knn

December 13, 2020

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1 Item-based Collaborative Filtering

Collaborative filtering considers users' opinion on different products and recommends the best products based on the products' previous rankings and the opinion of other similar types of users.

Here we focus on non-probablistic collaborative filtering algorithms, which can be divided to two categories: **memory-based** and **model-based**.

Memory-based algorithm is essentially linear algebra calculation and can be implemented with **k-nearest neighbors**. Model-based algorithm involves matrix factorization, and will be detailed in the next notebook.

Item-based collaborative filtering is the common practice in recommender systems. The intuition is to generate predictions based on similarities between items.

Item-based collaborative filtering was developed by Amazon. It is faster when there are more users than items. It is also more stable because the average rating received by an item usually doesn't change as quickly as the average rating given by a user to different items.

The advantage of item-based collaborative filtering is that it does not require knowledge about the product.

[ ]:

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1.0.1 import requirements

[168]:

```
# import library
import pandas as pd
import numpy as np
import scipy as sp

import matplotlib.pyplot as plt
import seaborn as sns

from collections import defaultdict
from collections import Counter
```

Source: surprise documentation

[169]:
```python
from surprise import Dataset
from surprise import Reader
from surprise import KNNWithMeans
from surprise.model_selection import GridSearchCV
from surprise import accuracy
```

[ ]:
```python

```

[171]:
```python
# load data
df = pd.read_csv('ratings_item0.csv', index_col=0)
df.head(3)
```

[171]:

	uid	bid	rating
10	276746	0425115801	0
11	276746	0449006522	0
12	276746	0553561618	0

[172]:
```python
df.shape
```

[172]: (456182, 3)

[173]:
```python
num_users = len(set(df['uid']))
num_books = len(set(df['bid']))
print(f'There are {num_users} users and {num_books} books in this dataset.')
```

```
There are 13808 users and 18318 books in this dataset.
```

[ ]:
```python

```

1.0.2 data loading

[22]:
```python
reader = Reader(rating_scale=(1,10))
```

[23]:
```python
data = Dataset.load_from_df(df[['uid', 'bid', 'rating']], reader)
```

[ ]:
```python

```

[178]:
```python
# param_grid = {
#     'bsl_options': {'method': ['als', 'sgd'],
#                     #'reg_i': [10],
#                     #'reg_u': [15],
#                     #'reg': [0.02],
#                     #'learning_rate': [0.005],
#                     'n_epochs': [10, 20]},
#     'k': [3, 5, 10, 20],
#     'sim_options': {'name': ['cosine', 'msd', 'pearson', 'pearson_baseline'],
#                     'min_support': [1, 3],
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#                       'user_based': [True, False]}
# }
```

[179]:
```
# gs = GridSearchCV(KNNWithMeans,
#                   param_grid,
#                   measures=['rmse', 'mae'],
#                   cv=3)
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[180]:
```
#gs.fit(data)
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[184]:
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# # best RMSE score
# print(gs.best_score)
```

```
{'rmse': 1.6651286278605182, 'mae': 1.2377969578142525}
```

[203]:
```
best_score = {'rmse': 1.6651286278605182, 'mae': 1.2377969578142525}
print(best_score)
```

```
{'rmse': 1.6651286278605182, 'mae': 1.2377969578142525}
```

[182]:
```
# # combination of parameters that gave the best RMSE score
# print(gs.best_params['rmse'])
```

```
{'bsl_options': {'method': 'als', 'n_epochs': 10}, 'k': 20, 'sim_options':
{'name': 'cosine', 'min_support': 1, 'user_based': False}}
```

[201]:
```
best_params = {'bsl_options': {'method': 'als', 'n_epochs': 10}, 'k': 20,␣
↪'sim_options': {'name': 'cosine', 'min_support': 1, 'user_based': False}}
print(best_params)
```

```
{'bsl_options': {'method': 'als', 'n_epochs': 10}, 'k': 20, 'sim_options':
{'name': 'cosine', 'min_support': 1, 'user_based': False}}
```

[183]:
```
# results_df = pd.DataFrame.from_dict(gs.cv_results)
# results_df.head()
```

[183]:
```
   split0_test_rmse  split1_test_rmse  split2_test_rmse  mean_test_rmse  \
0          1.767441          1.782065          1.775103        1.774870
1          1.732224          1.735080          1.739080        1.735462
2          1.807058          1.821138          1.828133        1.818776
3          1.723783          1.739371          1.732963        1.732039
4          1.763404          1.794554          1.775311        1.777756

   std_test_rmse  rank_test_rmse  split0_test_mae  split1_test_mae  \
0       0.005973             186         1.327541         1.339127
1       0.002812             129         1.291303         1.295970
```

```
2       0.008764               251          1.351508          1.345143
3       0.006397               116          1.293963          1.298640
4       0.012834               190          1.318364          1.340988

   split2_test_mae  mean_test_mae  std_test_mae  rank_test_mae  mean_fit_time  \
0         1.325365       1.330678      0.006040            217       0.801336
1         1.295773       1.294349      0.002155             96       0.294262
2         1.357642       1.351431      0.005103            251       0.406097
3         1.300495       1.297699      0.002748            133       0.098307
4         1.320052       1.326468      0.010290            207       0.308598

   std_fit_time  mean_test_time  std_test_time  \
0      0.015515        0.417113       0.011231
1      0.018206        0.306368       0.053522
2      0.085957        0.406642       0.038261
3      0.008631        0.270384       0.015879
4      0.009363        0.463069       0.052258

                                              params  \
0  {'bsl_options': {'method': 'als', 'n_epochs': …
1  {'bsl_options': {'method': 'als', 'n_epochs': …
2  {'bsl_options': {'method': 'als', 'n_epochs': …
3  {'bsl_options': {'method': 'als', 'n_epochs': …
4  {'bsl_options': {'method': 'als', 'n_epochs': …

                   param_bsl_options  param_k  \
0  {'method': 'als', 'n_epochs': 10}        3
1  {'method': 'als', 'n_epochs': 10}        3
2  {'method': 'als', 'n_epochs': 10}        3
3  {'method': 'als', 'n_epochs': 10}        3
4  {'method': 'als', 'n_epochs': 10}        3

                                  param_sim_options
0  {'name': 'cosine', 'min_support': 1, 'user_bas…
1  {'name': 'cosine', 'min_support': 1, 'user_bas…
2  {'name': 'cosine', 'min_support': 3, 'user_bas…
3  {'name': 'cosine', 'min_support': 3, 'user_bas…
4  {'name': 'msd', 'min_support': 1, 'user_based'…
```

[185]:
```
#results_df.to_csv('knn_results.csv')
```

Save the hypertuning results so next time I don't have to run that again and can directly use the results.

[ ]:
```

```

1.0.3 evaluation

1.0.4 MAE (mean absolute error)

Mean Average Error (MAE) does not give any bias to extrema in error terms. If there are outliers or large error terms, it will weigh those equally to the other predictions. Therefore, MAE should be preferred when looking toward rating accuracy when you're not really looking toward the importance of outliers. To get a holistic view or representation of the Recommender System, use MAE.

1.0.5 RMSE (root mean squared error)

Root Mean Squared Error tends to disproportionately penalize large errors as the residual (error term) is squared. This means RMSE is more prone to being affected by outliers or bad predictions.

MAE can only accurately recreate 0.8 of the data set. RSME is a lot more mathematically convenient whenever calculating distance, gradient, or other metrics. That's why most cost functions in Machine Learning avoid using MAE and rather use sum of squared errors or Root Means Squared Error.

By definition, RMSE will never be as small as MAE. This paper establishes that both metrics are useful in evaluating algorithms.

[233]:
```
#results_df = pd.read_csv('knn_results.csv')
```

[225]:
```
# results_df = results_df[
#     ['split0_test_rmse', 'rank_test_rmse', 'params',
#      'param_bsl_options', 'param_k', 'param_sim_options']]
```

[226]:
```
# results_df = pd.concat([
#     results_df.drop(['param_bsl_options'], axis=1),
#     results_df['param_bsl_options'].apply(pd.Series)
#     ], axis=1)
```

[228]:
```
# results_df = pd.concat([
#     results_df.drop(['param_sim_options'], axis=1),
#     results_df['param_sim_options'].apply(pd.Series)
#     ], axis=1)
```

[231]:
```
#results_df.to_csv('knn_results_cleaned.csv')
```

[235]:
```
results_df = pd.read_csv('knn_results_cleaned.csv', index_col=0)
```

[258]:
```
results_df.sort_values(by='rank_test_rmse')[:5]
```

[258]:
```
     split0_test_rmse  rank_test_rmse  \
177          1.663016               1
241          1.663016               2
49           1.663016               3
113          1.663016               4
```

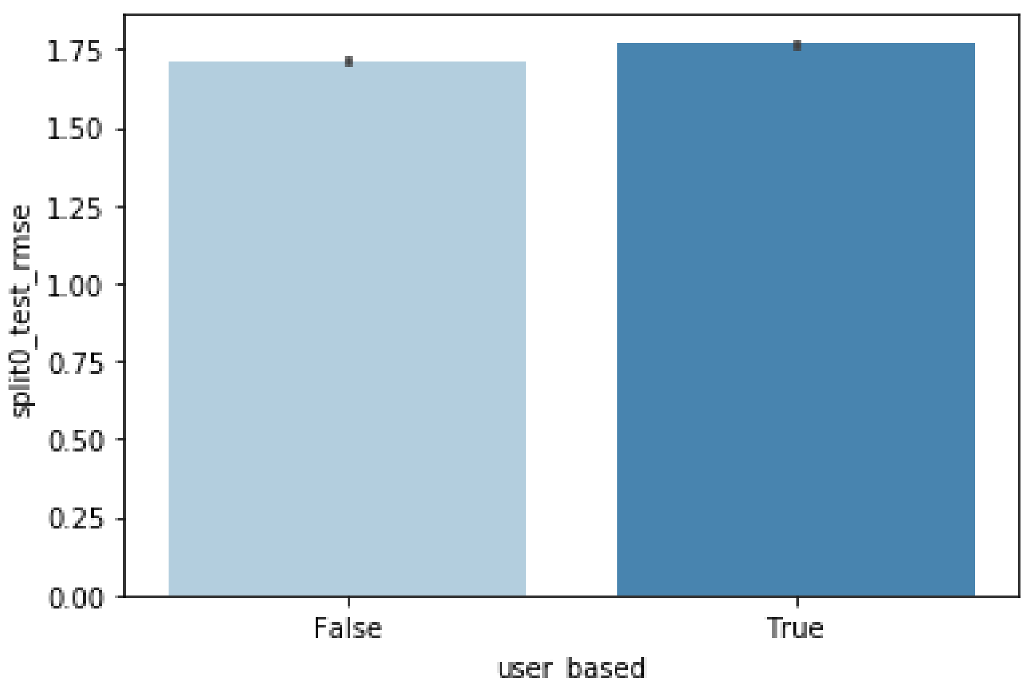
```
161          1.668153              5

                                                   params  param_k method  \
177  {'bsl_options': {'method': 'sgd', 'n_epochs': …       20     sgd
241  {'bsl_options': {'method': 'sgd', 'n_epochs': …       20     sgd
49   {'bsl_options': {'method': 'als', 'n_epochs': …       20     als
113  {'bsl_options': {'method': 'als', 'n_epochs': …       20     als
161  {'bsl_options': {'method': 'sgd', 'n_epochs': …       10     sgd

     n_epochs    name  min_support  user_based
177        10  cosine            1       False
241        20  cosine            1       False
49         10  cosine            1       False
113        20  cosine            1       False
161        10  cosine            1       False
```

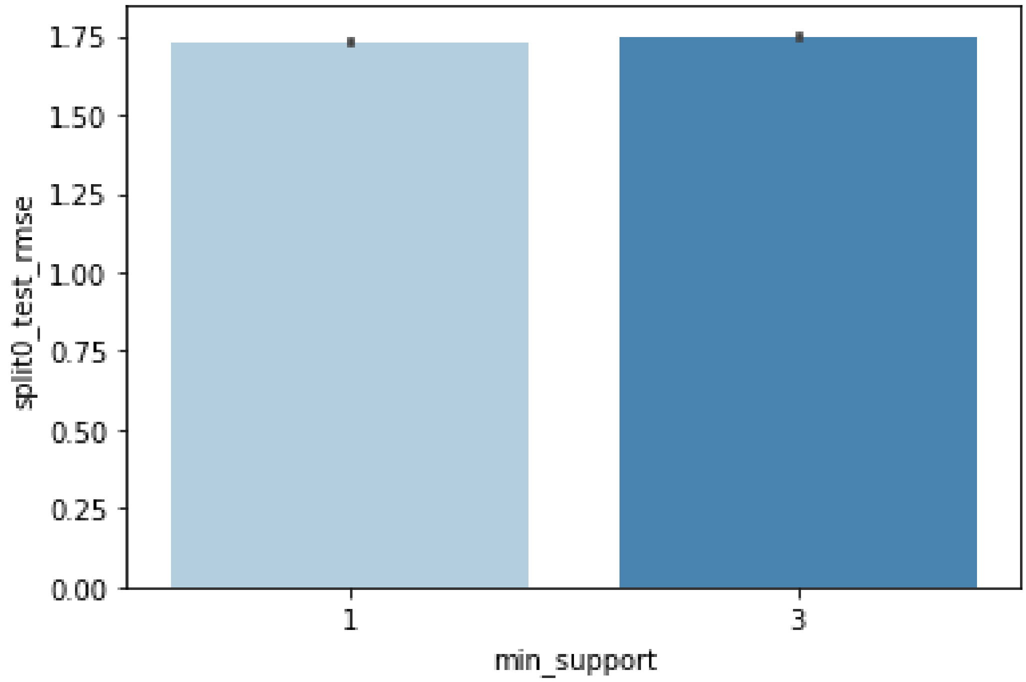
[328]:
```
sns.barplot(x=results_df['user_based'], y=results_df['split0_test_rmse'],␣
↪palette='Blues')
```

[328]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x13b7b0df0>
```



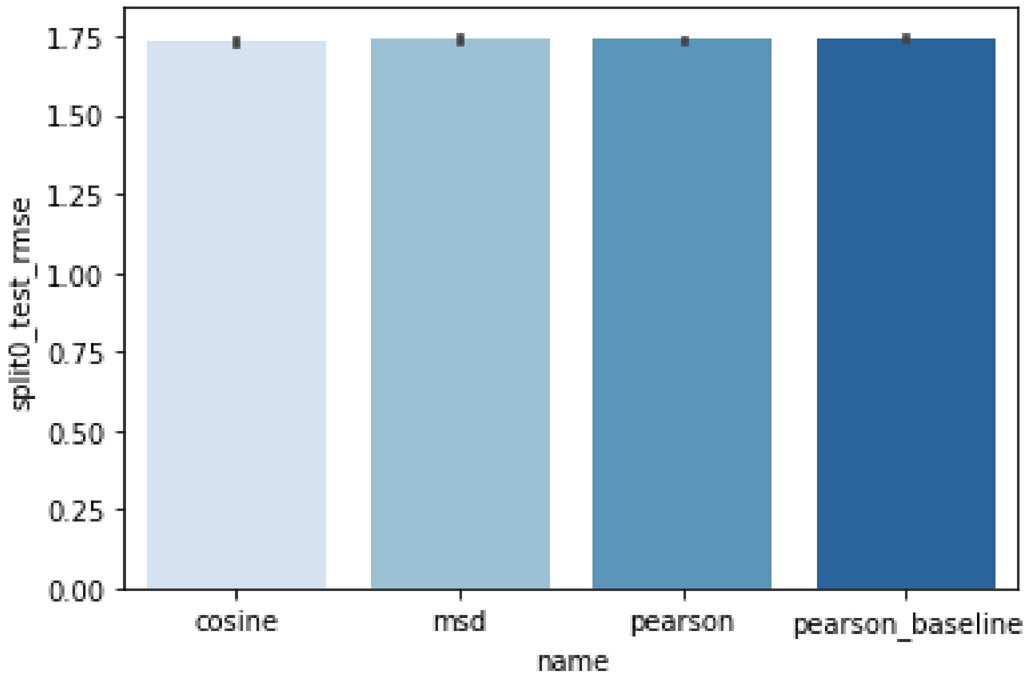
[329]:
```
sns.barplot(x=results_df['min_support'], y=results_df['split0_test_rmse'],␣
↪palette='Blues')
```

[329]: <matplotlib.axes._subplots.AxesSubplot at 0x13b530fa0>



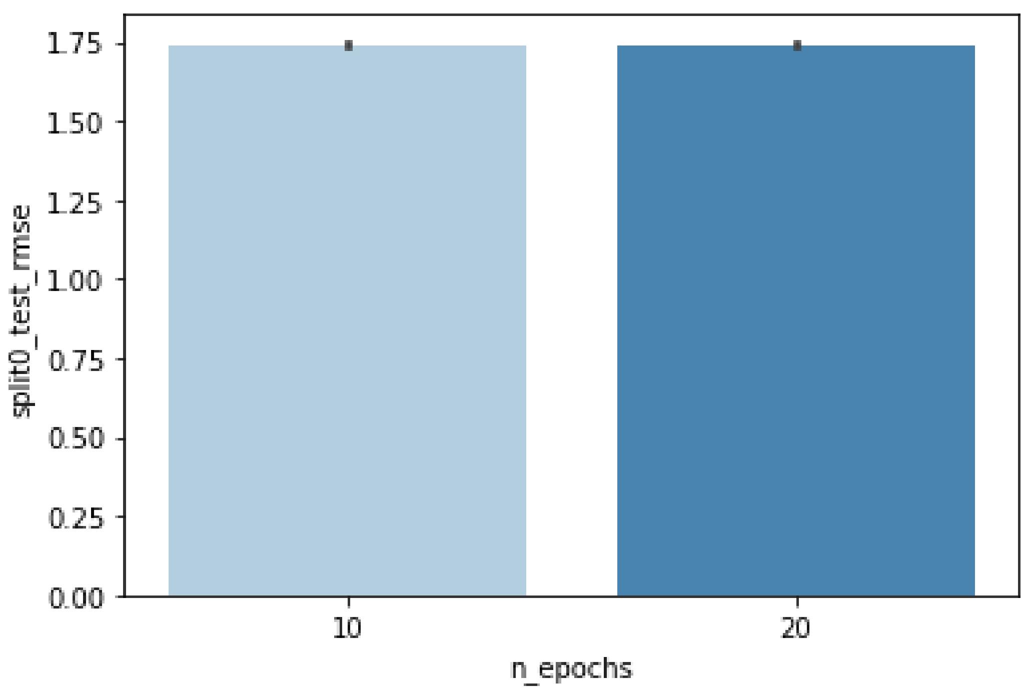
[330]:
```
sns.barplot(x=results_df['name'], y=results_df['split0_test_rmse'],␣
 ↪palette='Blues')
```

[330]: <matplotlib.axes._subplots.AxesSubplot at 0x13b398eb0>



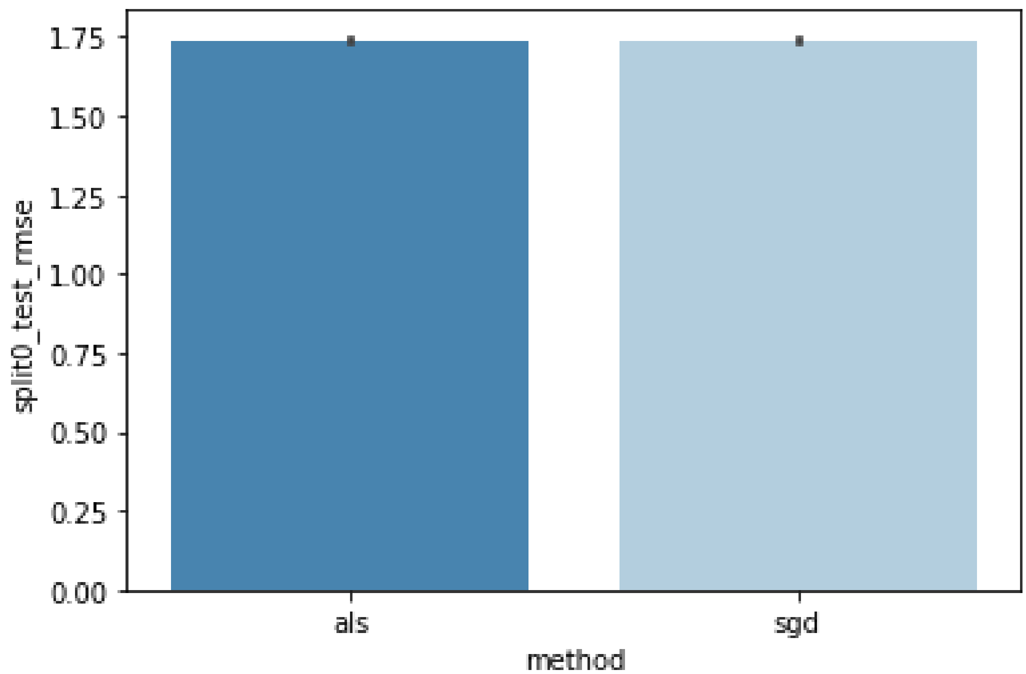
[333]:
```
sns.barplot(x=results_df['n_epochs'], y=results_df['split0_test_rmse'],
 ↪palette='Blues')
```

[333]: <matplotlib.axes._subplots.AxesSubplot at 0x13a6add00>



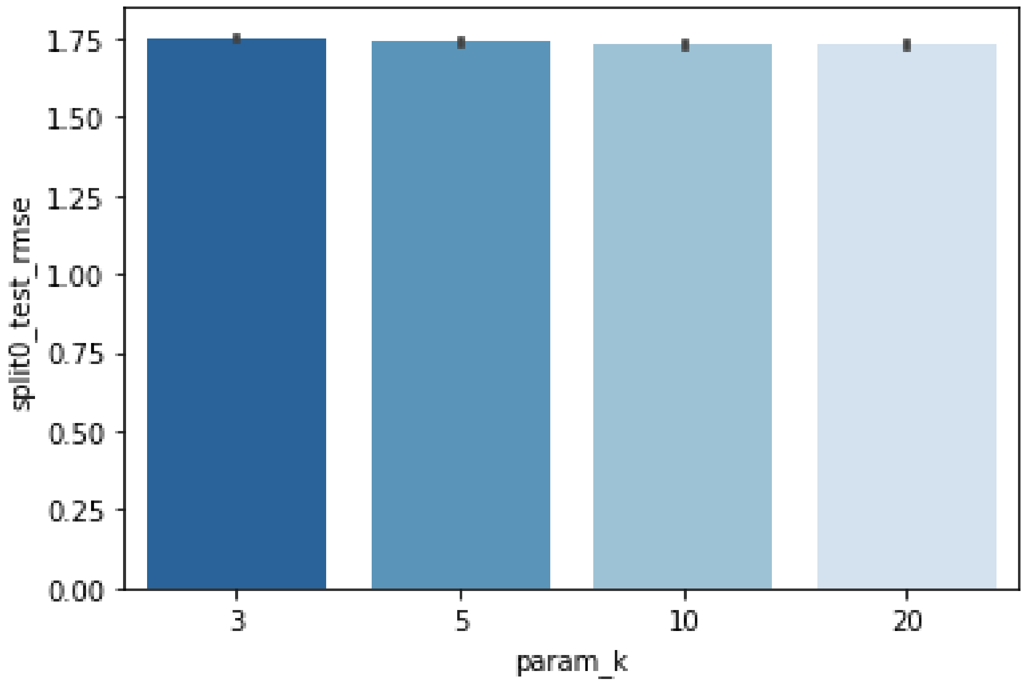
[332]:
```
sns.barplot(x=results_df['method'], y=results_df['split0_test_rmse'],
 palette='Blues_r')
```

[332]: <matplotlib.axes._subplots.AxesSubplot at 0x13b47f6d0>



[331]:
```
sns.barplot(x=results_df['param_k'], y=results_df['split0_test_rmse'],
 palette='Blues_r')
```

[331]: <matplotlib.axes._subplots.AxesSubplot at 0x13a5d02e0>



[254]:
```
results_df.sort_values(by='rank_test_rmse')
```

[254]:
```
     split0_test_rmse  rank_test_rmse  \
177          1.663016               1
241          1.663016               2
49           1.663016               3
113          1.663016               4
161          1.668153               5
..                …             …
66           1.807058             252
198          1.812107             253
70           1.812107             254
6            1.812107             255
134          1.812107             256

                                                params  param_k method  \
177  {'bsl_options': {'method': 'sgd', 'n_epochs': …       20    sgd
241  {'bsl_options': {'method': 'sgd', 'n_epochs': …       20    sgd
49   {'bsl_options': {'method': 'als', 'n_epochs': …       20    als
113  {'bsl_options': {'method': 'als', 'n_epochs': …       20    als
161  {'bsl_options': {'method': 'sgd', 'n_epochs': …       10    sgd
..                                                 …      …    …
66   {'bsl_options': {'method': 'als', 'n_epochs': …        3    als
198  {'bsl_options': {'method': 'sgd', 'n_epochs': …        3    sgd
```

```
70   {'bsl_options': {'method': 'als', 'n_epochs': …        3    als
6    {'bsl_options': {'method': 'als', 'n_epochs': …        3    als
134  {'bsl_options': {'method': 'sgd', 'n_epochs': …        3    sgd

     n_epochs    name  min_support  user_based
177        10  cosine            1       False
241        20  cosine            1       False
49         10  cosine            1       False
113        20  cosine            1       False
161        10  cosine            1       False
..        …     …          …         …
66         20  cosine            3        True
198        20     msd            3        True
70         20     msd            3        True
6          10     msd            3        True
134        10     msd            3        True

[256 rows x 9 columns]
```

[ ]:

[ ]:

[ ]:

1.1 get top-N recommendations for each user

Source: documentation

We first train an SVD algorithm on the whole dataset, and then predict all the ratings for the pairs (user, item) that are not in the training set. We then retrieve the top-10 prediction for each user.

[188]:
```
def get_top_n(predictions, n=10):
    """
    Return the top-N recommendation for each user from a set of predictions.

    Args:
        predictions(list of Prediction objects): The list of predictions, as
            returned by the test method of an algorithm.
        n(int): The number of recommendation to output for each user. Default␣
↪is 10.

    Returns:
    A dict where keys are user (raw) ids and values are lists of tuples:
        [(raw item id, rating estimation), ...] of size n.
    """
```

```
    # First map the predictions to each user.
    top_n = defaultdict(list)
    for uid, iid, true_r, est, _ in predictions:
        top_n[uid].append((iid, est))

    # Then sort the predictions for each user and retrieve the k highest ones.
    for uid, user_ratings in top_n.items():
        user_ratings.sort(key=lambda x: x[1], reverse=True)
        top_n[uid] = user_ratings[:n]

    return top_n
```

[ ]:

```

```

[213]:

```
trainset, testset = train_test_split(data, test_size=.25)
```

[214]:

```
algo = KNNWithMeans(k=20,
                    bsl_options={'method':'als', 'n_epochs':10},
                    sim_options={'name':'cosine', 'min_support':1,
                                 'user_based':False})
```

[215]:

```
predictions = algo.fit(trainset).test(testset)
```

```
Computing the cosine similarity matrix…
Done computing similarity matrix.
```

[ ]:

```

```

[189]:

```
#top_10 = get_top_n(predictions, n=10)
```

[326]:

```
# # Print the recommended items for each user
# for uid, user_ratings in top_10.items():
#     pass
#     #print(uid, [bid for (bid, _) in user_ratings])
```

[206]:

```
test_df = pd.DataFrame(testset, columns=['uid', 'bid', 'rating'])
test_df.head(3)
```

[206]:

	uid	bid	rating
0	212849	0684853515	9.0
1	115003	0375700757	8.0
2	11676	0425163407	8.0

[281]:

```
#test_df[test_df['uid']==115003]
```

[282]:

```
#top_10[115003]
```

[283]:
```
# bought = set(test_df[test_df['uid']==115003]['bid'])
# predicted = set([bid for bid, rating in top_10[115003]])
# bought.intersection(predicted)
```

[286]:
```
# # the rate our recommended books in user's bought list
# len(bought.intersection(predicted)) / len(predicted)
```

[ ]:
```

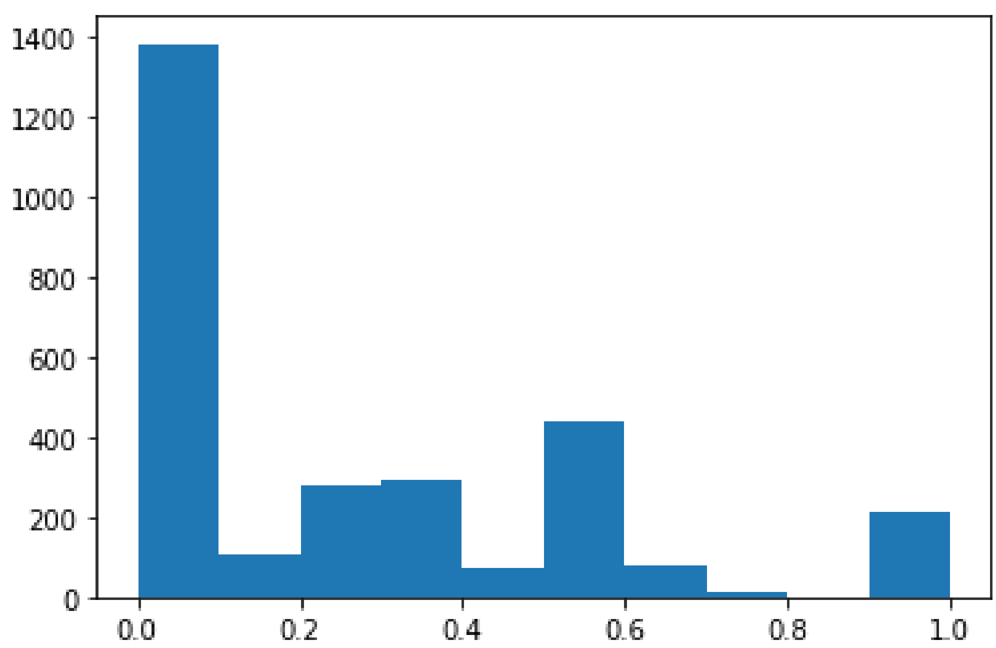
```

[327]:
```
top_10 = get_top_n(predictions, n=10)
accuracy = []

# Print the recommended items for each user
for uid, user_ratings in top_10.items():
    bought = set(test_df[test_df['uid']==uid]['bid'])
    predicted = set([bid for bid, rating in user_ratings])
    rate = len(bought.intersection(predicted)) / len(predicted)
    accuracy.append(rate)
print(sum(accuracy)/len(accuracy))
```

```
0.24570465736843541
```

[325]:
```
plt.hist(accuracy)
plt.show()
```



[ ]:
```

```

This means that based on our current recommender system, when we predict them thier top 10 books, we can accurately recommend around 25% of the books they would end up actually buying.

[ ]:

```

```

[298]:

```
n = np.arange(1,21,1)
avg_accuracy = []

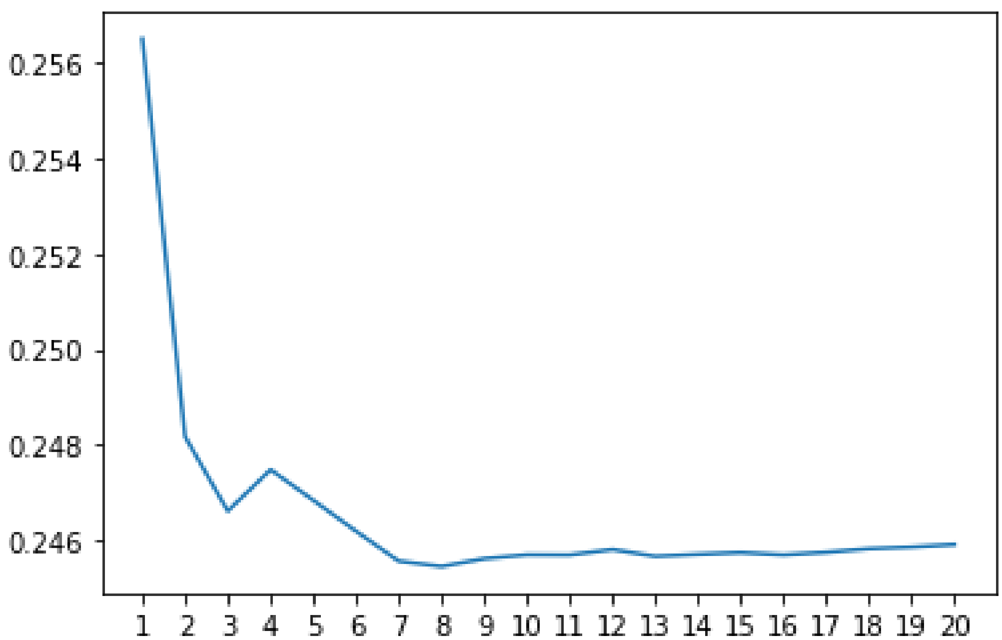
for i in n:
    top_n = get_top_n(predictions, n=i)
    accuracy = []

    for uid, user_ratings in top_n.items():
        bought = set(test_df[test_df['uid']==uid]['bid'])
        predicted = set([bid for bid, rating in user_ratings])
        rate = len(bought.intersection(predicted)) / len(predicted)
        accuracy.append(rate)

    avg_accuracy.append(sum(accuracy)/len(accuracy))
```

[317]:

```
plt.plot(avg_accuracy)
plt.xticks(np.arange(0,20,1),n)
plt.show()
```



[ ]:

```

```

Interestingly, our recommendation accuracy does not yield better results when we predict more items, and there is an optimal result accuracy when we recommend 4 items to users.

```
[ ]:
```

1.2 Issues in collaborative filtering

- Sparseness in user-item matrix (sparsity=$1 - |R|/|I| * |U|$)
- Cold start for users and items

Next, we would try to resolve these issues using matrix factorization.

```
[ ]:
```