		2			3	
e		3					5			4	5				5					1			5	4	
f			4				1		3	5		4	1		5	4	4		4				3		
g	2	4				4		2			5		1	4	5		4	2	4		5			4	
h			2		1		4		3	5		4	2		5	4	5						5		
i		1					3			5				5		4	4		5			4		3	
j			4			4				5			1		5		4		4				4		
k		5				4			2		5		1	5		4		2		4				2	
l					3			3				4	1		4		4	2	4					3	
m	5		3					5	3		5	4		5	5	3			4	4	5	4		4	
n			1		4	5				4	5		1	5		4		3		4		4	3		
o			4			4				5		4		5			4	2		5		5		3	
p				4			5								5	4		2	4	4	5	4		2	
q					3			3					1	5		4	4		4			4		3	
r		4			1	4		2					2		5		4				5	4		4	
s			2		4		4			5			1			4		2	4		4		5		
t		1		4			3					4		5	5		4			4				3	
u			2		1		4		3				1		5	4		2	4		5	4			
v					4	5				4	3		5			2					2			5	
w				2			2		3			5			4	5		4	2		3	4			
x	4			5				3		3				4	5					1					
y			1			3				2	3						3	3		5		4			

Co-funded by the European Union

smarco

Project 101186291 — SMARCO
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

A case study-museum recommendation

- The Dataset includes:
  - userID: A unique identifier for each user.
  - museumID: A unique identifier for each museum.
  - rating: A rating (e.g., from 1 to 5) given by the user to the museum.
- This setup is ideal for collaborative filtering since we can recommend museums to users based on the ratings given by similar users.

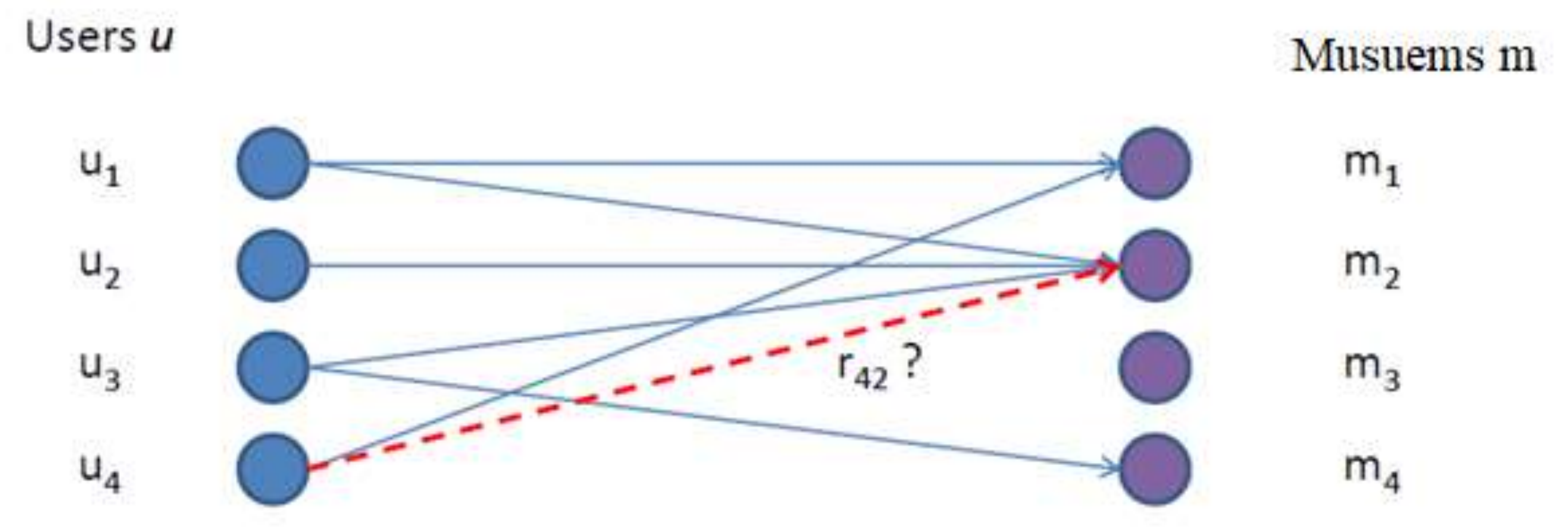
Co-funded by the European Union

smarco

Project 101186291 — SMARCO
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

Rating Prediction Task

- Given a set of users U that have rated some set of museums M, for each rating not yet present, predict the rating rij that user ui will give to museum mj



- Evaluate RSME (root mean squared error) = sum over all users and predicted ratings of $(r\hat{}_{ij} - r_{ij})^2$

Co-funded by the European Union

smarco

Project 101186291 — SMARCO
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

How Knn works for recommendation systems

1. User-Based kNN: "Users who are similar to you liked these museums — you might like them too."

- Steps:
  - Compute similarity between users (e.g., cosine similarity).
  - Find the k nearest users (most similar users).
  - Look at what those users liked that you haven't rated yet.
  - Recommend the top museums from that list.

2. Item-Based kNN: "You'll like items similar to the ones you already liked."

- Steps:
  - Compute similarity between museums (based on users' ratings).
  - For a target item, find k most similar museums.
  - Predict rating for an unseen item by looking at how you rated its similar museums.

Co-funded by the European Union

smarco

Project 101186291 — SMARCO
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

Recommendation system

- Each user has rated some museums

```
!pip install surprise
!pip install numpy==1.26.4
```

The **surprise** library is a Python library designed for building and analyzing recommender systems. It provides a convenient interface for various collaborative filtering algorithms and is widely used in tasks related to recommendation systems.

```
import pandas as pd
import matplotlib.pyplot as plt
from surprise import prediction_algorithms, accuracy, Reader, Dataset
```

```
!wget --no-check-certificate https://thalis.math.upatras.gr/~sotos/ratings.csv
data = pd.read_csv('ratings.csv')
```

Co-funded by the European Union

smarco

Project 101186291 — SMARCO
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

Ratings of userId=1

```
[5] data[data['userId']==1]
```

	userId	museumId	rating
0	1	31	2.5
1	1	1029	3.0
2	1	1061	3.0
3	1	1129	2.0
4	1	1172	4.0
5	1	1263	2.0
6	1	1287	2.0
7	1	1293	2.0
8	1	1339	3.5
9	1	1343	2.0
10	1	1371	2.5
11	1	1405	1.0
12	1	1953	4.0
13	1	2105	4.0
14	1	2150	3.0

Co-funded by the European Union

smarco

Project 101186291 — SMARCO
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

Ratings for museumId=1

```
[6] data[data['museumId']==1]
```

	userId	museumId	rating
495	7	1	3.0
699	9	1	4.0
889	13	1	5.0
962	15	1	2.0
3105	19	1	3.0
3528	20	1	3.5
4008	23	1	3.0
4781	26	1	5.0
5048	30	1	4.0
6625	37	1	4.0
7142	43	1	4.0
7252	44	1	4.0
7337	47	1	5.0
7375	48	1	4.0
8222	55	1	3.0

Co-funded by the European Union

smarco

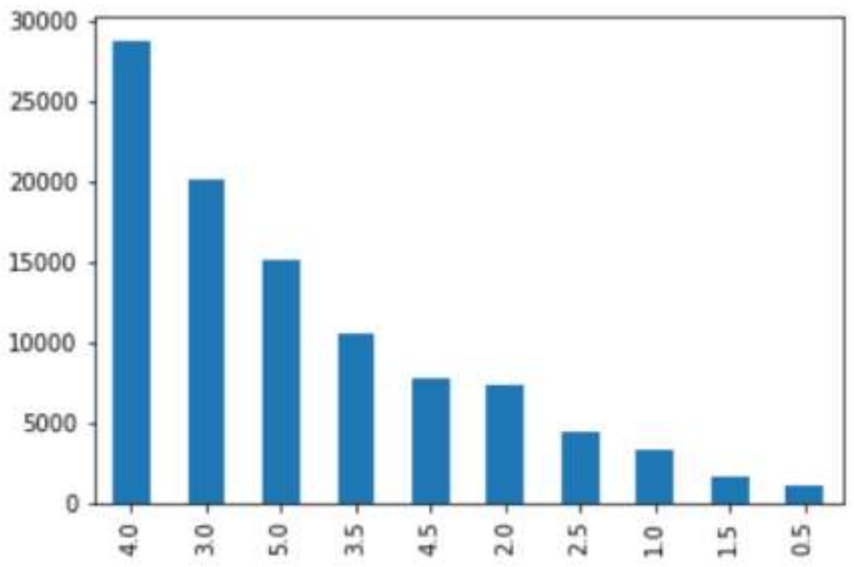
Project 101186291 — SMARCO
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

Visualizing the ratings values

```
[7]  data.rating.value_counts()

     4.0    28750
     3.0    20064
     5.0    15095
     3.5    10538
     4.5     7723
     2.0     7271
     2.5     4449
     1.0     3326
     1.5     1687
     0.5     1101
     Name: rating, dtype: int64
```

```
[8]  data.rating.value_counts().plot(kind='bar')
     plt.show()
```



Co-funded by the European Union

smarco

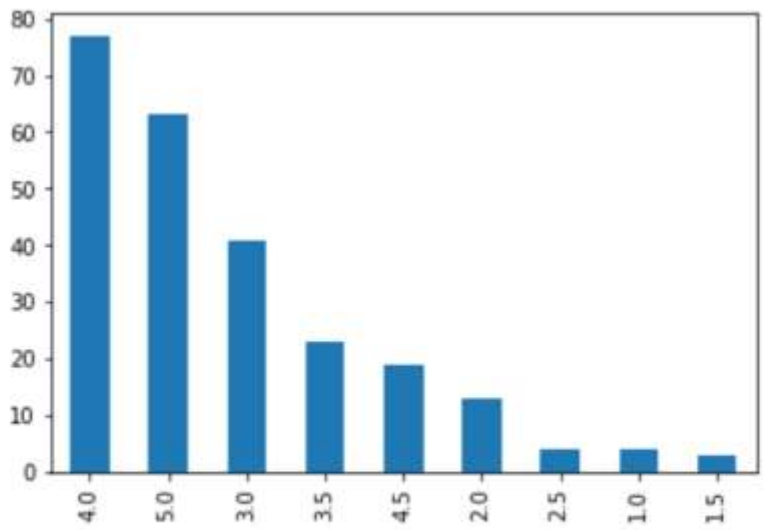
Project 101186291 — SMARCO
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

For a specific museum

```
[9]  data[data['museumId']==1].rating.value_counts()

4.0    77
5.0    63
3.0    41
3.5    23
4.5    19
2.0    13
2.5     4
1.0     4
1.5     3
Name: rating, dtype: int64
```

```
[10]  data[data['museumId']==1].rating.value_counts().plot(kind='bar')
      plt.show()
```




```
data[data['museumId']==1].rating.mean()

3.8724696356275303
```

Co-funded by
the European Union

smarco

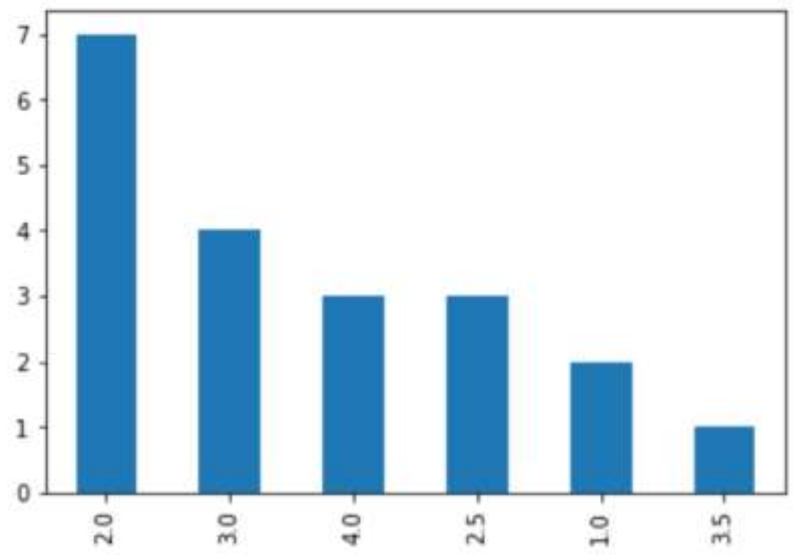
Project 101186291 — SMARCO
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

For a specific user

```
[12] data[data['userId']==1].rating.value_counts()
```

```
2.0    7
3.0    4
4.0    3
2.5    3
1.0    2
3.5    1
Name: rating, dtype: int64
```

```
[13] data[data['userId']==1].rating.value_counts().plot(kind='bar')
     plt.show()
```




```
data[data['userId']==1].rating.mean()
```

```
2.55
```

Co-funded by the European Union

smarco

Project 101186291 — SMARCO
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

Estimating the error of knn algorithm in predictions

```
from surprise.model_selection import train_test_split
trainset, testset = train_test_split(data1, test_size=0.25)
# We'll use the KNN algorithm.
algo = prediction_algorithms.knns.KNNBasic(k=5)
# Train the algorithm on the trainset, and predict ratings for the testset
algo.fit(trainset)
predictions = algo.test(testset)
accuracy.rmse(predictions) #estimation of mean squared error of the predictions
```

```
Computing the msd similarity matrix...
Done computing similarity matrix.
RMSE: 2.1926
2.192641309993067
```

Co-funded by the European Union

smarco

Project 101186291 — SMARCO
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

Estimating the rating of userId=1 to museumId=31

```
[12] userid = 1  # user id
     museumid = 31  # museum id
     # get a prediction for specific users and items.
     pred = algo.predict(userid , museumid, verbose=True)

user: 1          item: 31         r_ui = None   est = 2.37   {'was_impossible': False}
```

Co-funded by the European Union

smarco

Project 101186291 — SMARCO
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

Estimating the ratings for all museums of userId=1

```
[13] preds=[]
     for i in data['museumId'].unique().tolist():
         preds.append(algo.predict(1, i, verbose=True))
```

```
user: 1        item: 31       r_ui = None   est = 2.37   {'was_impossible': False}
user: 1        item: 1029     r_ui = None   est = 2.84   {'was_impossible': False}
user: 1        item: 1061     r_ui = None   est = 2.65   {'was_impossible': False}
user: 1        item: 1129     r_ui = None   est = 2.48   {'was_impossible': False}
user: 1        item: 1172     r_ui = None   est = 3.74   {'was_impossible': False}
user: 1        item: 1263     r_ui = None   est = 3.15   {'was_impossible': False}
user: 1        item: 1287     r_ui = None   est = 2.67   {'was_impossible': False}
user: 1        item: 1293     r_ui = None   est = 2.93   {'was_impossible': False}
user: 1        item: 1339     r_ui = None   est = 2.82   {'was_impossible': False}
user: 1        item: 1343     r_ui = None   est = 2.75   {'was_impossible': False}
user: 1        item: 1371     r_ui = None   est = 2.35   {'was_impossible': False}
user: 1        item: 1405     r_ui = None   est = 2.14   {'was_impossible': False}
user: 1        item: 1953     r_ui = None   est = 3.42   {'was_impossible': False}
user: 1        item: 2105     r_ui = None   est = 3.00   {'was_impossible': False}
user: 1        item: 2150     r_ui = None   est = 2.85   {'was_impossible': False}
user: 1        item: 2193     r_ui = None   est = 2.28   {'was_impossible': False}
user: 1        item: 2294     r_ui = None   est = 2.60   {'was_impossible': False}
user: 1        item: 2455     r_ui = None   est = 2.70   {'was_impossible': False}
user: 1        item: 2968     r_ui = None   est = 2.24   {'was_impossible': False}
user: 1        item: 3671     r_ui = None   est = 3.17   {'was_impossible': False}
user: 1        item: 10       r_ui = None   est = 2.86   {'was_impossible': False}
user: 1        item: 17       r_ui = None   est = 3.10   {'was_impossible': False}
user: 1        item: 39       r_ui = None   est = 2.82   {'was_impossible': False}
user: 1        item: 47       r_ui = None   est = 3.05   {'was_impossible': False}
user: 1        item: 50       r_ui = None   est = 3.34   {'was_impossible': False}
user: 1        item: 52       r_ui = None   est = 2.85   {'was_impossible': False}
user: 1        item: 62       r_ui = None   est = 2.58   {'was_impossible': False}
```

Co-funded by the European Union

smarco

Project 101186291 — SMARCO
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

Sort the predictions and recommend 10 museums

```
[14] preds[0][3]
```

```
2.37255765791946
```

```
[15] from operator import itemgetter
     sorted(preds, key=itemgetter(3), reverse=True)[:10]
```

```
[Prediction(uid=1, iid=923, r_ui=None, est=3.826523785906033, details={'was_impossible': False}),
 Prediction(uid=1, iid=1172, r_ui=None, est=3.7432091089099324, details={'was_impossible': False}),
 Prediction(uid=1, iid=3462, r_ui=None, est=3.668612504713015, details={'was_impossible': False}),
 Prediction(uid=1, iid=926, r_ui=None, est=3.6363795403607564, details={'was_impossible': False}),
 Prediction(uid=1, iid=1945, r_ui=None, est=3.631949384670269, details={'was_impossible': False}),
 Prediction(uid=1, iid=858, r_ui=None, est=3.6254624885858857, details={'was_impossible': False}),
 Prediction(uid=1, iid=2019, r_ui=None, est=3.624081153908831, details={'was_impossible': False}),
 Prediction(uid=1, iid=1207, r_ui=None, est=3.6210900479621744, details={'was_impossible': False}),
 Prediction(uid=1, iid=2692, r_ui=None, est=3.6080696825878054, details={'was_impossible': False}),
 Prediction(uid=1, iid=318, r_ui=None, est=3.597104254676668, details={'was_impossible': False})]
```

Co-funded by the European Union

smarco

Project 101186291 — SMARCO
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

You can run the full example code

https://colab.research.google.com/drive/1mACBx1gA4Cw_FR4sghGZkiyLf3ujLCOp

You can save a copy in your drive to execute the code from your PC via colab.

Co-funded by the European Union

smarco

Project 101186291 — SMARCO
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

Other applications of recommendation systems in a smart city

- Local Restaurant and Shopping Recommendations: a system that recommends local restaurants and shopping establishments that users may be interested in.
- Community Engagement: a system that allows users to participate in local events, crowdsourcing initiatives, and more.
- Connecting citizens to job opportunities

Co-funded by
the European Union

smarco

Project 101186291 — SMARCO
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

List of references

- Cantuarias-Villessuzanne, C., Weigel, R., & Blain, J. (2021). Clustering of European Smart Cities to Understand the Cities' Sustainability Strategies. Sustainability, 13(2), 513. https://doi.org/10.3390/su13020513
- Yousif, Z., Hussain, I., Djahel, S., & Hadjadj-Aoul, Y. (2021). A Novel Energy-Efficient Clustering Algorithm for More Sustainable Wireless Sensor Networks Enabled Smart Cities Applications. Journal of Sensor and Actuator Networks, 10(3), 50. https://doi.org/10.3390/jsan10030050
- Rafique, W., Hafid, A. S., & Qadir, J. (2023). Developing smart city services using intent-aware recommendation systems: A survey. Transactions on Emerging Telecommunications Technologies, 34(4). Portico. https://doi.org/10.1002/ett.4728

Co-funded by the European Union

smarco

Project 101186291 — SMARCO
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

Further reading

- Yang, J., Guo, B., Wang, Z., & Ma, Y. (2021). Hierarchical Prediction Based on Network-Representation-Learning-Enhanced Clustering for Bike-Sharing System in Smart City. IEEE Internet of Things Journal, 8(8), 6416-6424. https://doi.org/10.1109/jiot.2020.3034991
- Xu, C., Guan, Z., Zhao, W., Wu, Q., Yan, M., Chen, L., & Miao, Q. (2021). Recommendation by Users’ Multimodal Preferences for Smart City Applications. IEEE Transactions on Industrial Informatics, 17(6), 4197-4205. https://doi.org/10.1109/tii.2020.3008923
- Zhang, Y. (2021). The application of e-commerce recommendation system in smart cities based on big data and cloud computing. Computer Science and Information Systems, 18(4), 1359-1378. https://doi.org/10.2298/csis200917026z
- Belhadi, A., Djenouri, Y., Norvag, K., Ramampiaro, H., Masseglia, F., & Lin, J. C.-W. (2020). Space-time series clustering: Algorithms, taxonomy, and case study on urban smart cities. Engineering Applications of Artificial Intelligence, 95, 103857. https://doi.org/10.1016/j.engappai.2020.103857

Co-funded by the European Union

smarco

Project 101186291 — SMARCO
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

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!

Co-funded by the European Union

smarco

Project 101186291 — SMARCO
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

SMARCO

SMARt COmmunities Skills Development in Europe

www.smarco.eu

info@smarco.eu

We are social! Follow us on:

@smarcoproject

@smarcoproject

@smarcoproject

Co-funded by the European Union

smarco

Project 101186291 — SMARCO

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.