



Final Report - Recommendation system Build a Personalized Online Course Recommender System with Machine Learning

Machine Learning Capston - IBM Professional Certificate

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For future reading, I am delighted to invite you for visiting my personal repository of IBM Machine Learning Professional Certificate @Coursera

<https://github.com/Peachgrape2501/IBM-Machine-Learning-Professional-Certificate-Capstone-Project.git>

Outline:

1. Capstone Overview
2. Exploratory Data Analysis and Feature Engineering
3. Unsupervised Learning based Recommendation System
4. Supervised Learning based Recommendation System
5. Deploy and showcase models on Streamlit
6. Conclusion and future work
7. Appendix

Capstone Overview - Motivation

The main goal of this project is to improve learners' learning experience via helping them quickly find new interested courses and better paving their learning paths. Meanwhile, with more learners interacting with more courses via your recommender systems, your company's revenue may also be increased.

This project is currently at the Proof of Concept (PoC) phase so the main focus at this moment is to explore and compare various machine learning models and find one with the best performance in off-line evaluations.

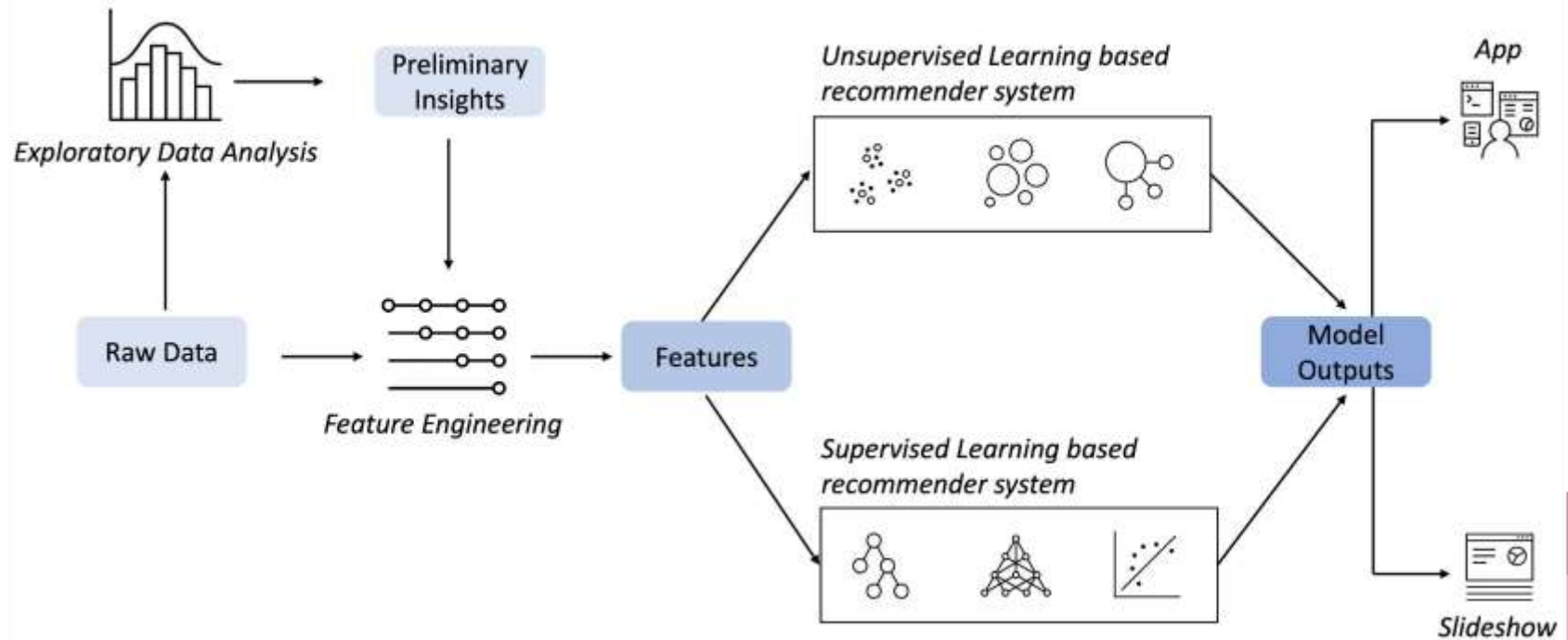


Capstone Overview - Machine learning pipeline

1. Collecting and understanding data
2. Performing exploratory data analysis on online course enrollments datasets
3. Extracting Bag of Words (BoW) features from course textual content
4. Calculating course similarity using BoW features
5. Building content-based recommender systems using various unsupervised learning algorithms, such as: Distance/Similarity measurements, K-means, Principal Component Analysis (PCA), etc.
6. Building collaborative-filtering recommender systems using various supervised learning algorithms K Nearest Neighbors, Non-negative Matrix Factorization (NMF), Neural Networks, Linear Regression, Logistic Regression, RandomForest, etc.
7. Deploying and demonstrate modeling via a web app built with `streamlit`. `Streamlit` is an open-source app framework for Machine Learning and Data Science to quickly demonstration.
8. Reporting in paper.



Capstone Overview - Machine learning pipeline



Exploratory Data Analysis and Feature Engineering

Exploratory Data Analysis

Pipeline:

1. Describe the statistic of data columns
2. Identify keywords in course titles using a WordCloud
3. Determine popular course genres
4. Calculate the summary statistics and create visualizations of the online course enrollment dataset



Exploratory Data Analysis



Identify keywords in course titles using a WordCloud

The omnipresences following by size respectively are:

1. data ->
2. data science ->
3. python ->
4. machine learning ->
5. data analysis ->
6. application ->
7. big data ->
8. java ->
9. microservice
10. web



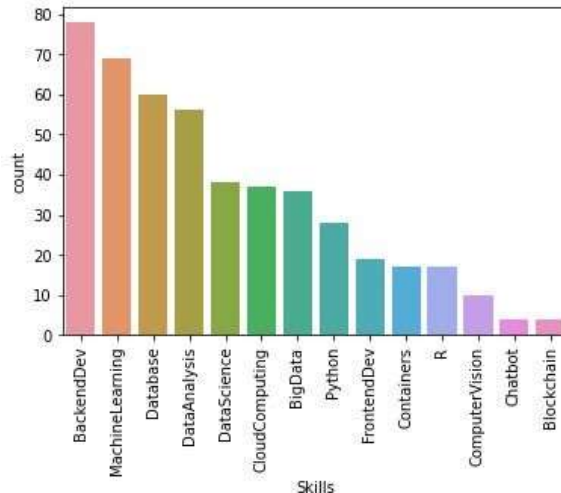
Exploratory Data Analysis

	Skills	count
11	BackendDev	78
5	MachineLearning	69
0	Database	60
3	DataAnalysis	56
7	DataScience	38
2	CloudComputing	37
8	BigData	36
1	Python	28
12	FrontendDev	19
4	Containers	17
10	R	17
6	ComputerVision	10
9	Chatbot	4
13	Blockchain	4

Determine popular course genres

BackendDev, MachineLearning, Database are the utmost popular genres.

While Blockchain, Chatbot, ComputerVision are the most less common ones.

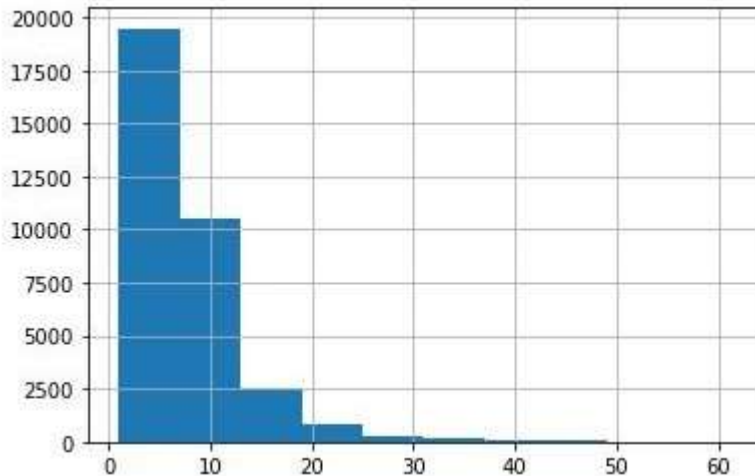


Exploratory Data Analysis

This given histogram illustrates the amount of user rating counts.

Almost users did not rate any courses or rated rarely.

A few exceptional students rated above 40 courses.



The histogram of user rating counts

This below table shows top 20 widespread courses.

9/10 courses of top 10 are belong to data topic.


Only the 4th is the part of software engineer topic.

Top 20 Most Popular Courses

	COURSE_ID	count	TITLE
0	DS0301EN	3624	data privacy fundamentals
1	BD0115EN	3670	mapreduce and yarn
2	DB0101EN	3697	sql and relational databases 101
3	CO0101EN	4480	docker essentials a developer introduction
4	CC0101EN	4883	introduction to cloud
5	ST0101EN	5015	statistics 101
6	RP0101EN	5237	r for data science
7	CB0103EN	5512	build your own chatbot
8	ML0115EN	6323	deep learning 101
9	DV0101EN	6709	data visualization with python
10	BC0101EN	6719	blockchain essentials
11	DS0105EN	7199	data science hands on with open source tools
12	BD0211EN	7551	spark fundamentals i
13	ML0101ENW3	7544	machine learning with python
14	DS0103EN	7719	data science methodology
15	DA0101EN	8303	data analysis with python
16	BD0111EN	10599	hadoop 101
17	BD0101EN	13291	big data 101
18	DS0101EN	14477	introduction to data science
19	PY0101EN	14936	python for data science

Feature Engineering

Pipeline:

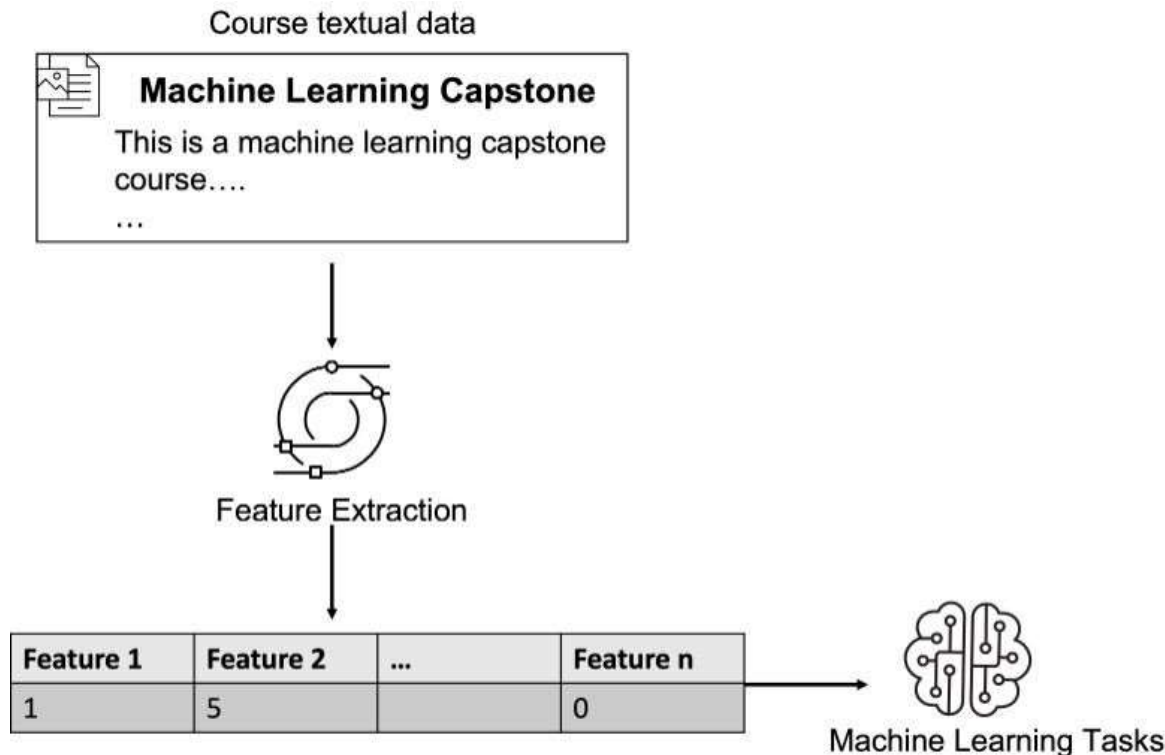
1. Extract Bag of Words (BoW) Features from Course Textual Content
 1. Bag of Words (BoW) features
 2. BoW dimensionality reduction
 3. Extract BoW features for course textual content and build a dataset
 2. Calculate Course Similarity using BoW Features
 1. Calculate the cosine similarity between two example courses
 2. Find similar courses to the specific course
- 

Feature Engineering

The main goal of recommender systems is to help users find items they potentially interested in. Depending on the recommendation tasks, an item can be a movie, a restaurant, or, in our case, an online course.

Machine learning algorithms cannot work on an item directly so we first need to extract features and represent the items mathematically, i.e., with a feature vector.

Many items are often described by text so they are associated with textual data, such as the titles and descriptions of a movie or course. Since machine learning algorithms can not process textual data directly, we need to transform the raw text into numeric feature vectors.



Feature Engineering - BoW

Bag of Words (BoW) features

BoW features are essentially the counts or frequencies of each word that appears in a text (string). Let's illustrate it with some simple examples.

Suppose we have two course descriptions as follows:

```
course1 = "this is an introduction data science course which introduces data science to beginners."
```

```
course2 = "machine learning for beginners"
```

```
courses = [course1, course2]  
courses
```

```
['this is an introduction data science course which introduces data science to beginners',  
 'machine learning for beginners']
```

The first step is to split the two strings into words (tokens). A token in the text processing context means the smallest unit of text such as a word, a symbol/punctuation, or a phrase, etc. The process to transform a string into a collection of tokens is called `tokenization`.

One common way to do `tokenization` is to use the Python built-in `split()` method of the `str` class. However, in this lab, we want to leverage the `nltk` (Natural Language Toolkit) package, which is probably the most commonly used package to process text or natural language.

More specifically, we will use the `word_tokenize()` method on the content of course (string):

```
# Tokenize the two courses  
tokenized_courses = [word_tokenize(course) for course in courses]
```

Feature Engineering - BoW

Bag of Words (BoW) features

```
Bag of words for course 0:  
--Token: 'an', Count:1  
--Token: 'beginners', Count:1  
--Token: 'course', Count:1  
--Token: 'data', Count:2  
--Token: 'introduces', Count:1  
--Token: 'introduction', Count:1  
--Token: 'is', Count:1  
--Token: 'science', Count:2  
--Token: 'this', Count:1  
--Token: 'to', Count:1  
--Token: 'which', Count:1  
Bag of words for course 1:  
--Token: 'beginners', Count:1  
--Token: 'for', Count:1  
--Token: 'learning', Count:1  
--Token: 'machine', Count:1
```

If we turn to the long list into a horizontal feature vectors, we can see the two courses become two numerical feature vectors:

	an	beginners	course	data	science	...
course1	1	1	1	2	2	
course2	0	1	0	0	0	

Feature Engineering - BoW

BoW dimensionality reduction

- A document may contain tens of thousands of words which makes the dimension of the BoW feature vector huge.
- To reduce the dimensionality, one common way is to filter the relatively meaningless tokens such as stop words or sometimes add position and adjective words.



Feature Engineering - BoW

BoW dimensionality reduction

Then we can filter those English stop words from the tokens in `course1`:

```
# Tokens in course 1  
tokenized_courses[0]
```

```
['this',  
 'is',  
 'am',  
 'introduction',  
 'data',  
 'science',  
 'course',  
 'which',  
 'introduces',  
 'data',  
 'science',  
 'to',  
 'beginners']
```

```
processed_tokens = [w for w in tokenized_courses[0] if not w.lower() in stop_words]
```

```
processed_tokens
```

```
['introduction',  
 'data',  
 'science',  
 'course',  
 'introduces',  
 'data',  
 'science',  
 'beginners']
```

You can see the number of tokens for `course1` has been reduced.

Another common way is to only keep nouns in the text. We can use the `nlk.pos_tag()` method to analyze the part of speech (POS) and annotate each word.

```
tags = nltk.pos_tag(tokenized_courses[0])  
tags
```

```
[('this', 'DT'),  
 ('is', 'VBZ'),  
 ('am', 'DT'),  
 ('introduction', 'NN'),  
 ('data', 'NNS'),  
 ('science', 'NN'),  
 ('course', 'NN'),  
 ('which', 'WD'),  
 ('introduces', 'VBZ'),  
 ('data', 'NNS'),  
 ('science', 'NN'),  
 ('to', 'TO'),  
 ('beginners', 'NNS')]
```

As we can see `introduction`, `data`, `science`, `course`, `beginners` are all of the nouns and we may keep them in the BoW feature vector.

Feature Engineering - BoW

Extract BoW features for course textual content and build a dataset

Then we need to create a token dictionary `tokens_dict`

TODO: Use `gensim.corpora.Dictionary(tokenized_courses)` to create a token dictionary.

```
# WRITE YOUR CODE HERE
```

```
tokens_dict = gensim.corpora.Dictionary(tokenized_courses)
print(tokens_dict.token2id)
```

```
{'ai': 0, 'apps': 1, 'build': 2, 'cloud': 3, 'coming': 4, 'create': 5, 'data': 6, 'developer': 7, 'found': 8, 'fun': 9, 'iot': 10, 'irobot': 11, 'learn': 12, 'node': 13, 'objects': 14, 'p
i': 15, 'pictures': 16, 'place': 17, 'program': 18, 'raspberr': 19, 'raspcam': 20, 'read': 21, 'recognize': 22, 'red': 23, 'robot': 24, 'robots': 25, 'services': 26, 'swift': 27, 'take':
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```

Feature Engineering - BoW

Extract BoW features for course textual content and build a dataset

Create a new `course_bow` dataframe based on the extracted BoW features. The new dataframe needs to include the following columns (you may include other relevant columns as well):

- 'doc_index': the course index starting from 0
- 'doc_id': the actual course id such as ML0201EN
- 'token': the tokens for each course
- 'bow': the bow value for each token

	doc_index	doc_id	token	bow
0	0	ML0201EN	ai	2
1	0	ML0201EN	apps	2
2	0	ML0201EN	build	2
3	0	ML0201EN	cloud	1
4	0	ML0201EN	coming	1
...
10358	306	excourse93	modifying	1
10359	306	excourse93	objectives	1
10360	306	excourse93	pieces	1
10361	306	excourse93	plugins	1
10362	306	excourse93	populate	1

10363 rows × 4 columns

Feature Engineering - Course Similarity using BoW Features

Similarity measurement between items is the foundation of many recommendation algorithms, especially for content-based recommendation algorithms. For example, if a new course is similar to user's enrolled courses, we could recommend that new similar course to the user. Or If user A is similar to user B, then we can recommend some of user B's courses to user A (the unseen courses) because user A and user B may have similar interests.

We can use many similarity measurements such as cosine, jaccard index, or euclidean distance, and these methods need to work on either two vectors or two sets (sometimes even matrices or tensors).

In previous section, we extracted the BoW features from course textual content. Given the course BoW feature vectors, we can easily apply similarity measurement to calculate the course similarity as shown in the next figure.



Feature Engineering - Course Similarity using BoW Features

Course 1: "Machine Learning for Everyone"

	machine	learning	for	everyone	beginners
course1	1	1	1	1	0

Course 2: "Machine Learning for Beginners"

	machine	learning	for	everyone	beginners
course2	1	1	1	0	1



Similarity Calculation:
Cosine, Euclidean, Jaccard index, ...

75%

Unsupervised Learning based Recomendation System

Unsupervised Learning based Recommendation System

Outline:

1. Content-based Course Recommender System using User Profile and Course Genres
2. Content-based Course Recommender System using Course Similarities
3. Clustering based Course Recommender System



1. Content-based Course Recommender System using User Profile and Course Genres

The most common type of content-based recommendation system is to recommend items to users based on their profiles.

The user's profile revolves around that user's preferences and tastes. It is shaped based on user ratings, including the number of times a user has clicked on different items or liked those items.

The recommendation process is based on the similarity between those items. The similarity or closeness of items is measured based on the similarity in the content of those items.

When we say content, we're talking about things like the item's category, tag, genre, and so on. Essentially the features about an item.



1. Content-based Course Recommender System using User Profile and Course Genres

For online course recommender systems, we already know how to extract features from courses (such as genres or BoW features). Next, based on the course genres and users' ratings, we want to further build user profiles (if unknown).

A user profile can be seen as the user feature vector that mathematically represents a user's learning interests.

With the user profile feature vectors and course genre feature vectors constructed, we can use several computational methods, such as a simple dot product, to compute or predict an interest score for each course and recommend those courses with high interest scores.



1. Content-based Course Recommender System using User Profile and Course Genres - Pipeline

Raw data

Course genres dataframe:
course_id, title, [genre_x,
genre_y,...]

User dataframe: user_id,
[genre_interest_x,
genre_interest_y,...]

Feature engineering

Analysis data
Drop the exceptions
Normalise data

Get recommend
score

Use dot product
between single user
vector and specific
course to get
recommend score

Recommendation

Make prediction by
comparing score
with determine
threshold

User 1078030's profile vector

	Python	...	Machine Learning
user1	1.0	0	1.0

Dot product

→ score

Threshold
check

	Genre
Python	1
...	...
Machine Learning	1

Course 5's genre vector

Enrolled courses of user1

Couse1
Couse2
Couse3

Unknown courses of user1

Couse4	?
Couse5	Y or N
Couse6	?
Couse7	?
Couse8	?
...	...
CouseN	?

1. Content-based Course Recommender System using User Profile and Course Genres - Result

	COURSE_ID	TITLE	Database	Python	CloudComputing	DataAnalysis	Containers	MachineLearning
0	ML0201EN	robots are coming build iot apps with watson ...	0	0	0	0	0	0
1	ML0122EN	accelerating deep learning with gpu	0	1	0	0	0	1
2	GPXX02G0EN	consuming restful services using the reactive ...	0	0	0	0	0	0
3	RP0105EN	analyzing big data in r using apache spark	1	0	0	1	0	0
4	GPXX02Z2PEN	containerizing packaging and running a sprin...	0	0	0	0	1	0



	user	Database	Python	CloudComputing	DataAnalysis	Containers	MachineLearning
0	2	52.0	14.0	6.0	43.0	3.0	33.0
1	4	40.0	2.0	4.0	28.0	0.0	14.0
2	5	24.0	8.0	18.0	24.0	0.0	30.0
3	7	2.0	0.0	0.0	2.0	0.0	0.0
4	8	6.0	0.0	0.0	4.0	0.0	0.0



	USER	COURSE_ID	SCORE
0	37465	RP0105EN	27.0
1	37465	GPXX06RFEN	12.0
2	37465	CC0271EN	15.0
3	37465	BD0145EN	24.0
4	37465	DE0205EN	15.0
...
53406	2087663	excourse88	15.0
53407	2087663	excourse89	15.0
53408	2087663	excourse90	15.0
53409	2087663	excourse92	15.0
53410	2087663	excourse93	15.0

2. Content-based Course Recommender System using Course Similarities

As we mentioned before, the content-based recommender system is highly based on the similarity calculation among items. The similarity or closeness of items is measured based on the similarity in the content or features of those items. The course genres are important features, and in addition to that, the BoW value is another important type of feature to represent course textual content.

In this lab, we will apply the course similarities metric to recommend new courses which are similar to a user's presently enrolled courses.



2. Content-based Course Recommender System using Course Similarities - Pipeline

Raw data

1. Course similarity matrix

2. Course dataframe:

```
course_id, title,  
description
```

Features

Visualise the similarity metric

Handle data text in title and description

- Remove stop words
- word2vec

Score

Turn a course description to a vector

Check similarity by compare 2 vector

Prediction

Determine rely on similar score

Course 1: "Machine Learning for Everyone"

	machine	learning	for	everyone	beginners
course1	1	1	1	1	0

Course 2: "Machine Learning for Beginners"

	machine	learning	for	everyone	beginners
course2	1	1	1	0	1



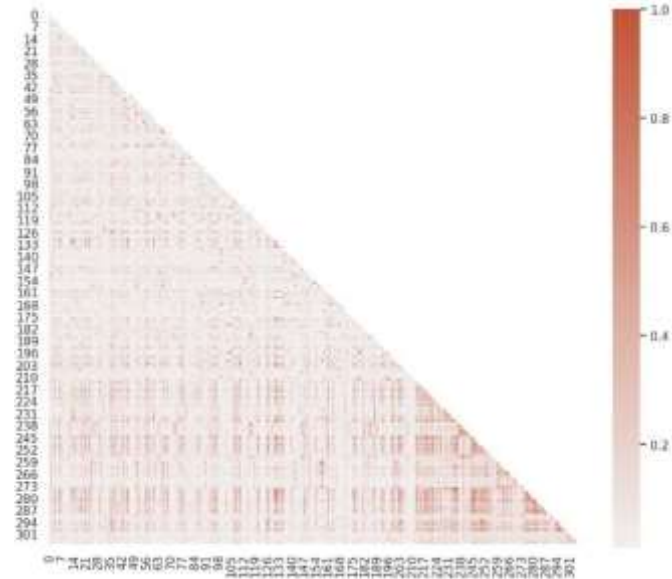
Similarity Calculation:
Cosine, Euclidean, Jaccard index, ...

75%

2. Content-based Course Recommender System using Course Similarities

Course similarity matrix:

	0	1	2	3	4
0	1.000000	0.088889	0.088475	0.065556	0.048810
1	0.088889	1.000000	0.055202	0.057264	0.012182
2	0.088475	0.055202	1.000000	0.026463	0.039406
3	0.065556	0.057264	0.026463	1.000000	0.000000
4	0.048810	0.012182	0.039406	0.000000	1.000000
...



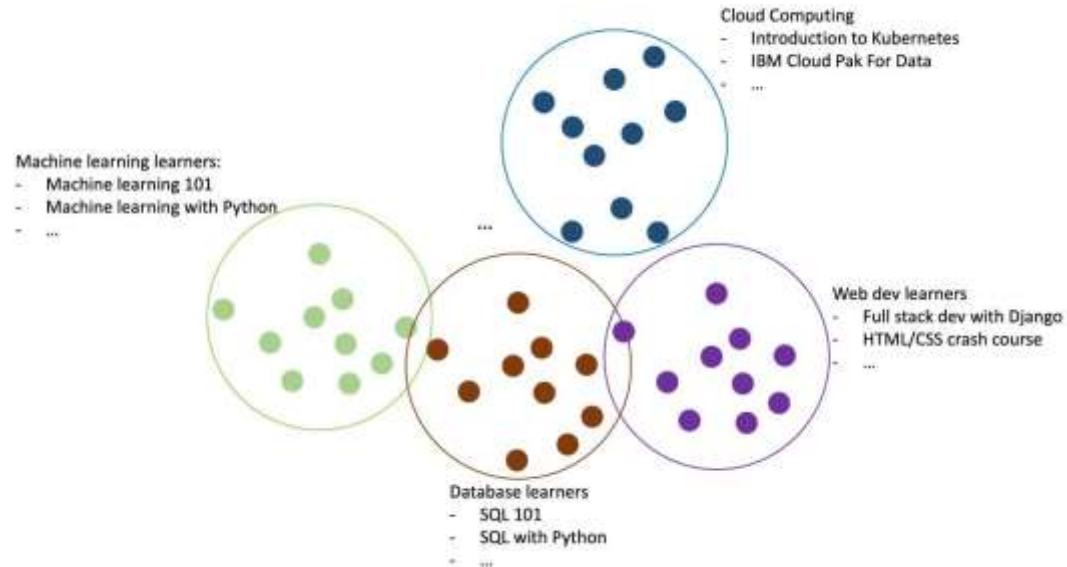
2. Content-based Course Recommender System using Course Similarities - Result

Generate course recommendations based on course similarities for all test users

	USER	COURSE_ID	SCORE
0	37465	excourse67	0.708214
1	37465	excourse72	0.652535
2	37465	excourse74	0.650071
3	37465	BD0145EN	0.623544
4	37465	excourse68	0.616759

3. Clustering based Course Recommender System

We could perform clustering algorithms such as K-means or DBSCAN to group users with similar learning interests. For example, in the below user clusters, we have user clusters whom have learned courses related to machine learning, cloud computing, databases, and web development, etc.



3. Clustering based Course Recommender System

- Pipeline

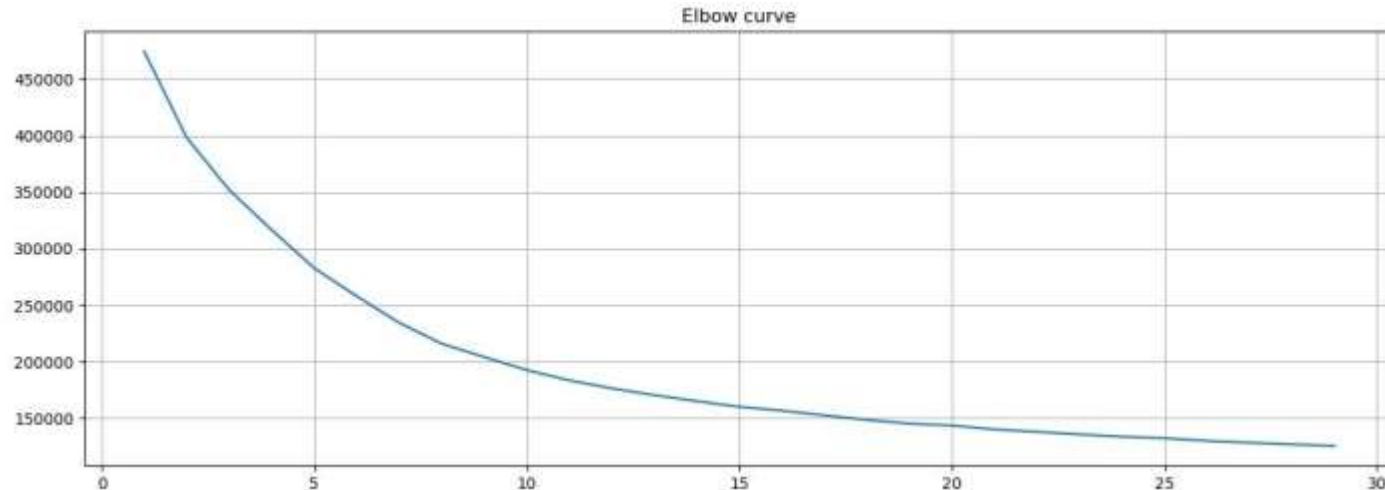


1. Raw data:
 - User profile dataframe: user_id, [genre_x, genre_y,...]
2. Features:
 - Normalise user profile features
 - Apply PCA to keep only important features
3. Apply Clustering algorithms to group similar courses
4. Make recommendation by taking courses in user's interest group

3. Clustering based Course Recommender System

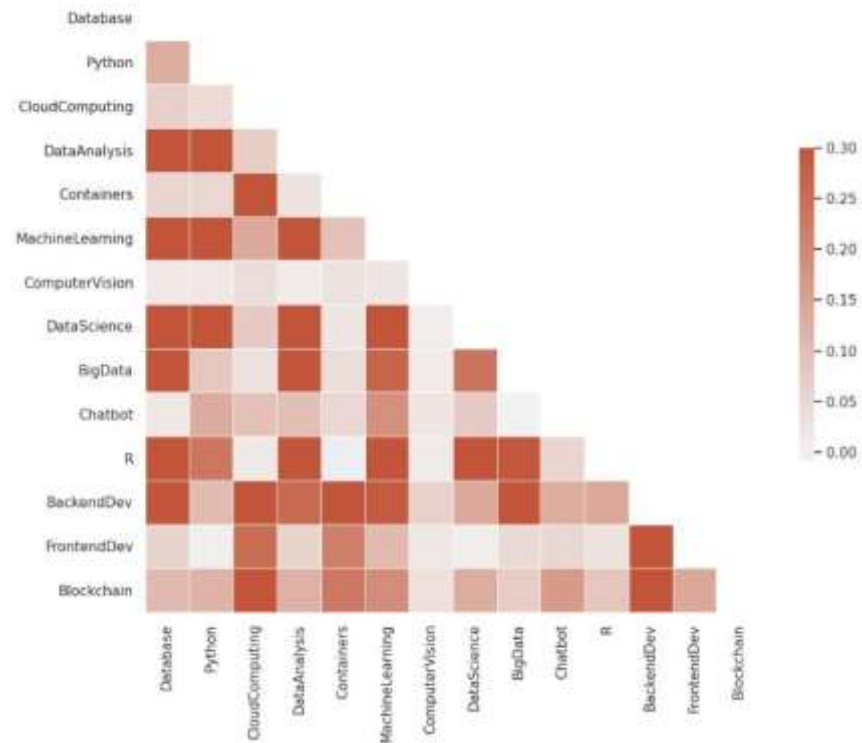
For KMeans algorithm, one important hyperparameter is the number of clusters $n_cluster$, and a good way to find the optimized $n_cluster$ is using to grid search a list of candidates and find the one with the best or optimized clustering evaluation metrics such as minimal sum of squared distance.

Grid search the optimized $n_cluster$ for KMeans() model



3. Clustering based Course Recommender System

Plot a covariance matrix of the user profile feature vectors with 14 features, we can observe that some features are actually correlated

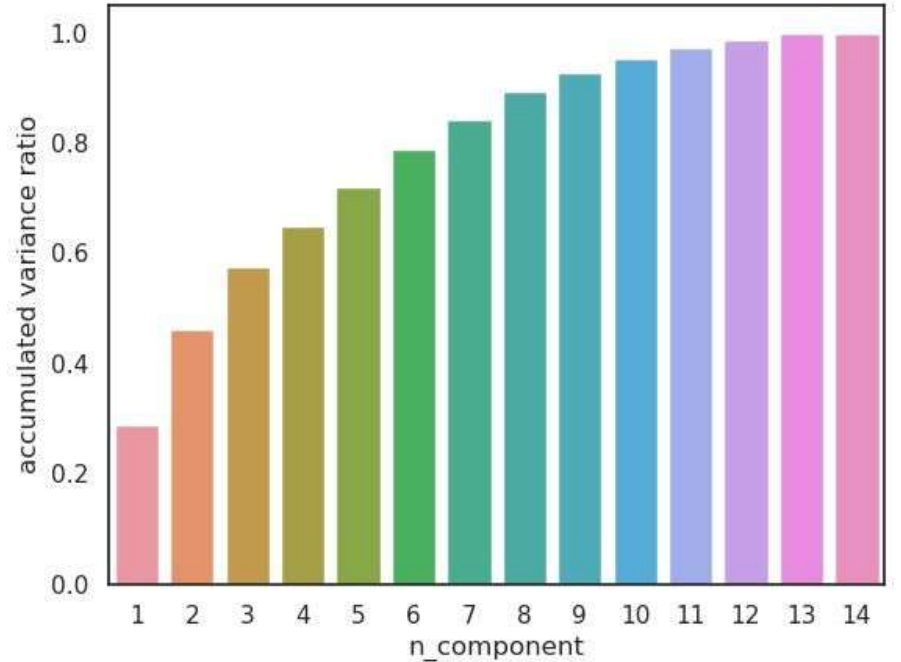


3. Clustering based Course Recommender System

Apply the PCA() provided by scikit-learn to find the main components in user profile feature vectors and see if we can reduce its dimensions by only keeping the main components.

If the accumulated variances ratio of a candidate `n_components` is larger than a threshold, e.g., 90%, then we can say the transformed `n_components` could explain about 90% of variances of the original data variance and can be considered as an optimized components size.

We select `n_component = 8`, due to the minimal ratio > 0.9



3. Clustering based Course Recommender System

Apply KMean on transformed features:

Apply PCA to features:

	user	PC0	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
0	2	17.772494	0.200681	1.730609	2.567359	-3.825814	2.707154	0.681042	2.312613	0.868272
1	4	7.145199	-2.847481	2.358636	-0.576654	0.398803	-0.134533	0.549769	0.469033	0.033405
2	5	11.363270	1.873619	-1.522077	1.076144	-1.711688	0.883212	1.677582	2.937669	2.097639
3	7	-1.834033	-0.277462	0.564905	0.053470	-0.064440	0.165757	0.030956	0.039519	0.210887
4	8	-1.049125	-0.684767	1.072765	0.006371	-0.005695	0.118686	0.118559	0.559292	0.186379
...
33896	2102054	0.633824	0.108815	-0.388871	-0.122665	-0.098364	0.358333	1.752049	1.486542	-0.523600
33897	2102356	-2.095339	0.135058	0.244727	-0.088185	0.025081	0.183641	0.046413	0.191709	0.260437
33898	2102680	0.625943	-0.547167	-1.692824	-0.630589	0.166632	0.676244	-0.055100	0.582091	1.703193
33899	2102983	-2.036832	-0.153534	0.162852	0.082651	-0.126419	0.255109	0.072496	0.113750	0.622900
33900	2103039	-2.036832	-0.153534	0.162852	0.082651	-0.126419	0.255109	0.072496	0.113750	0.622900

33901 rows × 10 columns

	user	cluster
0	2	9
1	4	23
2	5	9
3	7	15
4	8	8
...
33896	2102054	21
33897	2102356	15
33898	2102680	17
33899	2102983	15
33900	2103039	15

33901 rows × 2 columns

3. Clustering based Course Recommender System

Find popular courses in clusters and suggest to user in cluster:

Insights:

- On average, how many new/unseen courses have been recommended per user (in the test user dataset)
- What are the most frequently recommended courses? Return the top-10 commonly recommended courses

```
user in cluster 0 will be sugessted 3 courses as ['BC0101EN' 'BD0101EN' 'DS0101EN']
user in cluster 1 will be sugessted 3 courses as ['C00101EN' 'CC0101EN' 'C00201EN']
user in cluster 2 will be sugessted 3 courses as ['PY0101EN' 'CB0103EN' 'DA0101EN']
user in cluster 3 will be sugessted 3 courses as ['CB0103EN' 'BC0101EN' 'PY0101EN']
user in cluster 4 will be sugessted 3 courses as []
user in cluster 5 will be sugessted 3 courses as ['PY0101EN' 'DS0101EN' 'DA0101EN']
user in cluster 6 will be sugessted 3 courses as ['CC0101EN' 'PY0101EN' 'CC0103EN']
user in cluster 7 will be sugessted 3 courses as ['BC0101EN' 'BC0201EN' 'PY0101EN']
user in cluster 8 will be sugessted 3 courses as ['BD0101EN' 'BD0111EN' 'DS0101EN']
user in cluster 9 will be sugessted 3 courses as ['BD0101EN' 'BD0111EN' 'SW0101EN']
user in cluster 10 will be sugessted 3 courses as ['DS0101EN' 'RP0101EN' 'PY0101EN']
user in cluster 11 will be sugessted 3 courses as ['C00101EN' 'LB0101ENV1' 'C00401EN']
user in cluster 12 will be sugessted 3 courses as ['BD0111EN' 'BD0115EN' 'BD0141EN']
user in cluster 13 will be sugessted 3 courses as ['C00101EN' 'C00201EN' 'C00301EN']
user in cluster 14 will be sugessted 3 courses as ['BC0101EN' 'PY0101EN' 'DA0101EN']
user in cluster 15 will be sugessted 3 courses as ['DS0101EN' 'BD0101EN' 'PY0101EN']
user in cluster 16 will be sugessted 3 courses as ['CB0103EN' 'PY0101EN' 'DA0101EN']
user in cluster 17 will be sugessted 3 courses as ['PY0101EN' 'ML0101ENV3' 'ML0115EN']
user in cluster 18 will be sugessted 3 courses as ['BD0111EN' 'BD0211EN' 'BD0101EN']
user in cluster 19 will be sugessted 3 courses as ['BD0211EN' 'BD0101EN' 'DS0101EN']
user in cluster 20 will be sugessted 3 courses as ['BD0111EN' 'BD0101EN' 'BD0211EN']
user in cluster 21 will be sugessted 3 courses as ['RP0101EN' 'DS0101EN' 'DS0103EN']
user in cluster 22 will be sugessted 3 courses as ['LB0101ENV1' 'LB0103ENV1' 'LB0105ENV1']
user in cluster 23 will be sugessted 3 courses as ['BD0111EN' 'PY0101EN' 'BD0211EN']
user in cluster 24 will be sugessted 3 courses as ['CB0103EN' 'DS0101EN' 'BD0101EN']
```

Supervised Learning based Recomendation System

Supervised Learning based Recommendation System

Outline:

1. CF using K Nearest Neighbor
2. CF using Non-negative Matrix Factorization
3. Course Rating Prediction using Neural Networks
4. Regression-Based Rating Score Prediction Using Embedding Features
5. Classification-based Rating Mode Prediction using Embedding Features



1. CF using K Nearest Neighbor

Collaborative filtering is probably the most commonly used recommendation algorithm, there are two main types of methods:

- **User-based** collaborative filtering is based on the user similarity or neighborhood
- **Item-based** collaborative filtering is based on similarity among items



1. CF using K Nearest Neighbor

User-based collaborative filtering looks for users who are similar. This is very similar to the user clustering method done previously; where we employed explicit user profiles to calculate user similarity. However, the user profiles may not be available, so how can we determine if two users are similar?

For most collaborative filtering-based recommender systems, the main dataset format is a 2-D matrix called the user-item interaction matrix. In the matrix, its row is labeled as the user id/index and column labelled to be the item id/index, and the element (i, j) represents the rating of user i to item j .

Below is a simple example of a user-item interaction matrix:

User-Item interaction matrix

	Machine Learning With Python	Machine Learning 101	Machine Learning Capstone	SQL with Python	Python 101
user2	3.0	3.0	3.0	3.0	3.0
user3	2.0	3.0	3.0	2.0	
user4	3.0	3.0	2.0	2.0	3.0
user5	2.0	3.0	3.0		
user6	3.0	3.0	?		3.0

Similar users

Predict the rating of user user6 to item Machine Learning Capstone

1. CF using K Nearest Neighbor

We used the library **Surprise** library to handle dataset and fit the data.

Distance metric: Only common users (or items) are taken into account. The cosine similarity is defined as:

$$\text{cosine_sim}(u, v) = \frac{\sum_{i \in I_{uv}} r_{ui} \cdot r_{vi}}{\sqrt{\sum_{i \in I_{uv}} r_{ui}^2} \cdot \sqrt{\sum_{i \in I_{uv}} r_{vi}^2}}$$

For users u, v:

For items i, j:

$$\text{cosine_sim}(i, j) = \frac{\sum_{u \in U_{ij}} r_{ui} \cdot r_{uj}}{\sqrt{\sum_{u \in U_{ij}} r_{ui}^2} \cdot \sqrt{\sum_{u \in U_{ij}} r_{uj}^2}}$$

1. CF using K Nearest Neighbor - Pipeline & Result

Raw data

User - item - rating -
dataframe: user_id, item,
rating

Spare data

Use *pivot* method in
pandas to turn data to
features

	user	AI0111EN	BC0101EN	BC0201EN	BC0202EN	BD0101EN
0	2	0.0	3.0	0.0	0.0	3.0
1	4	0.0	0.0	0.0	0.0	2.0
2	5	2.0	2.0	2.0	0.0	2.0
3	7	0.0	0.0	0.0	0.0	0.0
4	8	0.0	0.0	0.0	0.0	0.0

5 rows × 7 columns

Model

Fit data to KNN model
based on *surprise*
library
Use distance metric
listed in previous page

Prediction

Make prediction by
test data, use RMSE
metric to evaluate
model performance

```
# Then compute RMSE  
accuracy.rmse(predictions)
```

```
Computing the msd similarity matrix...  
Done computing similarity matrix.  
RMSE: 0.1935
```

```
: 0.19350741218895207
```

2. CF using Non-negative Matrix Factorization

A dimensionality reduction algorithm called Non-negative matrix factorization (NMF), which decomposes a big sparse matrix into two smaller and dense matrices.

Non-negative matrix factorization can be one solution to big matrix issues. The main idea is to decompose the big and sparse user-interaction into two smaller dense matrices, one represents the transformed user features and another represents the transformed item features



2. CF using Non-negative Matrix Factorization

An example is shown below, suppose we have a user-item interaction matrix A with 10000 users and 100 items (10000 x 100), and its element (j, k) represents the rating of item k from user j . Then we could decompose A into two smaller and dense matrices U (10000 x 16) and I (16 x 100). for user matrix U , each row vector is a transformed latent feature vector of a user, and for the item matrix I , each column is a transformed latent feature vector of an item.

Here the dimension 16 is a hyperparameter defines the size of the hidden user and item features, which means now the shape of transposed user feature vector and item feature vector is now 16 x 1.

The magic here is when we multiply the row j of U and column k of matrix I , we can get an estimation to the original rating \hat{r}_{jk} .

For example, if we perform the dot product user one's row vector in U and item one's column vector in I , we can get the rating estimation of user one to item one, which is the element $(1, 1)$ in the original interaction matrix I .

2. CF using Non-negative Matrix Factorization

User-item interaction matrix: **A** 10000 x 100

	item1	...	item100
user1	
user2	3.0	3.0	3.0
user3	2.0	2.0	-
user4	3.0	2.0	3.0
user5	2.0	-	-
user6	3.0	-	3.0
...	

\approx

User matrix: **U** 10000 x 16

	feature1	...	feature16
user1
user2
user3
user4
...
...
user6

\times

Item matrix: **I** 16 x 100

	item1	...	item100
feature1
feature2
...
feature16

2. CF using Non-negative Matrix Factorization - Pipeline & Result

Raw data

User - item - rating -
dataframe: `user_id,`
`item, rating`

Decomposed
matrix

Use *surprise* library to
decompose full matrix
to two smaller and
denser ones: user
matrix and item
matrix

Model

Dot product each row
in user matrix with
each column in item
matrix

Prediction

Make prediction by
test data, use RMSE
metric to evaluate
model performance

User-item interaction matrix: **A** 10000 x 100

	item1	...	item100
user1
user2	3.0	3.0	3.0
user3	2.0	2.0	-
user4	3.0	2.0	3.0
user5	2.0	-	-
user6	3.0	-	3.0
...

User matrix: **U** 10000 x 16

	feature1	...	feature16
user1
user2
user3
user4
...
user6

≈

X

Item matrix: **I** 16 x 100

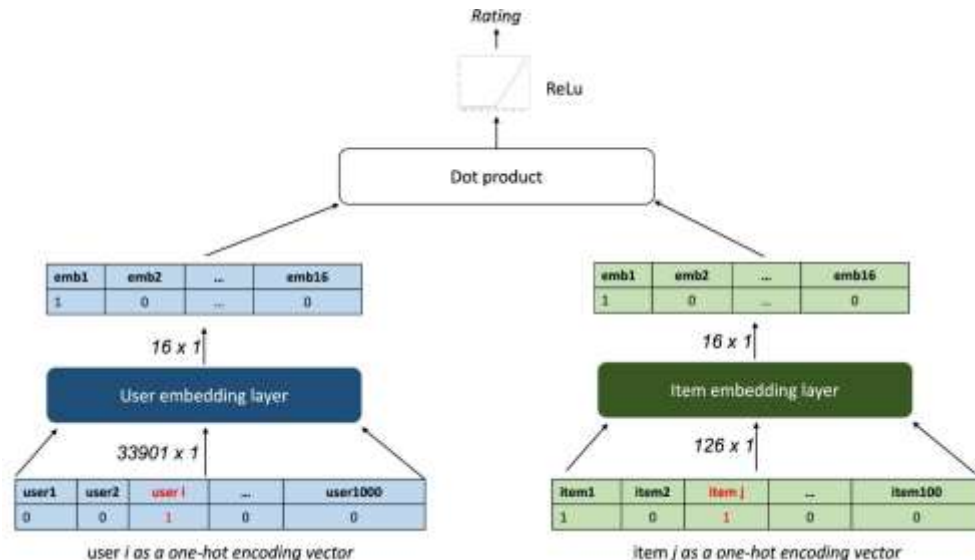
	item1	...	item100
feature1
feature2
...
feature16

```
Processing epoch 39
Processing epoch 40
Processing epoch 41
Processing epoch 42
Processing epoch 43
Processing epoch 44
Processing epoch 45
Processing epoch 46
Processing epoch 47
Processing epoch 48
Processing epoch 49
RMSE: 0.2078
0.20782347708297272
```

3. Course Rating Prediction using Neural Networks

The goal is to create a neural network structure that can take the user and item one-hot vectors as inputs and outputs a rating estimation or the probability of interaction (such as the probability of completing a course).

While training and updating the weights in the neural network, its hidden layers should be able to capture the pattern or features for each user and item. Based on this idea, we can design a simple neural network architecture like the following:



3. Course Rating Prediction using Neural Networks

Model:

- Optimizer: Adam
- Loss: Mean Square Error
- Metric: Mean Square Error
- Epoch 12
- Batch size: 512

Model: "recommender_net"

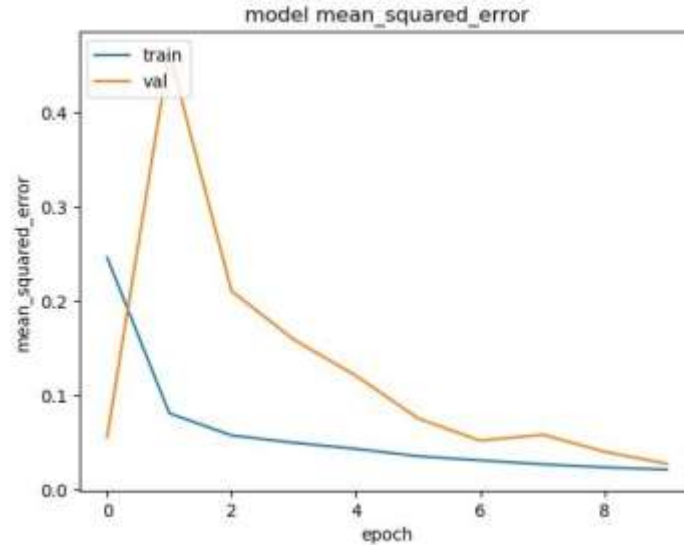
Layer (type)	Output Shape	Param #
user_embedding_layer (Embedding)	multiple	542416
user_bias (Embedding)	multiple	33901
item_embedding_layer (Embedding)	multiple	2016
item_bias (Embedding)	multiple	126
Total params: 578,459		
Trainable params: 578,459		
Non-trainable params: 0		

3. Course Rating Prediction using Neural Networks

-

Train and Val data:

Result

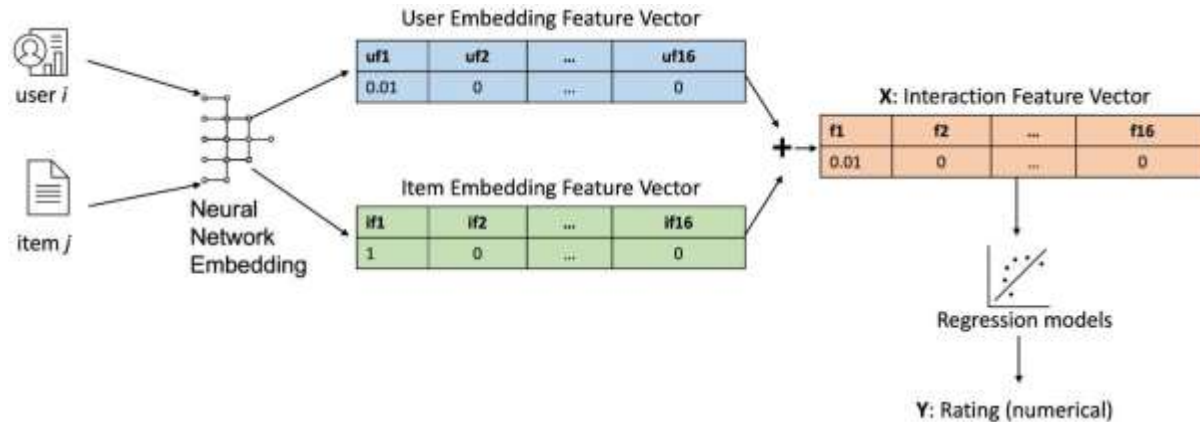


Result on test data:

Mean squared error: 0.258

Root mean squared error: 0.508

4. Regression-Based Rating Score Prediction Using Embedding Features



Another way to make rating predictions is to use the embedding as an input to a neural network by aggregating them into a single feature vector as input data **X**.

With the interaction label **Y** such as a rating score or an enrollment mode, we can build our other standalone predictive models to approximate the mapping from **X** to **Y**, as shown in the above flowchart.

4. Regression-Based Rating Score Prediction Using Embedding Features - Result

```
# Evaluation metrics
mae_lm = metrics.mean_absolute_error(y_test, lm_prediction)
mse_lm = metrics.mean_squared_error(y_test, lm_prediction)
rmse_lm = np.sqrt(mse_lm)

print('MAE:', mae_lm)
print('MSE:', mse_lm)
print('RMSE:', rmse_lm)

MAE: 0.41428838883833687
MSE: 0.9932500760760065
RMSE: 0.9966193235513781

TODO: Try different regression models such as Ridge, Lasso, Elastic.
```

```
from sklearn.linear_model import Ridge
from sklearn.linear_model import Lasso
from sklearn.linear_model import ElasticNet

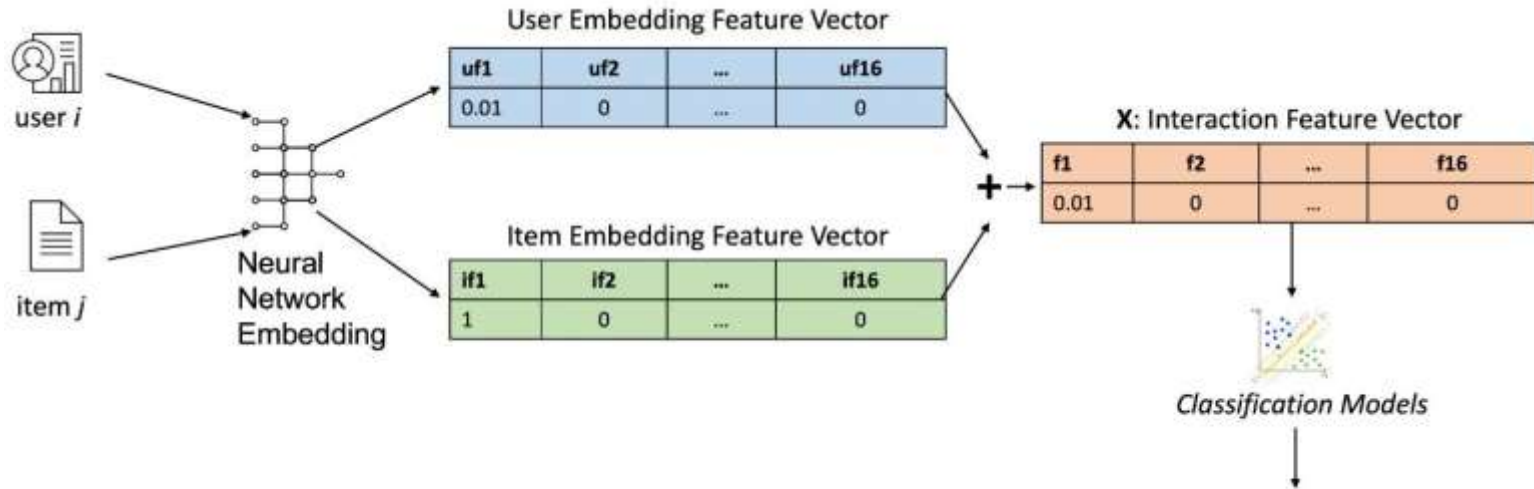
## WRITE YOUR CODE HERE
rd = ElasticNet()
rd.fit(X_train, y_train)
rd_prediction = rd.predict(X_test)

mae_rd = metrics.mean_absolute_error(y_test, rd_prediction)
mse_rd = metrics.mean_squared_error(y_test, rd_prediction)
rmse_rd = np.sqrt(mse_rd)

print('MAE:', mae_rd)
print('MSE:', mse_rd)
print('RMSE:', rmse_rd)

MAE: 0.4167848022681181
MSE: 1.0000000000000002
RMSE: 1.0
```

Classification-based Rating Mode Prediction using Embedding Features



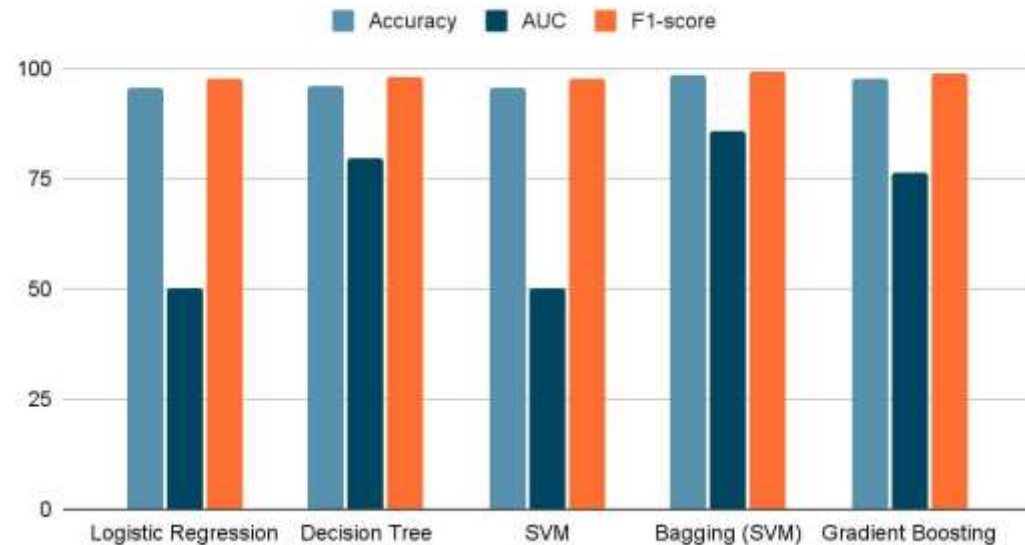
We first extract two embedding matrices out of the neural network, and aggregate them to be a single interaction feature vector as input data X.

This time, with the interaction label Y as categorical rating mode, we can build classification models to approximate the mapping from X to Y, as shown in the above flowchart.

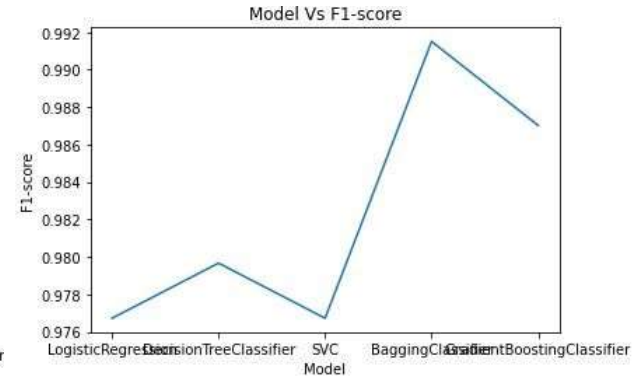
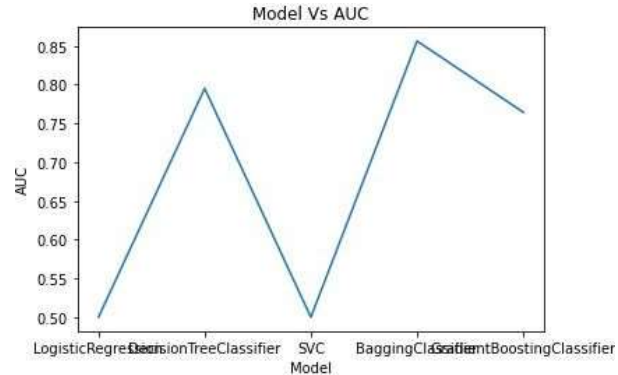
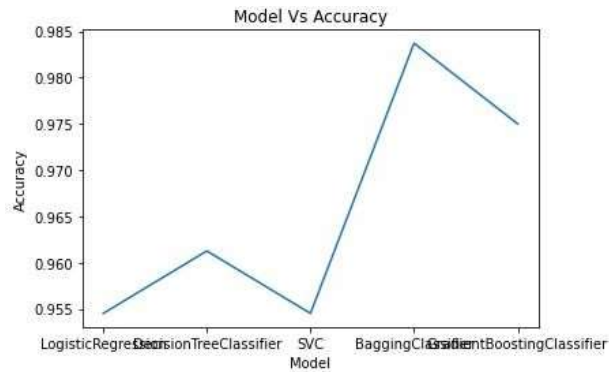
5. Classification-based Rating Mode Prediction using Embedding Features

	Accuracy	AUC	F1-score
Logistic Regression	95.45	0.5	97.67
Decision Tree	96.12	79.51	97.97
SVM	95.45	0.5	97.67
Bagging (SVM)	98.37	85.62	99.15
Gradient Boosting	97.5	76.44	98.7

Accuracy, AUC and F1-score

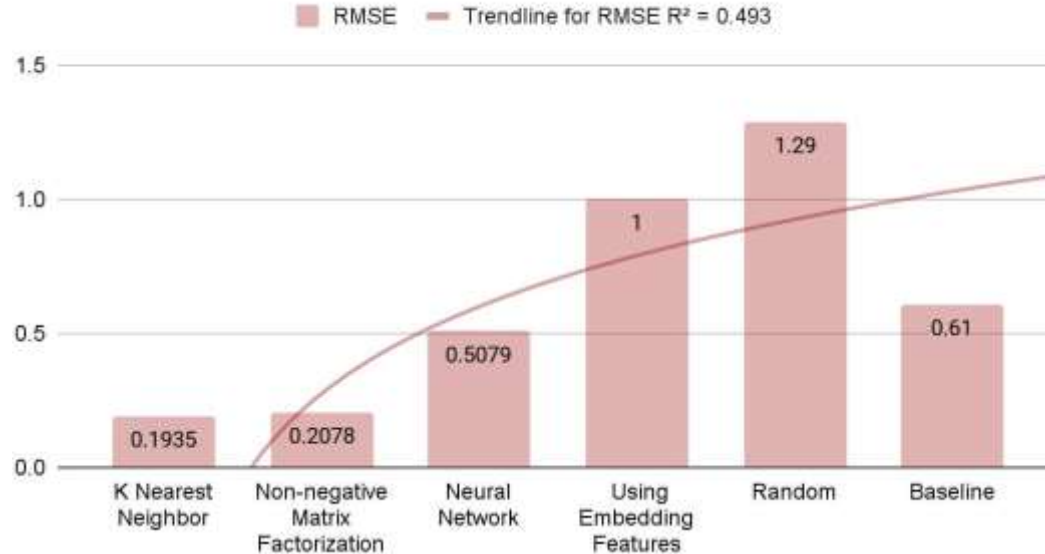


5. Classification-based Rating Mode Prediction using Embedding Features




Compare the performance of collaborative-filtering models

Model RMSE Comparison



Insights:

- Random prediction is obviously worst
- KNN method have



Deploy and showcase models on Streamlit

Deploy and showcase models on Streamlit

Personalized Learning Recommender

1. Select recommendation models:

Select model:

Course Similarity

2. Tune Hyper-parameters:

Top courses

0 100

Course Similarity Threshold %

0 100

3. Training:

Train Model

4. Prediction

Recommend New Courses

Datasets loaded successfully...

Select courses that you have audited or completed:

COURSE_ID	TITLE	DESCRIPTION
<input type="checkbox"/> CPXX0T0FEN	Project: Deploy A Serverless App For Image Processing	in this project you will learn about serverless computing will practice deploying a real application to a serverless environment bas
<input type="checkbox"/> D50107	Data Science Career Talks	data science career talks
<input type="checkbox"/> D50110EN	Data Science With Open Data	data science with open data
<input type="checkbox"/> DX0107EN	Data Science Bootcamp With Python For University Professors	data science bootcamp with python for university professors
<input type="checkbox"/> D50321EN	Bitcoin 101	greetings and welcome to the introduction to bitcoin course
<input type="checkbox"/> D50105EN	Data Science Hands On With Open Source Tools	what tools do data scientists use in this course you'll learn how to use the most popular data science tools including jupyter note
<input type="checkbox"/> D50103EN	Data Science Methodology	grab you lab coat breakers and pocket calculator, wait what wrong path fast forward and get in line with emerging data science me
<input type="checkbox"/> CPXX04FEN	Creating Asynchronous Java Microservices Using Microprofile Reactive Messaging	learn how to write reactive java microservices using microprofile reactive messaging
<input type="checkbox"/> CPXX06KEEN	Build A Smart Search Form With Algolia	great search is an essential feature that all of the best applications share in this project we'll leverage the power of algolia to bui
<input type="checkbox"/> CPXX0Y0FEN	Documenting Restful APIs Using Microprofile Openapi	explore how to document and filter restful apis from code or static files by using microprofile openapi
<input type="checkbox"/> LB0109ENv1	Reactive Architecture Distributed Messaging Patterns	reactive architecture distributed messaging patterns
<input type="checkbox"/> CPXX0K0HEN	Data Science In Agriculture Land Use Classification	in this lab we will learn the basic methods of images transformation classification

Your courses:

	COURSE_ID	TITLE
0	ML0201EN	Robots Are Coming Build IoT Apps With Watson Swift And Node Red
1	GPXX022PEN	Containerizing Packaging And Running A Spring Boot Application
2	DX0106EN	Data Science Bootcamp With R For University Professors

Deploy and showcase models on Streamlit

Personalized Learning Recommender

1. Select recommendation models

Select model:

Course Similarity

2. Tune Hyper-parameters:

Top courses

0 100

Course Similarity Threshold %

0 100

3. Training:

Train Model

4. Prediction

Recommend New Courses

Your courses:

	COURSE_ID	TITLE
0	ML0201EN	#Robots Are Coming Build IoT Apps With Watson Swift And Node Red
1	GPXX022PEN	Containerizing Packaging And Running A Spring Boot Application
2	DX0306EN	Data Science Bootcamp With R For University Professors
3	RAVSCTEST1	Scorm Test 1

Recommendations generated!

	SCORE	TITLE	DESCRIPTION
0	0.9476	Data Science Bootcamp	a multi day intensive in person data science bootcamp offered by big data university
1	0.6823	Data Science Bootcamp With Python For University Professors	data science bootcamp with python for university professors
2	0.6685	Data Science Bootcamp With Python For University Professors Advance	data science bootcamp with python for university professors advance
3	0.6499	Data Science Bootcamp With Python	data science bootcamp with python
4	0.6065	Data Science With Open Data	data science with open data

Future work

This project shows how a end-to-end machine learning pipeline work. Although we pass all requirement of course's creator, there are several enhancements can be applied for better accuracy and complete the perfection:

- Experience with real customer data
- Apply more pre-processing techniques
- Deal with spare data which can cause full of memory



Appendix

- Presenter: Taotao Ouyang ([Linkedin](#))
- Github repository: [Capstone Project](#)





Thank you for your time!