Case Study 4.1 - Movies

Note: If you close this notebook at any time, you will have to run all cells again upon re-opening it.

BEGINNER PYTHON

As this is a beginner version, we include a lot of code here to help you along the way.

Identification Information

In [1]:

```
# YOUR NAME              = Hiral
# YOUR MITX PRO USERNAME = hiralsatasia
# YOUR MITX PRO E-MAIL   = hiralsatasia@live.com
```

Setup

Run these cells to install all the packages you need to complete the remainder of the case study. This may take a few minutes, so please be patient.

In [2]:

```
!pip install surprise==0.1
```

```
Requirement already satisfied: surprise==0.1 in /home/nbuser/anaconda3_501/lib/python3.6/site-packages (0.1)
Requirement already satisfied: scikit-surprise in /home/nbuser/anaconda3_501/lib/python3.6/site-packages (from surprise==0.1) (1.0.6)
Requirement already satisfied: numpy>=1.11.2 in /home/nbuser/anaconda3_501/lib/python3.6/site-packages (from scikit-surprise->surprise==0.1) (1.15.2)
Requirement already satisfied: joblib>=0.11 in /home/nbuser/anaconda3_501/lib/python3.6/site-packages (from scikit-surprise->surprise==0.1) (0.12.5)
Requirement already satisfied: scipy>=1.0.0 in /home/nbuser/anaconda3_501/lib/python3.6/site-packages (from scikit-surprise->surprise==0.1) (1.1.0)
Requirement already satisfied: six>=1.10.0 in /home/nbuser/anaconda3_501/lib/python3.6/site-packages (from scikit-surprise->surprise==0.1) (1.11.0)
You are using pip version 18.0, however version 18.1 is available.
You should consider upgrading via the 'pip install --upgrade pip' command.
```

Now, you must press **Kernel > Restart.** This allows the installation to take effect. Once you see the blue **Connected/Kernel ready** button in the top right, you are good to go.

Import

Import the required tools into the notebook.

In [3]:

```
import pandas as pd
import matplotlib
from surprise import Dataset, SVD, NormalPredictor, BaselineOnly, KNNBasic, NMF
from surprise.model_selection import cross_validate, KFold
print('Imports successful!')
```

```
Imports successful!
```

```
Imports successful!
```

In [4]:

```
%matplotlib inline
```

Data

Load the MovieLens data. A dialog may pop up saying **"Dataset ml-100k could not be found. Do you want to download it? [Y/n]"** Type Y and hit Enter to start the download process.

In [5]:

```
data = Dataset.load_builtin('ml-100k')
print('Data load successful!')
```

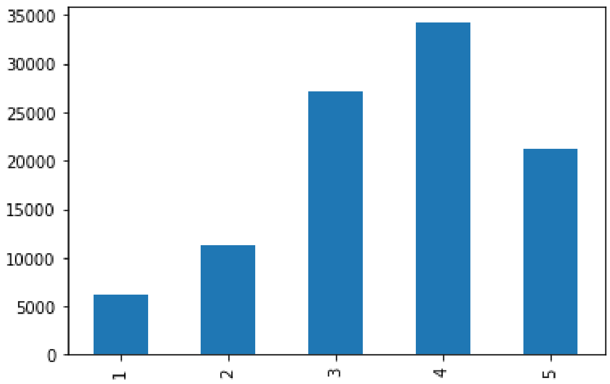
```
Data load successful!
```

We also want to get a sense of what the data looks like. Let's create a histogram of all the ratings we have in the dataset.

In [6]:

```
# 1. Get the ratings file from the data object
# This is just a filename that has all the data stored in it
ratings_file = data.ratings_file

# 2. Load that table using pandas, a commmon python data loading tool
# We set the column names manually here
col_names = ['user_id', 'item_id', 'rating', 'timestamp']
raw_data = pd.read_table(ratings_file, names=col_names)

# 3. Get the rating column
ratings = raw_data.rating

# 4. Generate a bar plot/histogram of that data
ratings.value_counts().sort_index().plot.bar()
freq= ratings.value_counts().sort_index()
print(freq)

print('Histogram generation successful!')
```

```
1     6110
2    11370
3    27145
4    34174
5    21201
Name: rating, dtype: int64
Histogram generation successful!
```



In [7]:

```
df_ratings=ratings.to_frame().reset_index()
#type(df_ratings)
#from pandas import dataframe as df
```

```
df_ratings.quantile([0.25,0.5,0.75])
```

Out[7]:

	index	rating
0.25	24999.75	3.0
0.50	49999.50	4.0
0.75	74999.25	4.0

In [8]:

```
import numpy as np

number_Ratings = len(raw_data)
number_Movies = len(np.unique(raw_data['item_id']))
number_Users = len(np.unique(raw_data['user_id']))
```

In [9]:

```
print('Number of ratings =', number_Ratings)
print('Number of movies =', number_Movies)
print('Number of users =', number_Users)
print('Sparsity in dataset =', 100*(1 - number_Ratings/(number_Movies*number_Users)), '%')
```

```
Number of ratings = 100000
Number of movies = 1682
Number of users = 943
Sparsity in dataset = 93.69533063577546 %
```

In [10]:

```
raw_data.groupby(raw_data.rating).count()/raw_data.rating.count()
```

Out[10]:

	user_id	item_id	timestamp
rating			
1	0.06110	0.06110	0.06110
2	0.11370	0.11370	0.11370
3	0.27145	0.27145	0.27145
4	0.34174	0.34174	0.34174
5	0.21201	0.21201	0.21201

QUESTION 1: DATA ANALYSIS

Describe the dataset. How many ratings are in the dataset? How would you describe the distribution of ratings? Is there anything else we should observe? Make sure the histogram is visible in the notebook.

Dataset represents 943 users, 1682 movies and total 100000 number of ratings. There are total 5 ratings in the dataset scaled from 1-5. By carrying statical analysis, around 75% of people rated below 4 and only 25% of people gave rating 5 to the movies. The data shows that just over 6% ratings were give 1 , 11.37% given 2, 27.14% given 3 , 34.174% given 4 and 21.201% ratings given 5.

This distibution shows over 82% movies has received rating of 3 or above.

Model 1: Random

In [11]:

```
# Create model object
model_random = NormalPredictor()
print('Model creation successful!')
```

```
Model creation successful!
```

In [12]:

```
# Train on data using cross-validation with k=5 folds, measuring the RMSE
model_random_results = cross_validate(model_random, data, measures=['RMSE'], cv=5, verbose=True)
print('Model training successful!')
```

```
Evaluating RMSE of algorithm NormalPredictor on 5 split(s).

                  Fold 1  Fold 2  Fold 3  Fold 4  Fold 5  Mean    Std     
RMSE (testset)    1.5133  1.5223  1.5209  1.5145  1.5152  1.5172  0.0036  
Fit time          0.56    0.71    0.69    0.66    0.84    0.69    0.09    
Test time         0.93    0.86    1.26    0.96    1.19    1.04    0.16    
Model training successful!
```

Model 2: User-Based Collaborative Filtering

In [13]:

```
# Create model object
model_user = KNNBasic(sim_options={'user_based': True})
print('Model creation successful!')
```

```
Model creation successful!
```

In [14]:

```
# Train on data using cross-validation with k=5 folds, measuring the RMSE
# Note, this may have a lot of print output
# You can set verbose=False to prevent this from happening
model_user_results = cross_validate(model_user, data, measures=['RMSE'], cv=5, verbose=True)
print('Model training successful!')
```

```
Computing the msd similarity matrix...
Done computing similarity matrix.
Computing the msd similarity matrix...
Done computing similarity matrix.
Computing the msd similarity matrix...
Done computing similarity matrix.
Computing the msd similarity matrix...
Done computing similarity matrix.
Computing the msd similarity matrix...
Done computing similarity matrix.
Evaluating RMSE of algorithm KNNBasic on 5 split(s).

                  Fold 1  Fold 2  Fold 3  Fold 4  Fold 5  Mean    Std     
RMSE (testset)    0.9754  0.9827  0.9813  0.9717  0.9750  0.9772  0.0041  
Fit time          1.88    1.34    1.62    1.38    1.59    1.56    0.19    
Test time         16.58   18.37   19.10   19.03   18.38   18.29   0.91    
Model training successful!
```

Model 3: Item-Based Collaborative Filtering

In [15]:

```
# Create model object
model_item = KNNBasic(sim_options={'user_based': False})
print('Model creation successful!')
```

```
Model creation successful!
```

In [16]:

```
# Train on data using cross-validation with k=5 folds, measuring the RMSE
# Note, this may have a lot of print output
# You can set verbose=False to prevent this from happening
model_item_results = cross_validate(model_item, data, measures=['RMSE'], cv=5, verbose=True)
print('Model training successful!')
```

```
Computing the msd similarity matrix...
Done computing similarity matrix.
Computing the msd similarity matrix...
Done computing similarity matrix.
Computing the msd similarity matrix...
Done computing similarity matrix.
Computing the msd similarity matrix...
Done computing similarity matrix.
Computing the msd similarity matrix...
Done computing similarity matrix.
Evaluating RMSE of algorithm KNNBasic on 5 split(s).

                  Fold 1  Fold 2  Fold 3  Fold 4  Fold 5  Mean    Std
RMSE (testset)    0.9740  0.9772  0.9729  0.9755  0.9739  0.9747  0.0015
Fit time          2.89    2.74    2.82    2.91    3.03    2.88    0.10
Test time         22.64   23.07   22.97   24.30   27.36   24.07   1.74
Model training successful!
```

QUESTION 2: COLLABORATIVE FILTERING MODELS

Compare the results from the user-user and item-item models. How do they compare to each other? How do they compare to our original "random" model? Can you provide any intuition as to why the results came out the way they did?

Item-Item model has slightly lower RMSE which means better performance, higher Std deviation. Both Item-Item and User-User models supply better performance compared to random.

Model 4: Matrix Factorization

In [17]:

```
# Create model object
model_matrix = SVD()
print('Model creation successful!')
```

```
Model creation successful!
```

In [18]:

```
# Train on data using cross-validation with k=5 folds, measuring the RMSE
# Note, this may take some time (2-3 minutes) to train, so please be patient
model_matrix_results = cross_validate(model_matrix, data, measures=['RMSE'], cv=5, verbose=True)
print('Model training successful!')
```

```
Evaluating RMSE of algorithm SVD on 5 split(s).

                  Fold 1  Fold 2  Fold 3  Fold 4  Fold 5  Mean    Std
RMSE (testset)    0.9339  0.9274  0.9395  0.9402  0.9425  0.9367  0.0055
Fit time          27.62   26.28   25.60   27.98   26.27   26.75   0.90
Test time         0.94    1.22    0.98    1.44    0.97    1.11    0.19
Model training successful!
```

QUESTION 3: MATRIX FACTORIZATION MODEL

The matrix factorization model is different from the collaborative filtering models. Briefly describe this difference. Also, compare the RMSE again. Does it improve? Can you offer any reasoning as to why that might be?

The matrix factorization model gives slightly better than User-User and Item-Item. The amounts of mapping features of user and item via linear combination . Matrix factorization can definately deal better with scallability than previous models.

Precision and Recall @ `k`

We now want to compute the precision and recall for 2 values of `k`: 5 and 10. We have provided some code here to help you do that.

First, we define a function that takes in some predictions, a value of `k` and a threshold parameter. This code is adapted from here. **Make sure you run this cell.**

In [19]:

```
def precision_recall_at_k(predictions, k=10, threshold=3.5):
    '''Return precision and recall at k metrics for each user.'''

    # First map the predictions to each user.
    user_est_true = dict()
    for uid, _, true_r, est, _ in predictions:
        current = user_est_true.get(uid, list())
        current.append((est, true_r))
        user_est_true[uid] = current

    precisions = dict()
    recalls = dict()
    for uid, user_ratings in user_est_true.items():

        # Sort user ratings by estimated value
        user_ratings.sort(key=lambda x: x[0], reverse=True)

        # Number of relevant items
        n_rel = sum((true_r >= threshold) for (_, true_r) in user_ratings)

        # Number of recommended items in top k
        n_rec_k = sum((est >= threshold) for (est, _) in user_ratings[:k])

        # Number of relevant and recommended items in top k
        n_rel_and_rec_k = sum(((true_r >= threshold) and (est >= threshold))
                              for (est, true_r) in user_ratings[:k])

        # Precision@K: Proportion of recommended items that are relevant
        precisions[uid] = n_rel_and_rec_k / n_rec_k if n_rec_k != 0 else 1

        # Recall@K: Proportion of relevant items that are recommended
        recalls[uid] = n_rel_and_rec_k / n_rel if n_rel != 0 else 1

    return precisions, recalls

print('Function creation successful!')
```

```
Function creation successful!
```

Next, we compute the precision and recall at `k` = 5 and 10 for each of our 4 models. We use 5-fold cross validation again to average the results across the entire dataseat.

Please note that this will take some time to compute.

QUESTION 4: PRECISION/RECALL

Compute the precision and recall, for each of the 4 models, at `k` = 5 and 10. This is 2 x 2 x 4 = 16 numerical values. Do you note anything interesting about these values? Anything differerent from the RMSE values you computed above?

Precesion has decreased when k=5 changed to K=10 for every model and Recall increased when k=5 changed to K=10. Smaller values of K give better Precision and Larger value of K give better Rececall. Every models do much better at Prediction and Recall than the NormalPredictor model.

In [20]:

```python
# Make list of k values
K = [5, 10]

# Make list of models
models = [model_random, model_user, model_item, model_matrix]

# Create k-fold cross validation object
kf = KFold(n_splits=5)

for k in K:
    for model in models:
        print(f'>>> k={k}, model={model.__class__.__name__}')
        # Run folder and take average
        p = []
        r = []
        for trainset, testset in kf.split(data):
            model.fit(trainset)
            predictions = model.test(testset, verbose=False)
            precisions, recalls = precision_recall_at_k(predictions, k=k, threshold=3.5)

            # Precision and recall can then be averaged over all users
            p.append(sum(prec for prec in precisions.values()) / len(precisions))
            r.append(sum(rec for rec in recalls.values()) / len(recalls))

        print('>>> precision:', round(sum(p) / len(p), 3))
        print('>>> reccall  :', round(sum(r) / len(r), 3))
        print('\n')

print('Precision and recall computation successful!')
```

```
>>> k=5, model=NormalPredictor
>>> precision: 0.587
>>> reccall  : 0.342


>>> k=5, model=KNNBasic
Computing the msd similarity matrix...
Done computing similarity matrix.
Computing the msd similarity matrix...
Done computing similarity matrix.
Computing the msd similarity matrix...
Done computing similarity matrix.
Computing the msd similarity matrix...
Done computing similarity matrix.
Computing the msd similarity matrix...
Done computing similarity matrix.
>>> precision: 0.767
>>> reccall  : 0.456


>>> k=5, model=KNNBasic
Computing the msd similarity matrix...
Done computing similarity matrix.
Computing the msd similarity matrix...
Done computing similarity matrix.
Computing the msd similarity matrix...
Done computing similarity matrix.
Computing the msd similarity matrix...
Done computing similarity matrix.
Computing the msd similarity matrix...
Done computing similarity matrix.
>>> precision: 0.818
>>> reccall  : 0.389


>>> k=5, model=SVD
>>> precision: 0.781
>>> reccall  : 0.432


>>> k=10, model=NormalPredictor
>>> precision: 0.592
>>> reccall  : 0.435
```

```
>>> k=10, model=KNNBasic
Computing the msd similarity matrix...
Done computing similarity matrix.
Computing the msd similarity matrix...
Done computing similarity matrix.
Computing the msd similarity matrix...
Done computing similarity matrix.
Computing the msd similarity matrix...
Done computing similarity matrix.
Computing the msd similarity matrix...
Done computing similarity matrix.
>>> precision: 0.737
>>> reccall  : 0.593


>>> k=10, model=KNNBasic
Computing the msd similarity matrix...
Done computing similarity matrix.
Computing the msd similarity matrix...
Done computing similarity matrix.
Computing the msd similarity matrix...
Done computing similarity matrix.
Computing the msd similarity matrix...
Done computing similarity matrix.
Computing the msd similarity matrix...
Done computing similarity matrix.
>>> precision: 0.786
>>> reccall  : 0.535


>>> k=10, model=SVD
>>> precision: 0.759
>>> reccall  : 0.561


Precision and recall computation successful!
```

Top-n Predictions

Finally, we can see what some of the actual movie ratings are for particular users, as outputs of our model.

Again, we define a helpful function.

In [21]:

```python
def get_top_n(predictions, n=5):
    '''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 = dict()
    for uid, iid, true_r, est, _ in predictions:
        current = top_n.get(uid, [])
        current.append((iid, est))
        top_n[uid] = current

    # 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
```

```
    return top_n

print('Function creation successful!')
```

```
Function creation successful!
```

Then, we call this function on each of our models, first training on **all** the data we have available, then predicting on the remaining, missing data. We use `n`=5 here, but you can pick any reasonable value of `n` you would like.

This may take some time to compute, so be patient.

In [22]:

```
trainset = data.build_full_trainset()
testset = trainset.build_anti_testset()
print('Trainset and testset creation successful!')
```

```
Trainset and testset creation successful!
```

QUESTION 5: TOP N PREDICTIONS

Do the top n predictions that you received make sense? What is the rating value (1-5) of these predictions? How could you use these predictions in the real-world if you were trying to build a generic content recommender system for a company?

Yes, it does make sense. As per below example user ID 196, all models are able to recommend the top 5 movies with the rating above 4. The algorithm that provides a greater precision with lower RMSE could be integrated into a recommendation system. Based on historical genre data and similar users'choice or rating the system could ask user as " You may be interested watching these films as "Recommendation".

In [23]:

```
for model in models:
    model.fit(trainset)
    predictions = model.test(testset)
    top_n = get_top_n(predictions, n=5)
    # Print the first one
    user = list(top_n.keys())[0]
    print(f'model: {model}, {user}: {top_n[user]}')

print('Top N computation successful!')
```

```
model: <surprise.prediction_algorithms.random_pred.NormalPredictor object at 0x7fcc772a6e10>, 196:
[('222', 5), ('1184', 5), ('392', 5), ('193', 5), ('1081', 5)]
Computing the msd similarity matrix...
Done computing similarity matrix.
model: <surprise.prediction_algorithms.knns.KNNBasic object at 0x7fcc7c562f60>, 196: [('1189', 5),
('1500', 5), ('814', 5), ('1536', 5), ('1599', 5)]
Computing the msd similarity matrix...
Done computing similarity matrix.
model: <surprise.prediction_algorithms.knns.KNNBasic object at 0x7fcc7111fc18>, 196: [('1414', 4.6
66666666666667), ('1309', 4.5), ('1310', 4.5), ('1675', 4.333333333333333), ('1676',
4.3076923076923075)]
model: <surprise.prediction_algorithms.matrix_factorization.SVD object at 0x7fcc76e46898>, 196: [(
'408', 4.696380994617735), ('114', 4.657716041448794), ('178', 4.585937964195576), ('169',
4.573887590204742), ('483', 4.552711816584793)]
Top N computation successful!
```

In [24]:

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

```
196 ['408', '114', '178', '169', '483']
```

```
186 ['408', '318', '483', '174', '96']
22 ['64', '56', '357', '313', '12']
244 ['127', '474', '408', '302', '134']
166 ['513', '657', '272', '603', '189']
298 ['64', '12', '513', '170', '169']
115 ['408', '169', '179', '134', '641']
253 ['178', '174', '313', '513', '603']
305 ['515', '124', '603', '516', '648']
6 ['654', '615', '603', '114', '651']
62 ['659', '223', '251', '493', '408']
286 ['318', '306', '114', '646', '98']
200 ['144', '963', '187', '181', '178']
210 ['318', '169', '515', '64', '513']
224 ['272', '64', '496', '83', '651']
303 ['313', '180', '135', '178', '346']
122 ['134', '178', '483', '654', '603']
194 ['114', '480', '408', '169', '59']
291 ['318', '408', '313', '127', '169']
234 ['1131', '408', '60', '61', '59']
119 ['173', '408', '169', '474', '318']
167 ['474', '408', '657', '179', '485']
299 ['178', '923', '223', '963', '661']
308 ['114', '474', '173', '647', '478']
95 ['318', '12', '124', '513', '493']
38 ['174', '483', '64', '50', '8']
102 ['408', '483', '169', '170', '114']
63 ['318', '127', '179', '83', '659']
160 ['156', '180', '197', '179', '357']
50 ['169', '603', '174', '408', '134']
301 ['313', '603', '165', '272', '520']
225 ['408', '178', '513', '483', '272']
290 ['408', '603', '963', '169', '313']
97 ['513', '64', '515', '12', '127']
157 ['98', '178', '12', '511', '483']
181 ['98', '257', '313', '22', '318']
278 ['483', '408', '169', '963', '114']
276 ['483', '114', '191', '515', '480']
7 ['408', '292', '493', '735', '59']
10 ['408', '427', '114', '641', '520']
284 ['169', '515', '408', '474', '64']
201 ['132', '963', '135', '484', '641']
287 ['302', '408', '12', '173', '223']
246 ['114', '190', '493', '320', '192']
242 ['98', '603', '515', '427', '480']
249 ['127', '199', '654', '488', '190']
99 ['318', '357', '302', '272', '89']
178 ['114', '186', '408', '169', '966']
251 ['174', '408', '318', '511', '483']
81 ['50', '12', '174', '64', '357']
260 ['480', '174', '483', '408', '127']
25 ['483', '313', '12', '223', '172']
59 ['223', '408', '475', '482', '661']
72 ['199', '1194', '612', '657', '483']
87 ['313', '12', '28', '483', '98']
42 ['22', '313', '257', '966', '520']
292 ['12', '192', '357', '474', '89']
20 ['923', '275', '694', '511', '408']
13 ['408', '134', '1063', '641', '192']
138 ['64', '408', '169', '174', '127']
60 ['169', '408', '223', '963', '487']
57 ['22', '174', '98', '513', '483']
223 ['64', '83', '408', '603', '272']
189 ['641', '315', '169', '408', '515']
243 ['169', '12', '408', '114', '178']
92 ['127', '357', '285', '603', '479']
241 ['64', '318', '251', '12', '483']
254 ['318', '169', '483', '1194', '527']
293 ['197', '493', '408', '59', '136']
127 ['603', '408', '484', '169', '513']
222 ['203', '187', '114', '316', '272']
267 ['134', '603', '357', '513', '657']
11 ['285', '408', '50', '172', '478']
8 ['12', '318', '114', '169', '483']
162 ['64', '169', '603', '178', '513']
279 ['963', '185', '223', '14', '205']
145 ['357', '168', '318', '144', '210']
28 ['64', '408', '114', '272', '192']
```

```
28 ['64', '408', '114', '272', '192']
135 ['408', '89', '127', '179', '169']
32 ['318', '98', '483', '169', '114']
90 ['513', '114', '408', '251', '1449']
216 ['127', '515', '190', '430', '114']
250 ['408', '318', '59', '178', '134']
271 ['408', '114', '483', '513', '316']
265 ['56', '169', '519', '430', '1194']
198 ['408', '169', '515', '199', '520']
168 ['12', '64', '98', '174', '178']
110 ['178', '604', '50', '483', '496']
58 ['23', '515', '114', '694', '896']
237 ['318', '496', '515', '427', '480']
94 ['408', '641', '137', '656', '124']
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Great job! Now, make sure you check out the **Conclusion** section of the instruction manual to wrap up this case study properly.