1. Business Problem

1.1 Problem Description

Netflix is all about connecting people to the movies they love. To help customers find those movies, they developed world-class movie recommendation system: CinematchSM. Its job is to predict whether someone will enjoy a movie based on how much they liked or disliked other movies. Netflix use those predictions to make personal movie recommendations based on each customer's unique tastes. And while **Cinematch** is doing pretty well, it can always be made better.

Now there are a lot of interesting alternative approaches to how Cinematch works that netflix haven't tried. Some are described in the literature, some aren't. We're curious whether any of these can beat Cinematch by making better predictions. Because, frankly, if there is a much better approach it could make a big difference to our customers and our business.

Credits: https://www.netflixprize.com/rules.html

1.2 Problem Statement

Netflix provided a lot of anonymous rating data, and a prediction accuracy bar that is 10% better than what Cinematch can do on the same training data set. (Accuracy is a measurement of how closely predicted ratings of movies match subsequent actual ratings.)

1.3 Sources

- https://www.netflixprize.com/rules.html
- https://www.kaggle.com/netflix-inc/netflix-prize-data
- Netflix blog: https://medium.com/netflix-techblog/netflix-recommendations-beyond-the-5-stars-part-1-55838468f429 (very nice blog)
- surprise library: http://surpriselib.com/ (we use many models from this library)
- surprise library doc: http://surprise.readthedocs.io/en/stable/getting_started.html (we use many models from this library)
- installing surprise: https://github.com/NicolasHug/Surprise#installation
- Research paper: http://courses.ischool.berkeley.edu/i290-dm/s11/SECURE/a1-koren.pdf (most of our work was inspired by this paper)
- SVD Decomposition : https://www.youtube.com/watch?v=P5mlg91as1c

1.4 Real world/Business Objectives and constraints

Objectives:

1. Predict the rating that a user would give to a movie that he ahs not yet rated.
2. Minimize the difference between predicted and actual rating (RMSE and MAPE)

Constraints:

1. Some form of interpretability.

2. Machine Learning Problem

2.1 Data

2.1.1 Data Overview

Get the data from : https://www.kaggle.com/netflix-inc/netflix-prize-data/data

Data files :

Data files :

- combined_data_1.txt
- combined_data_2.txt
- combined_data_3.txt
- combined_data_4.txt
- movie_titles.csv


```
The first line of each file [combined_data_1.txt, combined_data_2.txt, combined_data_
3.txt, combined_data_4.txt] contains the movie id followed by a colon. Each subsequen
t line in the file corresponds to a rating from a customer and its date in the
following format:

CustomerID,Rating,Date

MovieIDs range from 1 to 17770 sequentially.
CustomerIDs range from 1 to 2649429, with gaps. There are 480189 users.
Ratings are on a five star (integral) scale from 1 to 5.
Dates have the format YYYY-MM-DD.
```

2.1.2 Example Data point

```
1:
1488844,3,2005-09-06
822109,5,2005-05-13
885013,4,2005-10-19
30878,4,2005-12-26
823519,3,2004-05-03
893988,3,2005-11-17
124105,4,2004-08-05
1248029,3,2004-04-22
1842128,4,2004-05-09
2238063,3,2005-05-11
1503895,4,2005-05-19
2207774,5,2005-06-06
2590061,3,2004-08-12
2442,3,2004-04-14
543865,4,2004-05-28
1209119,4,2004-03-23
804919,4,2004-06-10
1086807,3,2004-12-28
1711859,4,2005-05-08
372233,5,2005-11-23
1080361,3,2005-03-28
1245640,3,2005-12-19
558634,4,2004-12-14
2165002,4,2004-04-06
1181550,3,2004-02-01
1227322,4,2004-02-06
427928,4,2004-02-26
814701,5,2005-09-29
808731,4,2005-10-31
662870,5,2005-08-24
337541,5,2005-03-23
786312,3,2004-11-16
1133214,4,2004-03-07
1537427,4,2004-03-29
1209954,5,2005-05-09
```

```
2381599,3,2005-09-12
525356,2,2004-07-11
1910569,4,2004-04-12
2263586,4,2004-08-20
2421815,2,2004-02-26
1009622,1,2005-01-19
1481961,2,2005-05-24
401047,4,2005-06-03
2179073,3,2004-08-29
1434636,3,2004-05-01
93986,5,2005-10-06
1308744,5,2005-10-29
2647871,4,2005-12-30
1905581,5,2005-08-16
2508819,3,2004-05-18
1578279,1,2005-05-19
1159695,4,2005-02-15
2588432,3,2005-03-31
2423091,3,2005-09-12
470232,4,2004-04-08
2148699,2,2004-06-05
1342007,3,2004-07-16
466135,4,2004-07-13
2472440,3,2005-08-13
1283744,3,2004-04-17
1927580,4,2004-11-08
716874,5,2005-05-06
4326,4,2005-10-29
```

2.2 Mapping the real world problem to a Machine Learning Problem

2.2.1 Type of Machine Learning Problem

```
For a given movie and user we need to predict the rating would be given by him/her to the
movie.
The given problem is a Recommendation problem
It can also seen as a Regression problem
```

2.2.2 Performance metric

- Mean Absolute Percentage Error: https://en.wikipedia.org/wiki/Mean_absolute_percentage_error
- Root Mean Square Error: https://en.wikipedia.org/wiki/Root-mean-square_deviation

2.2.3 Machine Learning Objective and Constraints

1. Minimize RMSE.
2. Try to provide some interpretability.

In [1]:

```
# this is just to know how much time will it take to run this entire ipython notebook
from datetime import datetime
# globalstart = datetime.now()
import pandas as pd
import numpy as np
import matplotlib
matplotlib.use('nbagg')

import matplotlib.pyplot as plt
plt.rcParams.update({'figure.max_open_warning': 0})
```

```
import seaborn as sns
sns.set_style('whitegrid')
import os
from scipy import sparse
from scipy.sparse import csr_matrix

from sklearn.decomposition import TruncatedSVD
from sklearn.metrics.pairwise import cosine_similarity
import random
```

3. Exploratory Data Analysis

3.1 Preprocessing

3.1.1 Converting / Merging whole data to required format: u_i, m_j, r_ij

In [2]:

```
start = datetime.now()
if not os.path.isfile('data.csv'):
    # Create a file 'data.csv' before reading it
    # Read all the files in netflix and store them in one big file('data.csv')
    # We re reading from each of the four files and appendig each rating to a global file
'train.csv'
    data = open('data.csv', mode='w')

    row = list()
    files=['combined_data_1.txt','combined_data_2.txt',
           'combined_data_3.txt', 'combined_data_4.txt']
    for file in files:
        print("Reading ratings from {}...".format(file))
        with open(file) as f:
            for line in f:
                del row[:] # you don't have to do this.
                line = line.strip()
                if line.endswith(':'):
                    # All below are ratings for this movie, until another movie appears.
                    movie_id = line.replace(':', '')
                else:
                    row = [x for x in line.split(',')]
                    row.insert(0, movie_id)
                    data.write(','.join(row))
                    data.write('\n')
        print("Done.\n")
    data.close()
print('Time taken :', datetime.now() - start)
```

```
Reading ratings from combined_data_1.txt...
Done.

Reading ratings from combined_data_2.txt...
Done.

Reading ratings from combined_data_3.txt...
Done.

Reading ratings from combined_data_4.txt...
Done.

Time taken : 0:06:05.637476
```

In [3]:

```
print("creating the dataframe from data.csv file..")
df = pd.read_csv('data.csv', sep=',',
                       names=['movie', 'user','rating','date'])
df.date = pd.to_datetime(df.date)
```

```python
df.date = pd.to_datetime(df.date)
print('Done.\n')

# we are arranging the ratings according to time.
print('Sorting the dataframe by date..')
df.sort_values(by='date', inplace=True)
print('Done..')
```

```
creating the dataframe from data.csv file..
Done.

Sorting the dataframe by date..
Done..
```

In [4]:

```python
df.head()
```

Out[4]:

	movie	user	rating	date
56431994	10341	510180	4	1999-11-11
9056171	1798	510180	5	1999-11-11
58698779	10774	510180	3	1999-11-11
48101611	8651	510180	2	1999-11-11
81893208	14660	510180	2	1999-11-11

In [5]:

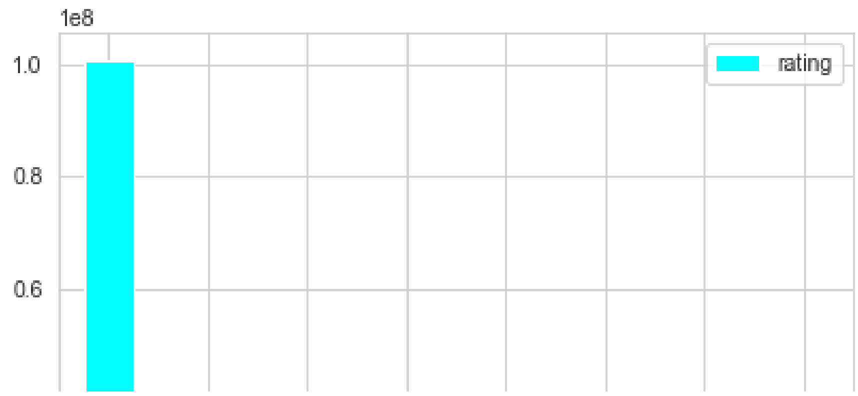
```python
df.describe()['rating']
```

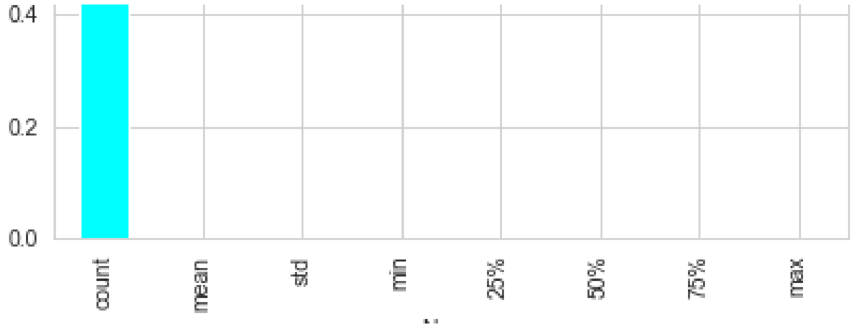
Out[5]:

```
count    1.004805e+08
mean     3.604290e+00
std      1.085219e+00
min      1.000000e+00
25%      3.000000e+00
50%      4.000000e+00
75%      4.000000e+00
max      5.000000e+00
Name: rating, dtype: float64
```

In [18]:

```python
# number of times each question appeared in our database

pd.DataFrame(df.describe()['rating']).plot(kind='bar',color='cyan')
plt.xlabel('Name')
plt.show()
```



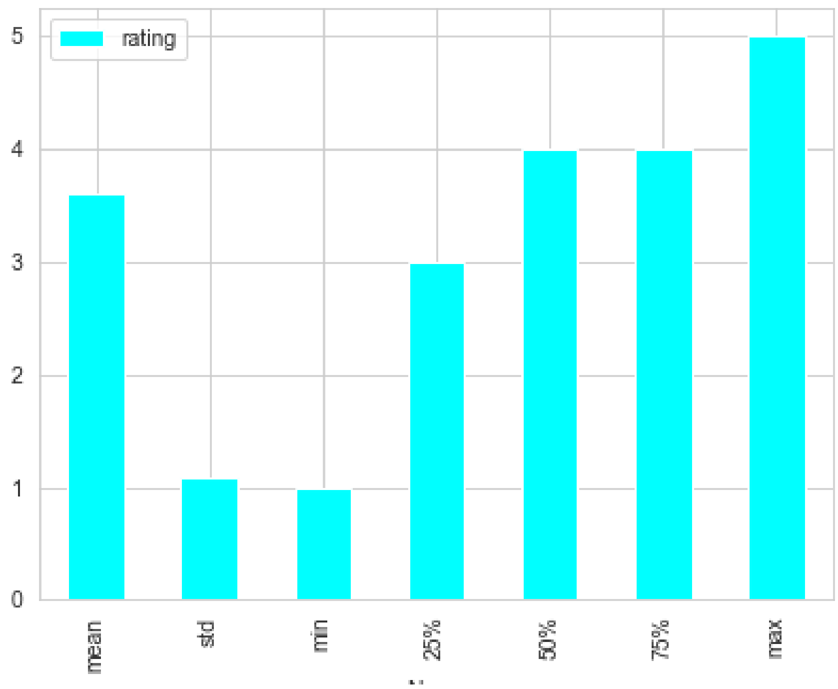


In [19]:

```
a = df.describe()['rating'].drop(['count'])
```

In [20]:

```
pd.DataFrame(a).plot(kind='bar',color='cyan')
plt.xlabel('Name')
plt.show()
```



3.1.2 Checking for NaN values

In [11]:

```
# just to make sure that all Nan containing rows are deleted..
print("No of Nan values in our dataframe : ", sum(df.isnull().any()))
```

```
No of Nan values in our dataframe :  0
```

3.1.3 Removing Duplicates

In [12]:

```
dup_bool = df.duplicated(['movie','user','rating'])
dups = sum(dup_bool) # by considering all columns..( including timestamp)
```

```
print("There are {} duplicate rating entries in the data..".format(dups))
```

```
There are 0 duplicate rating entries in the data..
```

3.1.4 Basic Statistics (#Ratings, #Users, and #Movies)

In [13]:

```
print("Total data ")
print("-"*50)
print("\nTotal no of ratings :",df.shape[0])
print("Total No of Users   :", len(np.unique(df.user)))
print("Total No of movies  :", len(np.unique(df.movie)))
```

```
Total data 
--------------------------------------------------

Total no of ratings : 100480507
Total No of Users   : 480189
Total No of movies  : 17770
```

3.2 Spliting data into Train and Test(80:20)

In [14]:

```
if not os.path.isfile('train.csv'):
    # create the dataframe and store it in the disk for offline purposes..
    df.iloc[:int(df.shape[0]*0.80)].to_csv("train.csv", index=False)

if not os.path.isfile('test.csv'):
    # create the dataframe and store it in the disk for offline purposes..
    df.iloc[int(df.shape[0]*0.80):].to_csv("test.csv", index=False)

train_df = pd.read_csv("train.csv", parse_dates=['date'])
test_df = pd.read_csv("test.csv")
```

3.2.1 Basic Statistics in Train data (#Ratings, #Users, and #Movies)

In [15]:

```
# movies = train_df.movie.value_counts()
# users = train_df.user.value_counts()
print("Training data ")
print("-"*50)
print("\nTotal no of ratings :",train_df.shape[0])
print("Total No of Users   :", len(np.unique(train_df.user)))
print("Total No of movies  :", len(np.unique(train_df.movie)))
```

```
Training data 
--------------------------------------------------

Total no of ratings : 80384405
Total No of Users   : 405041
Total No of movies  : 17424
```

3.2.2 Basic Statistics in Test data (#Ratings, #Users, and #Movies)

In [16]:

```
print("Test data ")
print("-"*50)
print("\nTotal no of ratings :",test_df.shape[0])
print("Total No of Users   :", len(np.unique(test_df.user)))
print("Total No of movies  :", len(np.unique(test_df.movie)))
```

```
Test data
--------------------------------------------------

Total no of ratings : 20096102
Total No of Users   : 349312
Total No of movies  : 17757
```

3.3 Exploratory Data Analysis on Train data

In [17]:

```
# method to make y-axis more readable
def human(num, units = 'M'):
    units = units.lower()
    num = float(num)
    if units == 'k':
        return str(num/10**3) + " K"
    elif units == 'm':
        return str(num/10**6) + " M"
    elif units == 'b':
        return str(num/10**9) +  " B"
```

3.3.1 Distribution of ratings

In [37]:

```
user_dist = df.groupby('user')['rating'].count()[:500]
movie_dist = df.groupby('movie')['rating'].count()[:500]
```

In [34]:

```
import plotly.graph_objs as go
from plotly.offline import iplot
from plotly.offline import init_notebook_mode
init_notebook_mode(connected=True)
```

Histogram plot of the distribution of count of ratings given for a movie for first 500 movies¶

In [40]:

```
hist = go.Histogram(x=movie_dist.values,name = 'Ratings',xbins = dict(start = 0,end = 7000,size = 1
00))

layout = go.Layout(title = 'Distribution Of Ratings Per Movie',
                   xaxis = dict(title = 'Ratings Per Movie'),
                   yaxis = dict(title = 'Count'),
                   bargap = 0.2)

fig = go.Figure(data=[hist], layout=layout)
iplot(fig)
```

Histogram plot of the distribution of ratings given per movie by first 500 users

In [41]:

```
trace = go.Histogram(x = user_dist.values,name = 'Ratings',xbins = dict(start = 0,end = 300,size = 
5))

layout = go.Layout(title = 'Distribution Of Ratings Per User',
                   xaxis = dict(title = 'Ratings Per User'),
                   yaxis = dict(title = 'Count'),
                   bargap = 0.2)

fig = go.Figure(data=[trace], layout=layout)
iplot(fig)
```

In [12]:

```
fig, ax = plt.subplots()
plt.title('Distribution of ratings over Training dataset', fontsize=15)
sns.countplot(train_df.rating)
ax.set_yticklabels([human(item, 'M') for item in ax.get_yticks()])
```

```
ax.set_ylabel('No. of Ratings(Millions)')

plt.show()
```

Add new column (week day) to the data set for analysis.

In [21]:

```
# It is used to skip the warning ''SettingWithCopyWarning''..
pd.options.mode.chained_assignment = None  # default='warn'

train_df['day_of_week'] = train_df.date.dt.weekday_name

train_df.tail()
```

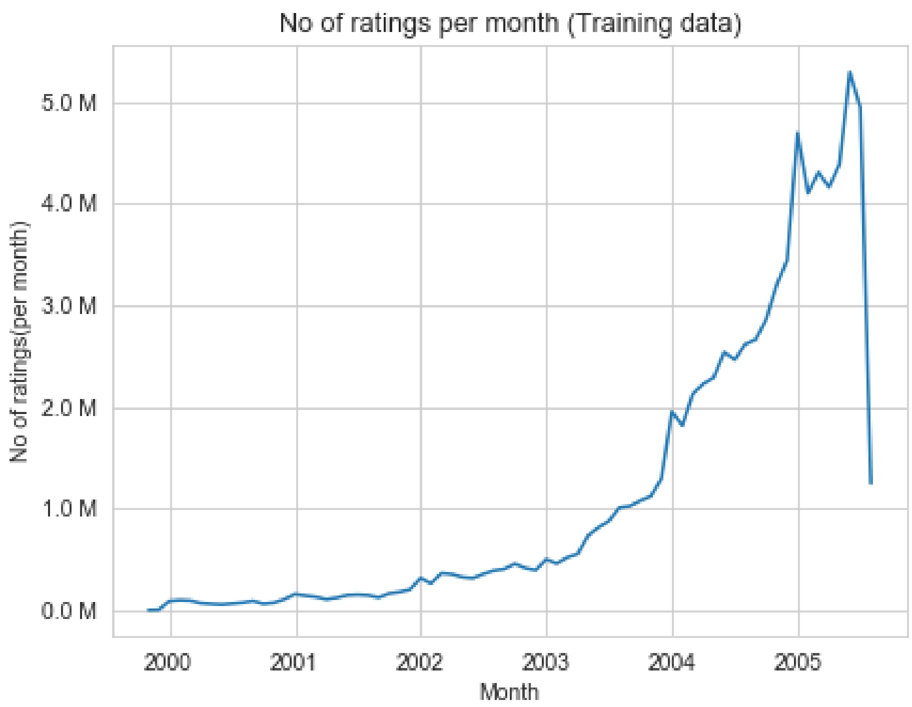
Out[21]:

	movie	user	rating	date	day_of_week
80384400	12074	2033618	4	2005-08-08	Monday
80384401	862	1797061	3	2005-08-08	Monday
80384402	10986	1498715	5	2005-08-08	Monday
80384403	14861	500016	4	2005-08-08	Monday
80384404	5926	1044015	5	2005-08-08	Monday

3.3.2 Number of Ratings per a month

In [14]:

```
ax = train_df.resample('m', on='date')['rating'].count().plot()
ax.set_title('No of ratings per month (Training data)')
plt.xlabel('Month')
plt.ylabel('No of ratings(per month)')
ax.set_yticklabels([human(item, 'M') for item in ax.get_yticks()])
plt.show()
```



3.3.3 Analysis on the Ratings given by user

In [22]:

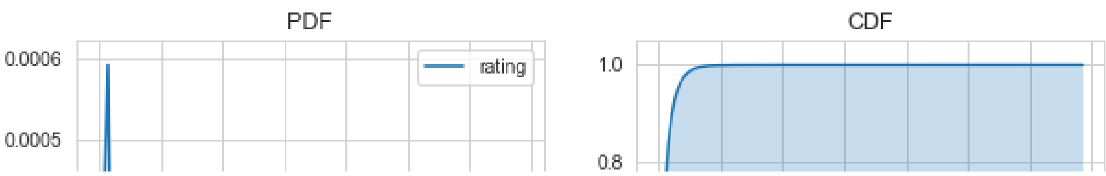
```
no_of_rated_movies_per_user = train_df.groupby(by='user')['rating'].count().sort_values(ascending=False)

no_of_rated_movies_per_user.head()
```

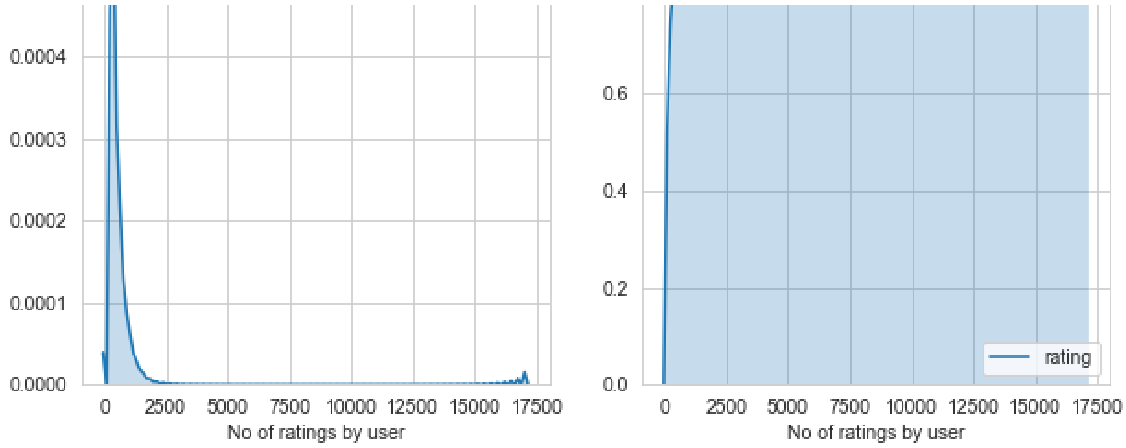
Out[22]:

```
user
305344     17112
2439493    15896
387418     15402
1639792     9767
1461435     9447
Name: rating, dtype: int64
```

In [16]:

```
fig = plt.figure(figsize=plt.figaspect(.5))

ax1 = plt.subplot(121)
sns.kdeplot(no_of_rated_movies_per_user, shade=True, ax=ax1)
plt.xlabel('No of ratings by user')
plt.title("PDF")

ax2 = plt.subplot(122)
sns.kdeplot(no_of_rated_movies_per_user, shade=True, cumulative=True,ax=ax2)
plt.xlabel('No of ratings by user')
plt.title('CDF')

plt.show()
```





In [23]:

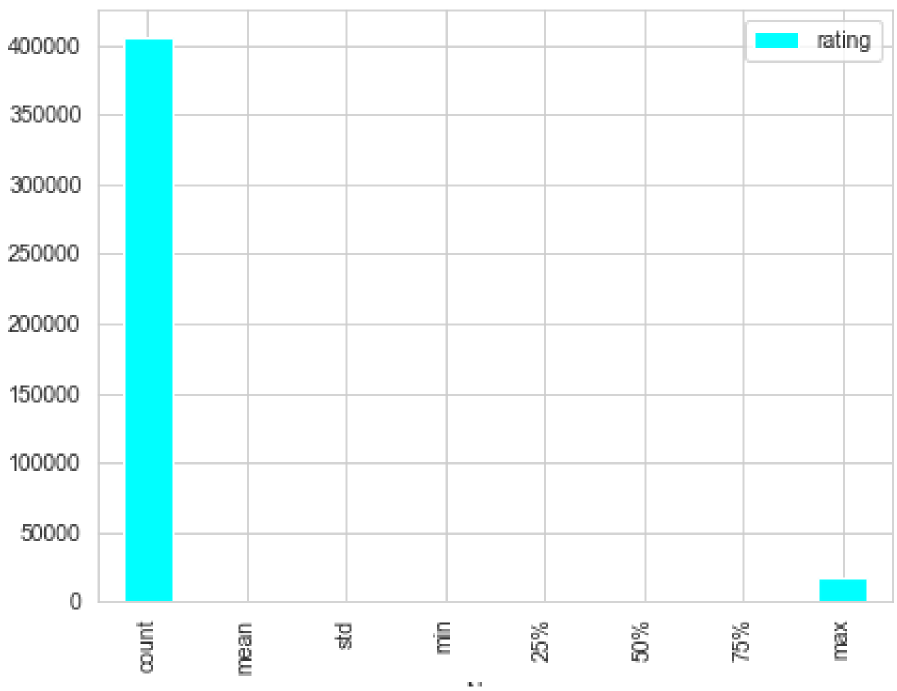
```
no_of_rated_movies_per_user.describe()
```

Out[23]:

```
count    405041.000000
mean        198.459921
std         290.793238
min           1.000000
25%          34.000000
50%          89.000000
75%         245.000000
max       17112.000000
Name: rating, dtype: float64
```

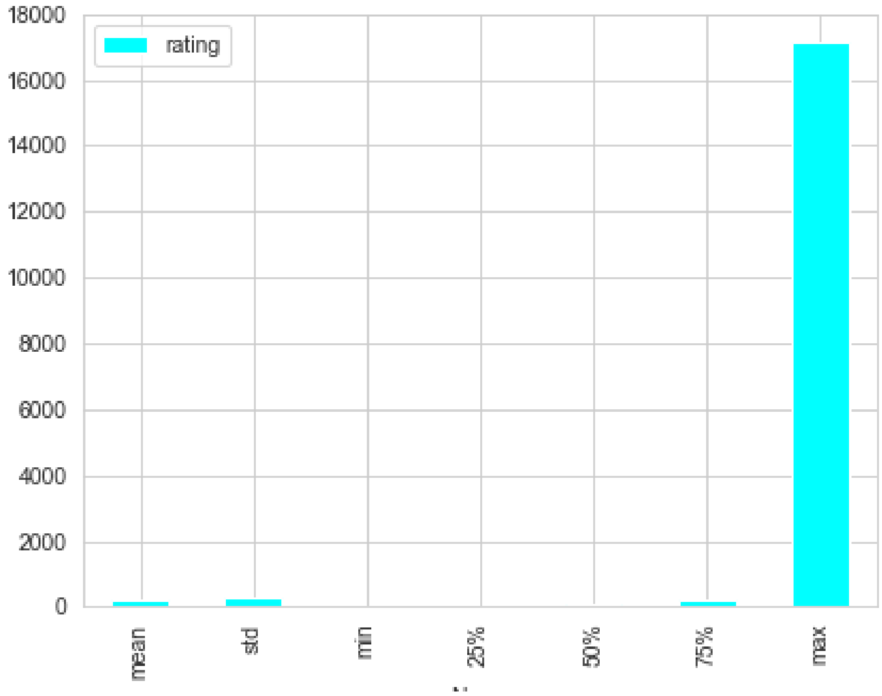
In [24]:

```
# number of times each question appeared in our database

pd.DataFrame(no_of_rated_movies_per_user.describe()).plot(kind='bar',color='cyan')
plt.xlabel('Name')
plt.show()
```



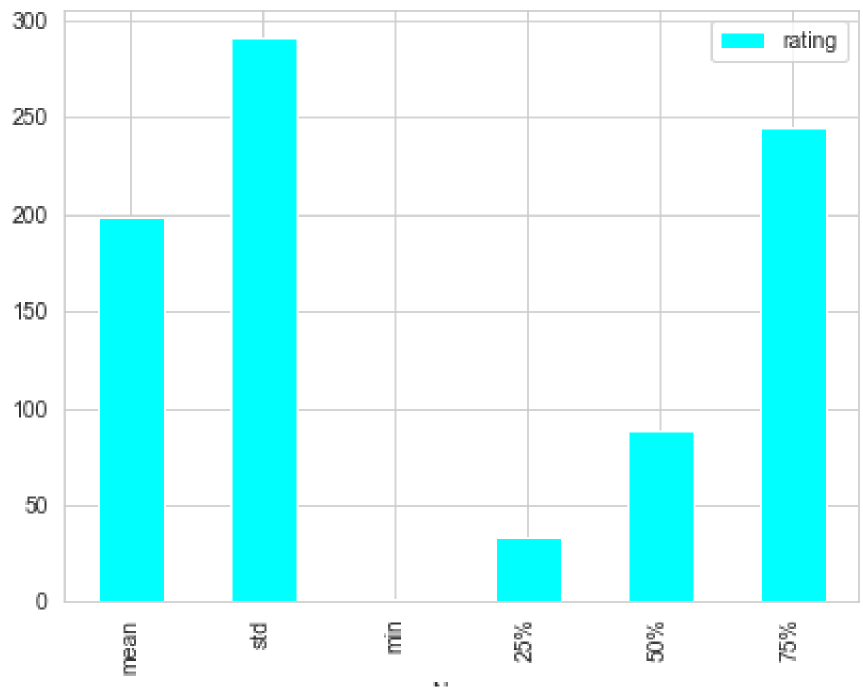
In [25]:

```
b=no_of_rated_movies_per_user.describe().drop(['count'])
pd.DataFrame(b).plot(kind='bar',color='cyan')
plt.xlabel('Name')
plt.show()
```



In [26]:

```
b=no_of_rated_movies_per_user.describe().drop(['count','max'])
pd.DataFrame(b).plot(kind='bar',color='cyan')
plt.xlabel('Name')
plt.show()
```



There is something interesting going on with the quantiles

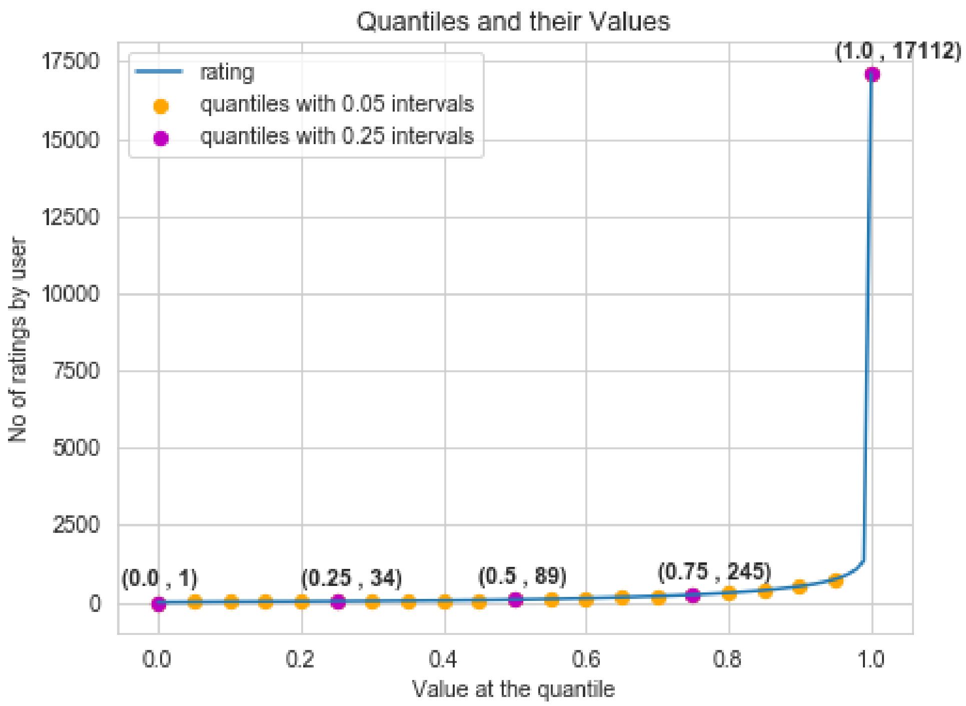
There, is something interesting going on with the quantiles..

In [27]:

```
quantiles = no_of_rated_movies_per_user.quantile(np.arange(0,1.01,0.01), interpolation='higher')
```

In [19]:

```
plt.title("Quantiles and their Values")
quantiles.plot()
# quantiles with 0.05 difference
plt.scatter(x=quantiles.index[::5], y=quantiles.values[::5], c='orange', label="quantiles with 0.05
intervals")
# quantiles with 0.25 difference
plt.scatter(x=quantiles.index[::25], y=quantiles.values[::25], c='m', label = "quantiles with 0.25
intervals")
plt.ylabel('No of ratings by user')
plt.xlabel('Value at the quantile')
plt.legend(loc='best')

# annotate the 25th, 50th, 75th and 100th percentile values....
for x,y in zip(quantiles.index[::25], quantiles[::25]):
    plt.annotate(s="({} , {})".format(x,y), xy=(x,y), xytext=(x-0.05, y+500)
                ,fontweight='bold')


plt.show()
```



In [20]:

```
quantiles[::5]
```

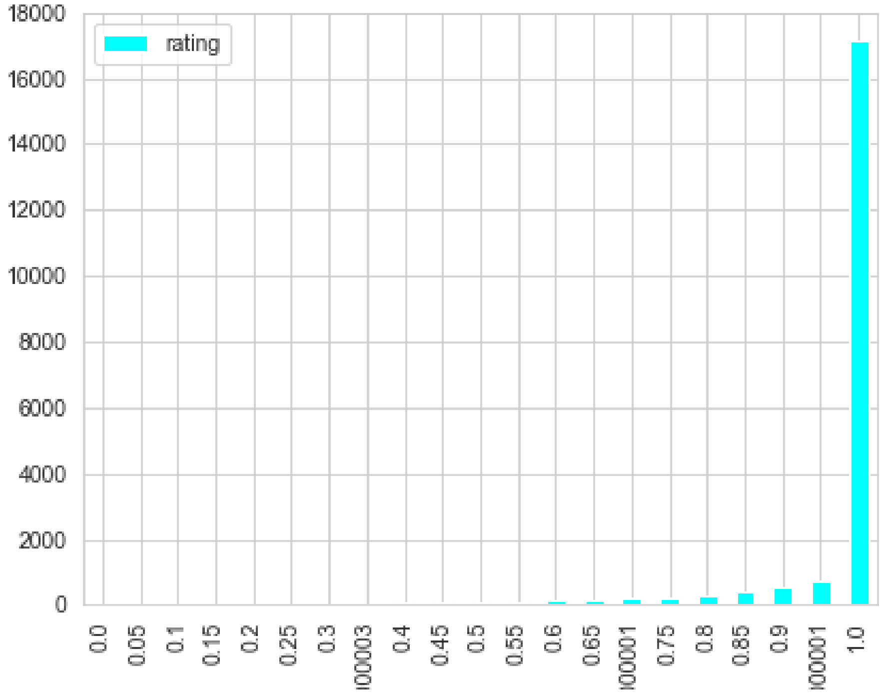
Out[20]:

```
0.00        1
0.05        7
0.10       15
0.15       21
0.20       27
0.25       34
0.30       41
0.35       50
0.40       60
```

```
0.45        73
0.50        89
0.55       109
0.60       133
0.65       163
0.70       199
0.75       245
0.80       307
0.85       392
0.90       520
0.95       749
1.00     17112
Name: rating, dtype: int64
```

In [28]:

```
pd.DataFrame(quantiles[::5]).plot(kind='bar',color='cyan')
plt.xlabel('No of ratings by user')
plt.xlabel('Value at the quantile')
plt.show()
```

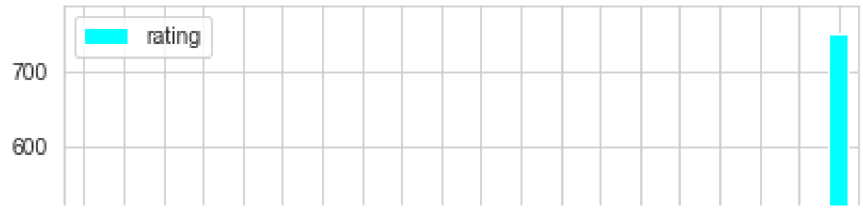


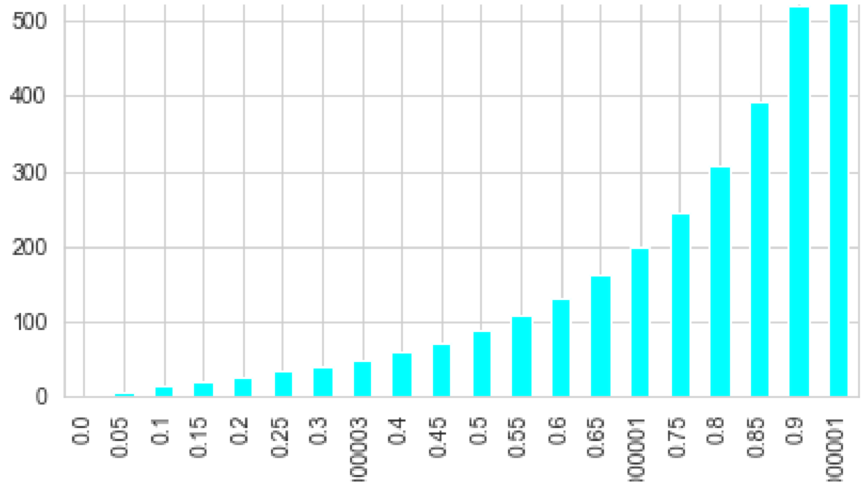
In [29]:

```
c=quantiles[:0.96:5]
```

In [30]:

```
pd.DataFrame(c).plot(kind='bar',color='cyan')
plt.xlabel('No of ratings by user')
plt.xlabel('Value at the quantile')
plt.show()
```





how many ratings at the last 5% of all ratings??

In [31]:

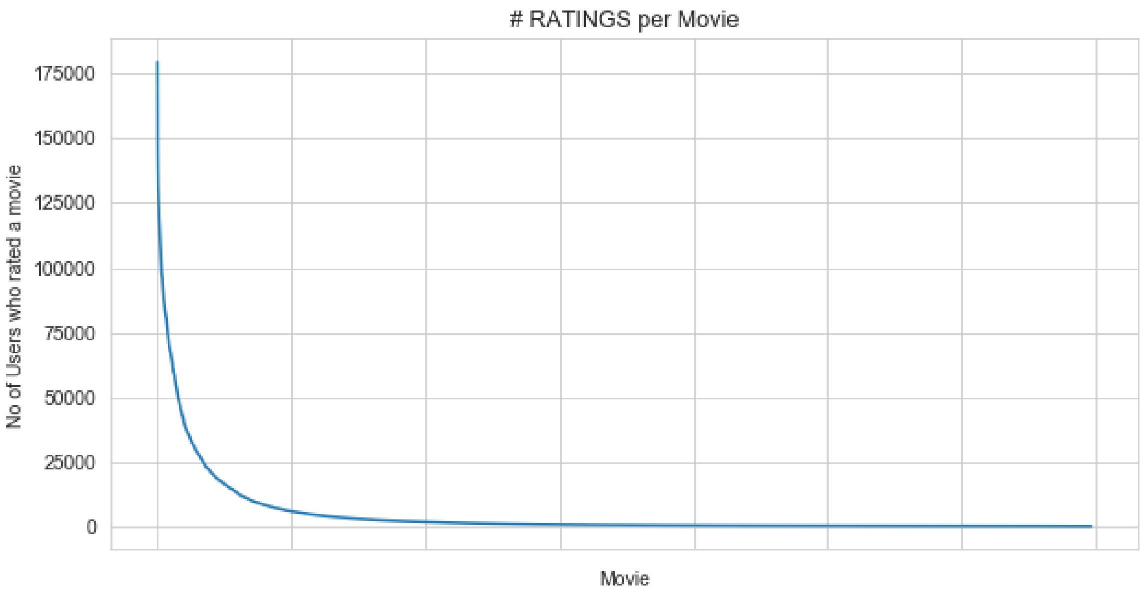
```
print('\n No of ratings at last 5 percentile : {}\n'.format(sum(no_of_rated_movies_per_user>= 749)
) )
```

```
 No of ratings at last 5 percentile : 20305
```

3.3.4 Analysis of ratings of a movie given by a user

In [22]:

```
no_of_ratings_per_movie = train_df.groupby(by='movie')
['rating'].count().sort_values(ascending=False)

fig = plt.figure(figsize=plt.figaspect(.5))
ax = plt.gca()
plt.plot(no_of_ratings_per_movie.values)
plt.title('# RATINGS per Movie')
plt.xlabel('Movie')
plt.ylabel('No of Users who rated a movie')
ax.set_xticklabels([])

plt.show()
```



- **It is very skewed.. just like nunmber of ratings given per user.**

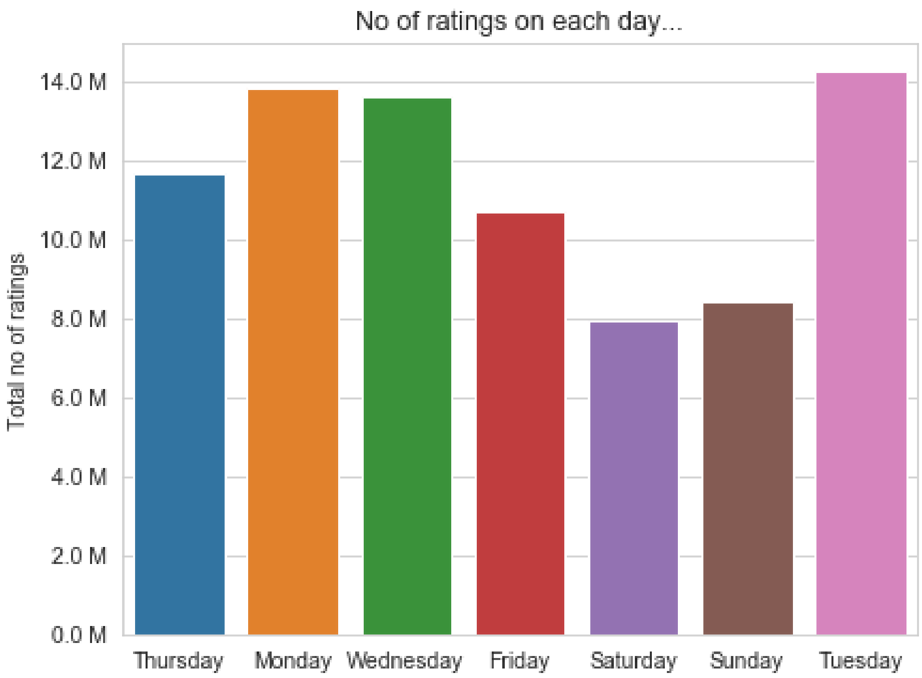
  - There are some movies (which are very popular) which are rated by huge number of users.

  - But most of the movies(like 90%) got some hundereds of ratings.

3.3.5 Number of ratings on each day of the week

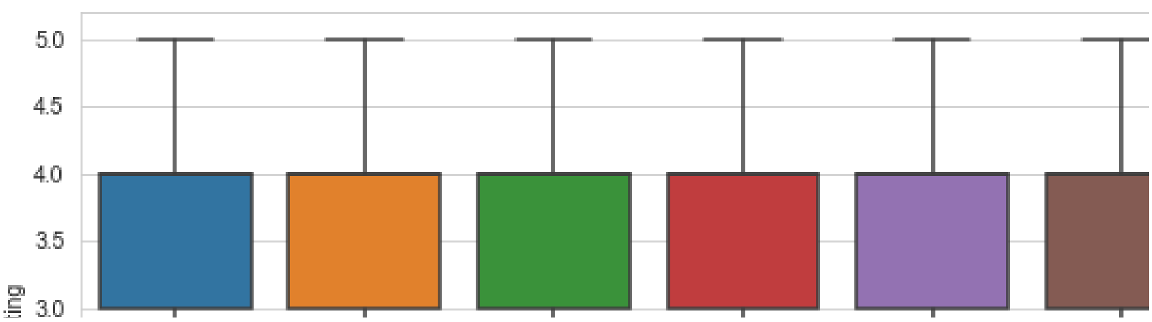
In [23]:

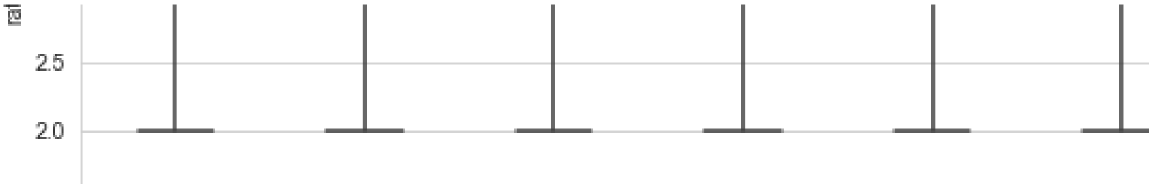
```
fig, ax = plt.subplots()
sns.countplot(x='day_of_week', data=train_df, ax=ax)
plt.title('No of ratings on each day...')
plt.ylabel('Total no of ratings')
plt.xlabel('')
ax.set_yticklabels([human(item, 'M') for item in ax.get_yticks()])
plt.show()
```



In [24]:

```
start = datetime.now()
fig = plt.figure(figsize=plt.figaspect(.45))
sns.boxplot(y='rating', x='day_of_week', data=train_df)
plt.show()
print(datetime.now() - start)
```





0:05:51.700825

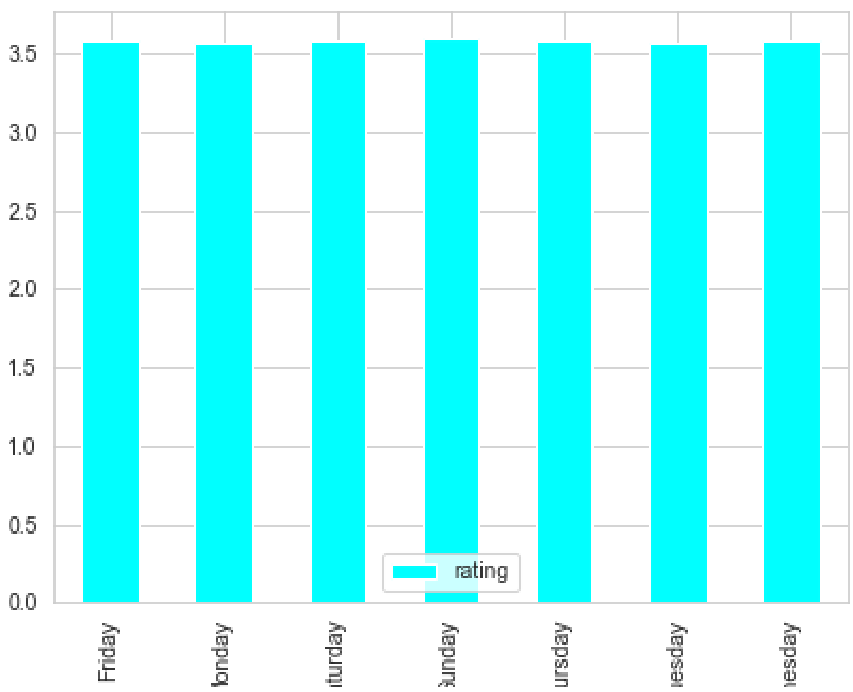
In [32]:

```
avg_week_df = train_df.groupby(by=['day_of_week'])['rating'].mean()
print(" AVerage ratings")
print("-"*30)
print(avg_week_df)
print("\n")
```

```
 AVerage ratings
------------------------------
day_of_week
Friday       3.585274
Monday       3.577250
Saturday     3.591791
Sunday       3.594144
Thursday     3.582463
Tuesday      3.574438
Wednesday    3.583751
Name: rating, dtype: float64
```

In [33]:

```
pd.DataFrame(avg_week_df).plot(kind='bar',color='cyan')
plt.xlabel('rating')
plt.xlabel('day')
plt.show()
```



3.3.6 Creating sparse matrix from data frame

3.3.6.1 Creating sparse matrix from train data frame

In [9]:

```
start = datetime.now()
if os.path.isfile('train_sparse_matrix.npz'):
    print("It is present in your pwd, getting it from disk....")
    # just get it from the disk instead of computing it
    train_sparse_matrix = sparse.load_npz('train_sparse_matrix.npz')
    print("DONE..")
else:
    print("We are creating sparse_matrix from the dataframe..")
    # create sparse_matrix and store it for after usage.
    # csr_matrix(data_values, (row_index, col_index), shape_of_matrix)
    # It should be in such a way that, MATRIX[row, col] = data
    train_sparse_matrix = sparse.csr_matrix((train_df.rating.values, (train_df.user.values,
                                               train_df.movie.values)),)

    print('Done. It\'s shape is : (user, movie) : ',train_sparse_matrix.shape)
    print('Saving it into disk for furthur usage..')
    # save it into disk
    sparse.save_npz("train_sparse_matrix.npz", train_sparse_matrix)
    print('Done..\n')

print(datetime.now() - start)
```

```
We are creating sparse_matrix from the dataframe..
Done. It's shape is : (user, movie) :  (2649430, 17771)
Saving it into disk for furthur usage..
Done..

0:01:03.856600
```

The Sparsity of Train Sparse Matrix

In [10]:

```
us,mv = train_sparse_matrix.shape
elem = train_sparse_matrix.count_nonzero()

print("Sparsity Of Train matrix : {} % ".format(  (1-(elem/(us*mv))) * 100) )
```

```
Sparsity Of Train matrix : 99.8292709259195 %
```

3.3.6.2 Creating sparse matrix from test data frame

In [11]:

```
start = datetime.now()
if os.path.isfile('test_sparse_matrix.npz'):
    print("It is present in your pwd, getting it from disk....")
    # just get it from the disk instead of computing it
    test_sparse_matrix = sparse.load_npz('test_sparse_matrix.npz')
    print("DONE..")
else:
    print("We are creating sparse_matrix from the dataframe..")
    # create sparse_matrix and store it for after usage.
    # csr_matrix(data_values, (row_index, col_index), shape_of_matrix)
    # It should be in such a way that, MATRIX[row, col] = data
    test_sparse_matrix = sparse.csr_matrix((test_df.rating.values, (test_df.user.values,
                                               test_df.movie.values)))

    print('Done. It\'s shape is : (user, movie) : ',test_sparse_matrix.shape)
    print('Saving it into disk for furthur usage..')
    # save it into disk
    sparse.save_npz("test_sparse_matrix.npz", test_sparse_matrix)
    print('Done..\n')
```

```
print(datetime.now() - start)
```

```
We are creating sparse_matrix from the dataframe..
Done. It's shape is : (user, movie) :  (2649430, 17771)
Saving it into disk for furthur usage..
Done..

0:00:17.071018
```

The Sparsity of Test data Matrix

In [12]:

```
us,mv = test_sparse_matrix.shape
elem = test_sparse_matrix.count_nonzero()

print("Sparsity Of Test matrix : {} % ".format(  (1-(elem/(us*mv))) * 100) )
```

```
Sparsity Of Test matrix : 99.95731772988694 %
```

3.3.7 Finding Global average of all movie ratings, Average rating per user, and Average rating per movie

In [13]:

```
# get the user averages in dictionary (key: user_id/movie_id, value: avg rating)

def get_average_ratings(sparse_matrix, of_users):

    # average ratings of user/axes
    ax = 1 if of_users else 0 # 1 - User axes,0 - Movie axes

    # ".A1" is for converting Column_Matrix to 1-D numpy array
    sum_of_ratings = sparse_matrix.sum(axis=ax).A1
    # Boolean matrix of ratings ( whether a user rated that movie or not)
    is_rated = sparse_matrix!=0
    # no of ratings that each user OR movie..
    no_of_ratings = is_rated.sum(axis=ax).A1

    # max_user  and max_movie ids in sparse matrix
    u,m = sparse_matrix.shape
    # creae a dictonary of users and their average ratigns..
    average_ratings = { i : sum_of_ratings[i]/no_of_ratings[i]
                                 for i in range(u if of_users else m)
                                    if no_of_ratings[i] !=0}

    # return that dictionary of average ratings
    return average_ratings
```

3.3.7.1 finding global average of all movie ratings

In [14]:

```
train_averages = dict()
# get the global average of ratings in our train set.
train_global_average = train_sparse_matrix.sum()/train_sparse_matrix.count_nonzero()
train_averages['global'] = train_global_average
train_averages
```

Out[14]:

```
{'global': 3.582890686321557}
```

3.3.7.2 finding average rating per user

In [15]:

```
train_averages['user'] = get_average_ratings(train_sparse_matrix, of_users=True)
print('\nAverage rating of user 10 :',train_averages['user'][10])
```

```
Average rating of user 10 : 3.3781094527363185
```

3.3.7.3 finding average rating per movie

In [16]:

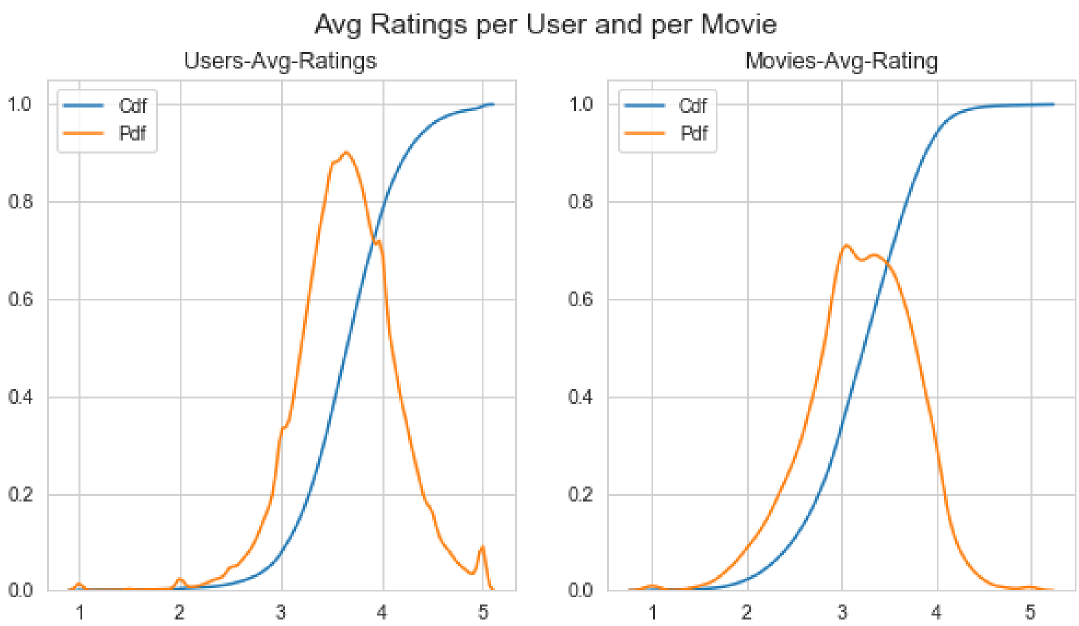
```
train_averages['movie'] =  get_average_ratings(train_sparse_matrix, of_users=False)
print('\n AVerage rating of movie 15 :',train_averages['movie'][15])
```

```
 AVerage rating of movie 15 : 3.3038461538461537
```

3.3.7.4 PDF's & CDF's of Avg.Ratings of Users & Movies (In Train Data)

In [34]:

```
start = datetime.now()
# draw pdfs for average rating per user and average
fig, (ax1, ax2) = plt.subplots(nrows=1, ncols=2, figsize=plt.figaspect(.5))
fig.suptitle('Avg Ratings per User and per Movie', fontsize=15)

ax1.set_title('Users-Avg-Ratings')
# get the list of average user ratings from the averages dictionary..
user_averages = [rat for rat in train_averages['user'].values()]
sns.distplot(user_averages, ax=ax1, hist=False,
             kde_kws=dict(cumulative=True), label='Cdf')
sns.distplot(user_averages, ax=ax1, hist=False,label='Pdf')

ax2.set_title('Movies-Avg-Rating')
# get the list of movie_average_ratings from the dictionary..
movie_averages = [rat for rat in train_averages['movie'].values()]
sns.distplot(movie_averages, ax=ax2, hist=False,
             kde_kws=dict(cumulative=True), label='Cdf')
sns.distplot(movie_averages, ax=ax2, hist=False, label='Pdf')

plt.show()
print(datetime.now() - start)
```




```
0:01:27.572334
```

3.3.8 Cold Start problem

3.3.8.1 Cold Start problem with Users

In [17]:

```
total_users = len(np.unique(df.user))
users_train = len(train_averages['user'])
new_users = total_users - users_train

print('\nTotal number of Users  :', total_users)
print('\nNumber of Users in Train data :', users_train)
print("\nNo of Users that didn't appear in train data: {}({} %) \n ".format(new_users,

np.round((new_users/total_users)*100, 2)))
```

```
Total number of Users  : 480189

Number of Users in Train data : 405041

No of Users that didn't appear in train data: 75148(15.65 %)
```

> We might have to handle **new users** (***75148***) who didn't appear in train data.

3.3.8.2 Cold Start problem with Movies

In [18]:

```
total_movies = len(np.unique(df.movie))
movies_train = len(train_averages['movie'])
new_movies = total_movies - movies_train

print('\nTotal number of Movies  :', total_movies)
print('\nNumber of Users in Train data :', movies_train)
print("\nNo of Movies that didn't appear in train data: {}({} %) \n ".format(new_movies,

np.round((new_movies/total_movies)*100, 2)))
```

```
Total number of Movies  : 17770

Number of Users in Train data : 17424

No of Movies that didn't appear in train data: 346(1.95 %)
```

> We might have to handle **346 movies** (small comparatively) in test data

3.4 Computing Similarity matrices

3.4.1 Computing User-User Similarity matrix

1. Calculating User User Similarity_Matrix is **not very easy**(*unless you have huge Computing Power and lots of time*) because of number of. usersbeing lare.
    - You can try if you want to. Your system could crash or the program stops with **Memory Error**

3.4.1.1 Trying with all dimensions (17k dimensions per user)

- We have **405,041 users** in out training set and computing similarities between them..(**17K dimensional vector..**) is time consuming..
- From above plot, It took roughly **8.88 sec** for computing simlilar users for **one user**
- We have **405,041 users** with us in training set.
- ${ 405041 \times 8.88 = 3596764.08 \sec } = 59946.068 \min = 999.101133333 \text{ hours} = 41.629213889 \text{ days}...$
  - Even if we run on 4 cores parallelly (a typical system now a days), It will still take almost **10 and 1/2** days.

  IDEA: Instead, we will try to reduce the dimentsions using SVD, so that **it might** speed up the process...

Here,

- $\sum \longleftarrow$ (netflix_svd.**singular_values_**)
- $\bigvee^T \longleftarrow$ (netflix_svd.**components_**)
- $\bigcup$ is not returned. instead **Projection_of_X** onto the new vectorspace is returned.
- It uses **randomized svd** internally, which returns **All 3 of them saperately**. Use that instead..

> I think 500 dimensions is good enough

- By just taking **(20 to 30)** latent factors, explained variance that we could get is **20 %**.
- To take it to **60%**, we have to take **almost 400 latent factors**. It is not fare.
- It basically is the **gain of variance explained**, if we ***add one additional latent factor to it.***
- By adding one by one latent factore too it, the **_gain in expained variance** with that addition is decreasing. (Obviously, because they are sorted that way).
- ***LHS Graph***:
  - **x** --- (No of latent factos),
  - **y** --- (The variance explained by taking x latent factors)
- **More decrease in the line (RHS graph)** :
  - We are getting more expained variance than before.
- **Less decrease in that line (RHS graph)** :
  - We are not getting benifitted from adding latent factor furthur. This is what is shown in the plots.
- ***RHS Graph***:
  - **x** --- (No of latent factors),
  - **y** --- (Gain n Expl_Var by taking one additional latent factor)

3.4.1.1 Trying with all dimensions (100 dimensions per user)

: This is taking more time for each user than Original one.

- from above plot, It took almost **12.18** for computing simlilar users for **one user**
- We have **405041 users** with us in training set.
- ${ 405041 \times 12.18 ==== 4933399.38 \sec } ==== 82223.323 \min ==== 1370.388716667 \text{ hours} ==== 57.099529861 \text{ days}...$
  - Even we run on 4 cores parallelly (a typical system now a days), It will still take almost **(14 - 15)** days.

- **Why did this happen...??**

  ```
  - Just think about it. It's not that difficult.
  ```

-------------------------------- *(sparse & dense.................get it ??)*----------------------------------

Is there any other way to compute user user similarity..??

-An alternative is to compute similar users for a particular user, whenenver required (**ie., Run time**)

```
- We maintain a binary Vector for users, which tells us whether we already computed or
not..
- ***If not*** :
    - Compute top (let's just say, 1000) most similar users for this given user, and add
this to our datastructure, so that we can just access it(similar users) without recomputing
it again.
    -
- ***If It is already Computed***:
    - Just get it directly from our datastructure, which has that information.
    - In production time, We might have to recompute similarities, if it is computed a long
time ago. Because user preferences changes over time. If we could maintain some kind of
Timer, which when expires, we have to update it ( recompute it ).
    -
- ***Which datastructure to use:***
    - It is purely implementation dependant.
    - One simple method is to maintain a **Dictionary Of Dictionaries**.
        -
        - **key    :** _userid_
        - __value__: _Again a dictionary_
            - __key__  : _Similar User_
            - __value__: _Similarity Value_
```

3.4.1.1 Trying with all dimensions (100 dimensions per user)

In [19]:

```python
row_index, col_index = train_sparse_matrix.nonzero()
rows = np.unique(row_index)
#Here, we are calculating user-user similarity matrix only for first 100 users in our sparse matri
x. And we are calculating
#top 100 most similar users with them.
def getUser_UserSimilarity(sparseMatrix, top = 100):
    startTimestamp20 = datetime.now()

    row_index, col_index = sparseMatrix.nonzero()  #this will give indices of rows in "row_index"
and indices of columns in
    #"col_index" where there is a non-zero value exist.
    rows = np.unique(row_index)
    similarMatrix = np.zeros(61700).reshape(617,100)    # 617*100 = 61700. As we are building simil
arity matrix only
    #for top 100 most similar users.
    timeTaken = []
    howManyDone = 0
    for row in rows[:top]:
        howManyDone += 1
        startTimestamp = datetime.now().timestamp()  #it will give seconds elapsed
        sim = cosine_similarity(sparseMatrix.getrow(row), sparseMatrix).ravel()
        top100_similar_indices = sim.argsort()[-top:]
        top100_similar = sim[top100_similar_indices]
        similarMatrix[row] = top100_similar
        timeforOne = datetime.now().timestamp() - startTimestamp
        timeTaken.append(timeforOne)
        if howManyDone % 20 == 0:
            print("Time elapsed for {} users = {}sec".format(howManyDone, (datetime.now() - startTi
mestamp20)))
    print("Average Time taken to compute similarity matrix for 1 user =
"+str(sum(timeTaken)/len(timeTaken))+"seconds")

    fig = plt.figure(figsize = (12,8))
    plt.plot(timeTaken, label = 'Time Taken For Each User')
    plt.plot(np.cumsum(timeTaken), label='Cumulative Time')
    plt.legend(loc='upper left', fontsize = 15)
    plt.xlabel('Users', fontsize = 20)
    plt.ylabel('Time(Seconds)', fontsize = 20)
    plt.tick_params(labelsize = 15)
```

```
    plt.show()

    return similarMatrix
simMatrix = getUser_UserSimilarity(train_sparse_matrix, 100)
```

```
Time elapsed for 20 users = 0:02:19.822752sec
Time elapsed for 40 users = 0:03:51.586852sec
Time elapsed for 60 users = 0:05:19.332173sec
Time elapsed for 80 users = 0:06:44.241236sec
Time elapsed for 100 users = 0:08:13.343842sec
Average Time taken to compute similarity matrix for 1 user = 4.892164406776428seconds
```

3.4.2 Computing Movie-Movie Similarity matrix

In [20]:

```
start = datetime.now()
if not os.path.isfile('m_m_sim_sparse.npz'):
    print("It seems you don't have that file. Computing movie_movie similarity...")
    start = datetime.now()
    m_m_sim_sparse = cosine_similarity(X=train_sparse_matrix.T, dense_output=False)
    print("Done..")
    # store this sparse matrix in disk before using it. For future purposes.
    print("Saving it to disk without the need of re-computing it again.. ")
    sparse.save_npz("m_m_sim_sparse.npz", m_m_sim_sparse)
    print("Done..")
else:
    print("It is there, We will get it.")
    m_m_sim_sparse = sparse.load_npz("m_m_sim_sparse.npz")
    print("Done ...")

print("It's a ",m_m_sim_sparse.shape," dimensional matrix")

print(datetime.now() - start)
```

```
It seems you don't have that file. Computing movie_movie similarity...
Done..
Saving it to disk without the need of re-computing it again..
Done..
```

```
It's a  (17771, 17771)  dimensional matrix
0:08:00.525306
```

In [21]:

```
m_m_sim_sparse.shape
```

Out[21]:

```
(17771, 17771)
```

- Even though we have similarity measure of each movie, with all other movies, We generally don't care much about least similar movies.
- Most of the times, only top_xxx similar items matters. It may be 10 or 100.
- We take only those top similar movie ratings and store them in a saperate dictionary.

In [22]:

```
movie_ids = np.unique(m_m_sim_sparse.nonzero()[1])
```

In [23]:

```
start = datetime.now()
similar_movies = dict()
for movie in movie_ids:
    # get the top similar movies and store them in the dictionary
    sim_movies = m_m_sim_sparse[movie].toarray().ravel().argsort()[::-1][1:]
    similar_movies[movie] = sim_movies[:100]
print(datetime.now() - start)

# just testing similar movies for movie_15
similar_movies[15]
```

```
0:01:49.558245
```

Out[23]:

```
array([ 8279,  8013, 16528,  5927, 13105, 12049,  4424, 10193, 17590,
        4549,  3755,   590, 14059, 15144, 15054,  9584,  9071,  6349,
       16402,  3973,  1720,  5370, 16309,  9376,  6116,  4706,  2818,
         778, 15331,  1416, 12979, 17139, 17710,  5452,  2534,   164,
       15188,  8323,  2450, 16331,  9566, 15301, 13213, 14308, 15984,
       10597,  6426,  5500,  7068,  7328,  5720,  9802,   376, 13013,
        8003, 10199,  3338, 15390,  9688, 16455, 11730,  4513,   598,
       12762,  2187,   509,  5865,  9166, 17115, 16334,  1942,  7282,
       17584,  4376,  8988,  8873,  5921,  2716, 14679, 11947, 11981,
        4649,   565, 12954, 10788, 10220, 10963,  9427,  1690,  5107,
        7859,  5969,  1510,  2429,   847,  7845,  6410, 13931,  9840,
        3706], dtype=int64)
```

3.4.3 Finding most similar movies using similarity matrix

Does Similarity really works as the way we expected...?
Let's pick some random movie and check for its similar movies....

In [24]:

```
# First Let's load the movie details into soe dataframe..
# movie details are in 'netflix/movie_titles.csv'

movie_titles = pd.read_csv("movie_titles.csv", sep=',', header = None,
                           names=['movie_id', 'year_of_release', 'title'], verbose=True,
                      index_col = 'movie_id', encoding = "ISO-8859-1")

movie_titles.head()
```

```
Tokenization took: 31.64 ms
Type conversion took: 662.74 ms
Parser memory cleanup took: 0.00 ms
```

Out[24]:

	year_of_release	title
movie_id		
1	2003.0	Dinosaur Planet
2	2004.0	Isle of Man TT 2004 Review
3	1997.0	Character
4	1994.0	Paula Abdul's Get Up & Dance
5	2004.0	The Rise and Fall of ECW

Similar Movies for 'Vampire Journals'

In [25]:

```
mv_id = 67

print("\nMovie ----->",movie_titles.loc[mv_id].values[1])

print("\nIt has {} Ratings from users.".format(train_sparse_matrix[:,mv_id].getnnz()))

print("\nWe have {} movies which are similarto this  and we will get only top most..".format(m_m_s
im_sparse[:,mv_id].getnnz()))
```

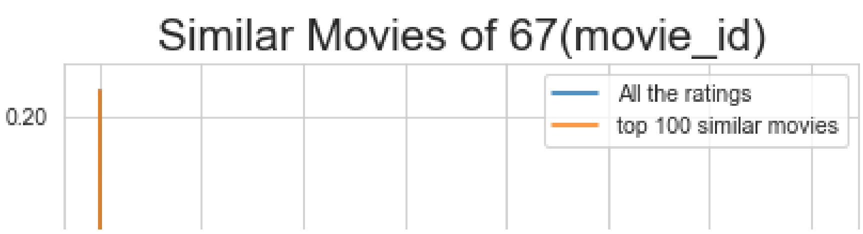
```
Movie -----> Vampire Journals

It has 270 Ratings from users.

We have 17284 movies which are similarto this  and we will get only top most..
```

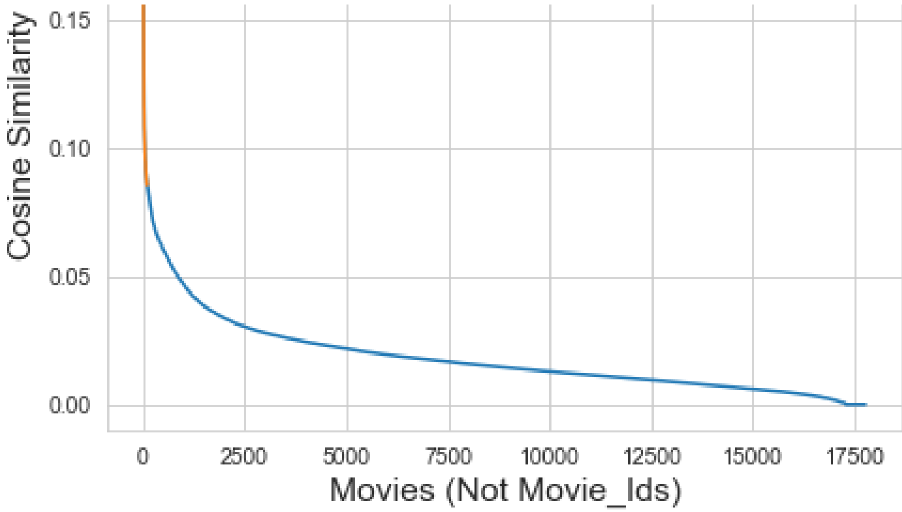
In [26]:

```
similarities = m_m_sim_sparse[mv_id].toarray().ravel()

similar_indices = similarities.argsort()[::-1][1:]

similarities[similar_indices]

sim_indices = similarities.argsort()[::-1][1:] # It will sort and reverse the array and ignore its
similarity (ie.,1)
                                               # and return its indices(movie_ids)
```

In [50]:

```
plt.plot(similarities[sim_indices], label='All the ratings')
plt.plot(similarities[sim_indices[:100]], label='top 100 similar movies')
plt.title("Similar Movies of {}(movie_id)".format(mv_id), fontsize=20)
plt.xlabel("Movies (Not Movie_Ids)", fontsize=15)
plt.ylabel("Cosine Similarity",fontsize=15)
plt.legend()
plt.show()
```





Top 10 similar movies

In [27]:

```
movie_titles.loc[sim_indices[:10]]
```

Out[27]:

	year_of_release	title
movie_id		
323	1999.0	Modern Vampires
4044	1998.0	Subspecies 4: Bloodstorm
1688	1993.0	To Sleep With a Vampire
13962	2001.0	Dracula: The Dark Prince
12053	1993.0	Dracula Rising
16279	2002.0	Vampires: Los Muertos
4667	1996.0	Vampirella
1900	1997.0	Club Vampire
13873	2001.0	The Breed
15867	2003.0	Dracula II: Ascension

> Similarly, we can ***find similar users*** and compare how similar they are.

4. Machine Learning Models

In [28]:

```
def get_sample_sparse_matrix(sparse_matrix, no_users, no_movies, path, verbose = True):
    """
        It will get it from the ''path'' if it is present  or It will create
```

```
    and store the sampled sparse matrix in the path specified.
    """

    # get (row, col) and (rating) tuple from sparse_matrix...
    row_ind, col_ind, ratings = sparse.find(sparse_matrix)
    users = np.unique(row_ind)
    movies = np.unique(col_ind)

    print("Original Matrix : (users, movies) -- ({} {})".format(len(users), len(movies)))
    print("Original Matrix : Ratings -- {}\n".format(len(ratings)))

    # It just to make sure to get same sample everytime we run this program..
    # and pick without replacement....
    np.random.seed(15)
    sample_users = np.random.choice(users, no_users, replace=False)
    sample_movies = np.random.choice(movies, no_movies, replace=False)
    # get the boolean mask or these sampled_items in originl row/col_inds..
    mask = np.logical_and( np.isin(row_ind, sample_users),
                  np.isin(col_ind, sample_movies) )

    sample_sparse_matrix = sparse.csr_matrix((ratings[mask], (row_ind[mask], col_ind[mask])),
                                             shape=(max(sample_users)+1, max(sample_movies)+1))

    if verbose:
        print("Sampled Matrix : (users, movies) -- ({} {})".format(len(sample_users), len(sample_mo
vies)))
        print("Sampled Matrix : Ratings --", format(ratings[mask].shape[0]))

    print('Saving it into disk for furthur usage..')
    # save it into disk
    sparse.save_npz(path, sample_sparse_matrix)
    if verbose:
            print('Done..\n')

    return sample_sparse_matrix
```

4.1 Sampling Data

4.1.1 Build sample train data from the train data

In [29]:

```
start = datetime.now()
path = "sample_train_sparse_matrix.npz"
if os.path.isfile(path):
    print("It is present in your pwd, getting it from disk....")
    # just get it from the disk instead of computing it
    sample_train_sparse_matrix = sparse.load_npz(path)
    print("DONE..")
else:
    # get 10k users and 1k movies from available data
    sample_train_sparse_matrix = get_sample_sparse_matrix(train_sparse_matrix, no_users=15000, no_m
ovies=1000,
                                             path = path)

print(datetime.now() - start)
```

```
Original Matrix : (users, movies) -- (405041 17424)
Original Matrix : Ratings -- 80384405

Sampled Matrix : (users, movies) -- (15000 1000)
Sampled Matrix : Ratings -- 193810
Saving it into disk for furthur usage..
Done..

0:01:47.870403
```

4.1.2 Build sample test data from the test data

In [30]:

```
start = datetime.now()

path = "sample_test_sparse_matrix.npz"
if os.path.isfile(path):
    print("It is present in your pwd, getting it from disk....")
    # just get it from the disk instead of computing it
    sample_test_sparse_matrix = sparse.load_npz(path)
    print("DONE..")
else:
    # get 5k users and 500 movies from available data
    sample_test_sparse_matrix = get_sample_sparse_matrix(test_sparse_matrix, no_users=7500, no_movi
es=500,
                                                 path = "sample_test_sparse_matrix.npz")
print(datetime.now() - start)
```

```
Original Matrix : (users, movies) -- (349312 17757)
Original Matrix : Ratings -- 20096102

Sampled Matrix : (users, movies) -- (7500 500)
Sampled Matrix : Ratings -- 10848
Saving it into disk for furthur usage..
Done..

0:00:14.509600
```

4.2 Finding Global Average of all movie ratings, Average rating per User, and Average rating per Movie (from sampled train)

In [31]:

```
sample_train_averages = dict()
```

4.2.1 Finding Global Average of all movie ratings

In [32]:

```
# get the global average of ratings in our train set.
global_average = sample_train_sparse_matrix.sum()/sample_train_sparse_matrix.count_nonzero()
sample_train_averages['global'] = global_average
sample_train_averages
```

Out[32]:

```
{'global': 3.575733966255611}
```

4.2.2 Finding Average rating per User

In [33]:

```
sample_train_averages['user'] = get_average_ratings(sample_train_sparse_matrix, of_users=True)
print('\nAverage rating of user 9186 :',sample_train_averages['user'][9186])
```

```
Average rating of user 9186 : 3.0
```

4.2.3 Finding Average rating per Movie

In [34]:

```
sample_train_averages['movie'] =  get_average_ratings(sample_train_sparse_matrix, of_users=False)
print('\n AVerage rating of movie 15153 :',sample_train_averages['movie'][15153])
```

```
 AVerage rating of movie 15153 : 2.6184210526315788
```

4.3 Featurizing data

In [35]:

```
print('\n No of ratings in Our Sampled train matrix is : {}\n'.format(sample_train_sparse_matrix.c
ount_nonzero()))
print('\n No of ratings in Our Sampled test  matrix is : {}\n'.format(sample_test_sparse_matrix.co
unt_nonzero()))
```

```
 No of ratings in Our Sampled train matrix is : 193810


 No of ratings in Our Sampled test  matrix is : 10848
```

4.3.1 Featurizing data for regression problem

4.3.1.1 Featurizing train data

In [36]:

```
# get users, movies and ratings from our samples train sparse matrix
sample_train_users, sample_train_movies, sample_train_ratings =
sparse.find(sample_train_sparse_matrix)
```

In [37]:

```
from multiprocessing import Manager, Process
from tqdm import tqdm
```

In [38]:

```
############################################################
# It took me almost 10 hours to prepare this train dataset.#
############################################################
start = datetime.now()
if os.path.isfile('reg_train.csv'):
    print("File already exists you don't have to prepare again..." )
else:
    print('preparing {} tuples for the dataset..\n'.format(len(sample_train_ratings)))
    with open('reg_train.csv', mode='w') as reg_data_file:
        count = 0
        for (user, movie, rating)  in zip(sample_train_users, sample_train_movies,
sample_train_ratings):
            st = datetime.now()
        #     print(user, movie)
            #--------------------- Ratings of "movie" by similar users of "user" ------------------
--
            # compute the similar Users of the "user"
            user_sim = cosine_similarity(sample_train_sparse_matrix[user],
sample_train_sparse_matrix).ravel()
            top_sim_users = user_sim.argsort()[::-1][1:] # we are ignoring 'The User' from its simi
lar users.
            # get the ratings of most similar users for this movie
            top_ratings = sample_train_sparse_matrix[top_sim_users, movie].toarray().ravel()
            # we will make it's length "5" by adding movie averages to .
            top_sim_users_ratings = list(top_ratings[top_ratings != 0][:5])
            top_sim_users_ratings.extend([sample_train_averages['movie'][movie]]*(5 -
len(top_sim_users_ratings)))
        #     print(top_sim_users_ratings, end=" ")


            #--------------------- Ratings by "user"  to similar movies of "movie" ----------------
----
            # compute the similar movies of the "movie"
            movie_sim = cosine_similarity(sample_train_sparse_matrix[:,movie].T,
sample_train_sparse_matrix.T).ravel()
```

```
            top_sim_movies = movie_sim.argsort()[::-1][1:] # we are ignoring 'The User' from its si
milar users.
            # get the ratings of most similar movie rated by this user..
            top_ratings = sample_train_sparse_matrix[user, top_sim_movies].toarray().ravel()
            # we will make it's length "5" by adding user averages to.
            top_sim_movies_ratings = list(top_ratings[top_ratings != 0][:5])
            top_sim_movies_ratings.extend([sample_train_averages['user']
[user]]*(5-len(top_sim_movies_ratings)))
        #     print(top_sim_movies_ratings, end=" : -- ")

            #-----------------prepare the row to be stores in a file-----------------#
            row = list()
            row.append(user)
            row.append(movie)
            # Now add the other features to this data...
            row.append(sample_train_averages['global']) # first feature
            # next 5 features are similar_users "movie" ratings
            row.extend(top_sim_users_ratings)
            # next 5 features are "user" ratings for similar_movies
            row.extend(top_sim_movies_ratings)
            # Avg_user rating
            row.append(sample_train_averages['user'][user])
            # Avg_movie rating
            row.append(sample_train_averages['movie'][movie])

            # finalley, The actual Rating of this user-movie pair...
            row.append(rating)
            count = count + 1

            # add rows to the file opened..
            reg_data_file.write(','.join(map(str, row)))
            reg_data_file.write('\n')
            if (count)%10000 == 0:
                # print(','.join(map(str, row)))
                print("Done for {} rows----- {}".format(count, datetime.now() - start))


print(datetime.now() - start)
```

```
preparing 193810 tuples for the dataset..

Done for 10000 rows----- 0:56:57.510419
Done for 20000 rows----- 1:53:46.600046
Done for 30000 rows----- 2:50:47.349229
Done for 40000 rows----- 3:47:36.608898
Done for 50000 rows----- 4:44:15.522799
Done for 60000 rows----- 5:40:52.699462
Done for 70000 rows----- 6:37:35.811366
Done for 80000 rows----- 7:34:37.902182
Done for 90000 rows----- 8:36:23.937560
Done for 100000 rows----- 9:33:02.292316
Done for 110000 rows----- 10:29:41.259039
Done for 120000 rows----- 11:26:18.591873
Done for 130000 rows----- 12:23:21.522594
Done for 140000 rows----- 13:20:05.032758
Done for 150000 rows----- 14:16:41.556443
Done for 160000 rows----- 15:13:22.468518
Done for 170000 rows----- 16:09:55.246737
Done for 180000 rows----- 17:06:26.107459
Done for 190000 rows----- 18:02:56.485854
18:24:27.423277
```

Reading from the file to make a Train_dataframe

In [144]:

```
reg_train = pd.read_csv('reg_train.csv', names = ['user', 'movie', 'GAvg', 'sur1', 'sur2', 'sur3',
'sur4', 'sur5','smr1', 'smr2', 'smr3', 'smr4', 'smr5', 'UAvg', 'MAvg', 'rating'], header=None)
reg_train.head()
```

Out[144]:

	user	movie	GAvg	sur1	sur2	sur3	sur4	sur5	smr1	smr2	smr3	smr4	smr5	UAvg	MAvg	rating

	user	movie	GAvg	sur1	sur2	sur3	sur4	sur5	smr1	smr2	smr3	smr4	smr5	UAvg	MAvg	rating
0	39297	33	3.575734	5.0	5.0	3.0	4.0	5.0	5.0	5.0	5.0	5.0	3.0	3.269565	4.143646	5
1	53406	33	3.575734	4.0	5.0	4.0	5.0	4.0	2.0	5.0	5.0	3.0	3.0	3.370370	4.143646	4
2	67390	33	3.575734	5.0	1.0	5.0	4.0	5.0	4.0	4.0	3.0	4.0	2.0	3.833333	4.143646	4
3	99540	33	3.575734	5.0	5.0	4.0	5.0	5.0	3.0	5.0	4.0	4.0	3.0	3.555556	4.143646	3
4	99865	33	3.575734	5.0	4.0	5.0	4.0	5.0	4.0	5.0	4.0	4.0	5.0	3.714286	4.143646	5

- **GAvg** : Average rating of all the ratings
- **Similar users rating of this movie**:
  - sur1, sur2, sur3, sur4, sur5 (top 5 similar users who rated that movie..)
- **Similar movies rated by this user**:
  - smr1, smr2, smr3, smr4, smr5 (top 5 similar movies rated by this movie..)
- **UAvg** : User's Average rating
- **MAvg** : Average rating of this movie
- **rating** : Rating of this movie by this user.

4.3.1.2 Featurizing test data

In [40]:

```
# get users, movies and ratings from the Sampled Test
sample_test_users, sample_test_movies, sample_test_ratings = sparse.find(sample_test_sparse_matrix
)
```

In [41]:

```
sample_train_averages['global']
```

Out[41]:

```
3.575733966255611
```

In [43]:

```
start = datetime.now()

if os.path.isfile('reg_test.csv'):
    print("It is already created...")
else:

    print('preparing {} tuples for the dataset..\n'.format(len(sample_test_ratings)))
    with open('reg_test.csv', mode='w') as reg_data_file:
        count = 0
        for (user, movie, rating)  in zip(sample_test_users, sample_test_movies,
sample_test_ratings):
            st = datetime.now()

        #--------------------- Ratings of "movie" by similar users of "user" ---------------------
            #print(user, movie)
            try:
                # compute the similar Users of the "user"
                user_sim = cosine_similarity(sample_train_sparse_matrix[user],
sample_train_sparse_matrix).ravel()
                top_sim_users = user_sim.argsort()[::-1][1:] # we are ignoring 'The User' from its
similar users.
                # get the ratings of most similar users for this movie
                top_ratings = sample_train_sparse_matrix[top_sim_users, movie].toarray().ravel()
                # we will make it's length "5" by adding movie averages to .
```

```
                top_sim_users_ratings = list(top_ratings[top_ratings != 0][:5])
                top_sim_users_ratings.extend([sample_train_averages['movie'][movie]]*(5 -
len(top_sim_users_ratings)))
                # print(top_sim_users_ratings, end="--")

            except (IndexError, KeyError):
                # It is a new User or new Movie or there are no ratings for given user for top simi
lar movies...
                ########## Cold STart Problem ##########
                top_sim_users_ratings.extend([sample_train_averages['global']]*(5 -
len(top_sim_users_ratings)))
                #print(top_sim_users_ratings)
            except:
                print(user, movie)
                # we just want KeyErrors to be resolved. Not every Exception...
                raise



            #--------------------- Ratings by "user"  to similar movies of "movie" ---------------
----
            try:
                # compute the similar movies of the "movie"
                movie_sim = cosine_similarity(sample_train_sparse_matrix[:,movie].T,
sample_train_sparse_matrix.T).ravel()
                top_sim_movies = movie_sim.argsort()[::-1][1:] # we are ignoring 'The User' from it
s similar users.
                # get the ratings of most similar movie rated by this user..
                top_ratings = sample_train_sparse_matrix[user, top_sim_movies].toarray().ravel()
                # we will make it's length "5" by adding user averages to.
                top_sim_movies_ratings = list(top_ratings[top_ratings != 0][:5])
                top_sim_movies_ratings.extend([sample_train_averages['user']
[user]]*(5-len(top_sim_movies_ratings)))
                #print(top_sim_movies_ratings)
            except (IndexError, KeyError):
                #print(top_sim_movies_ratings, end=" : -- ")

top_sim_movies_ratings.extend([sample_train_averages['global']]*(5-len(top_sim_movies_ratings)))
                #print(top_sim_movies_ratings)
            except :
                raise

            #-----------------prepare the row to be stores in a file-----------------#
            row = list()
            # add usser and movie name first
            row.append(user)
            row.append(movie)
            row.append(sample_train_averages['global']) # first feature
            #print(row)
            # next 5 features are similar_users "movie" ratings
            row.extend(top_sim_users_ratings)
            #print(row)
            # next 5 features are "user" ratings for similar_movies
            row.extend(top_sim_movies_ratings)
            #print(row)
            # Avg_user rating
            try:
                row.append(sample_train_averages['user'][user])
            except KeyError:
                row.append(sample_train_averages['global'])
            except:
                raise
            #print(row)
            # Avg_movie rating
            try:
                row.append(sample_train_averages['movie'][movie])
            except KeyError:
                row.append(sample_train_averages['global'])
            except:
                raise
            #print(row)
            # finalley, The actual Rating of this user-movie pair...
            row.append(rating)
            #print(row)
            count = count + 1

            # add rows to the file opened..
```

```
            reg_data_file.write(','.join(map(str, row)))
            #print(','.join(map(str, row)))
            reg_data_file.write('\n')
            if (count)%1000 == 0:
                #print(','.join(map(str, row)))
                print("Done for {} rows----- {}".format(count, datetime.now() - start))
    print("",datetime.now() - start)
```

```
It is already created...
```

Reading from the file to make a test dataframe

In [145]:

```
reg_test_df = pd.read_csv('reg_test.csv', names = ['user', 'movie', 'GAvg', 'sur1', 'sur2', 'sur3', 'sur4', 'sur5',
                                                          'smr1', 'smr2', 'smr3', 'smr4', 'smr5',
                                                          'UAvg', 'MAvg', 'rating'], header=None)
reg_test_df.head(4)
```

Out[145]:

	user	movie	GAvg	sur1	sur2	sur3	sur4	sur5	smr1	smr2	smr3	smr4	s
0	808635	71	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.57!
1	898730	71	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.57!
2	941866	71	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.57!
3	1280761	71	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.57!

- **GAvg** : Average rating of all the ratings
- **Similar users rating of this movie**:
  - sur1, sur2, sur3, sur4, sur5 (top 5 simiular users who rated that movie..)
- **Similar movies rated by this user**:
  - smr1, smr2, smr3, smr4, smr5 (top 5 simiular movies rated by this movie..)
- **UAvg** : User AVerage rating
- **MAvg** : Average rating of this movie
- **rating** : Rating of this movie by this user.

4.3.2 Transforming data for Surprise models

In [65]:

```
from surprise import Reader, Dataset
```

4.3.2.1 Transforming train data

- We can't give raw data (movie, user, rating) to train the model in Surprise library.
- They have a saperate format for TRAIN and TEST data, which will be useful for training the models like SVD, KNNBaseLineOnly....etc..,in Surprise.
- We can form the trainset from a file, or from a Pandas DataFrame. http://surprise.readthedocs.io/en/stable/getting_started.html#load-dom-dataframe-py

In [117]:

```
# It is to specify how to read the dataframe.
# for our dataframe, we don't have to specify anything extra..
reader = Reader(rating_scale=(1,5))

# create the traindata from the dataframe...
train_data = Dataset.load_from_df(reg_train[['user', 'movie', 'rating']], reader)

# build the trainset from traindata.., It is of dataset format from surprise library..
trainset = train_data.build_full_trainset()
```

4.3.2.2 Transforming test data

- Testset is just a list of (user, movie, rating) tuples. (Order in the tuple is impotant)

In [118]:

```
testset = list(zip(reg_test_df.user.values, reg_test_df.movie.values, reg_test_df.rating.values))
testset[:3]
```

Out[118]:

```
[(808635, 71, 5), (898730, 71, 3), (941866, 71, 4)]
```

4.4 Applying Machine Learning models

- Global dictionary that stores rmse and mape for all the models....
    - It stores the metrics in a dictionary of dictionaries

> **keys** : model names(string)
>
> **value**: dict(**key** : metric, **value** : value)

In [68]:

```
models_evaluation_train = dict()
models_evaluation_test = dict()

models_evaluation_train, models_evaluation_test
```

Out[68]:

```
({}, {})
```

In [116]:

```
train_data
```

Out[116]:

```
<surprise.dataset.DatasetAutoFolds at 0x18e5d957358>
```

> **Utility functions for running regression models**

In [69]:

```
# to get rmse and mape given actual and predicted ratings..
def get_error_metrics(y_true, y_pred):
    rmse = np.sqrt(np.mean([ (y_true[i] - y_pred[i])**2 for i in range(len(y_pred)) ]))
```

```
    mape = np.mean(np.abs( (y_true - y_pred)/y_true )) * 100
    return rmse, mape

###################################################################
###################################################################
def run_xgboost(algo,  x_train, y_train, x_test, y_test, verbose=True):
    """
    It will return train_results and test_results
    """

    # dictionaries for storing train and test results
    train_results = dict()
    test_results = dict()


    # fit the model
    print('Training the model..')
    start =datetime.now()
    algo.fit(x_train, y_train, eval_metric = 'rmse')
    print('Done. Time taken : {}\n'.format(datetime.now()-start))
    print('Done \n')

    # from the trained model, get the predictions....
    print('Evaluating the model with TRAIN data...')
    start =datetime.now()
    y_train_pred = algo.predict(x_train)
    # get the rmse and mape of train data...
    rmse_train, mape_train = get_error_metrics(y_train.values, y_train_pred)

    # store the results in train_results dictionary..
    train_results = {'rmse': rmse_train,
                    'mape' : mape_train,
                    'predictions' : y_train_pred}

    #######################################
    # get the test data predictions and compute rmse and mape
    print('Evaluating Test data')
    y_test_pred = algo.predict(x_test)
    rmse_test, mape_test = get_error_metrics(y_true=y_test.values, y_pred=y_test_pred)
    # store them in our test results dictionary.
    test_results = {'rmse': rmse_test,
                    'mape' : mape_test,
                    'predictions':y_test_pred}
    if verbose:
        print('\nTEST DATA')
        print('-'*30)
        print('RMSE : ', rmse_test)
        print('MAPE : ', mape_test)

    # return these train and test results...
    return train_results, test_results
```

Utility functions for Surprise modes

In [70]:

```
# it is just to makesure that all of our algorithms should produce same results
# everytime they run...

my_seed = 15
random.seed(my_seed)
np.random.seed(my_seed)

##########################################################
# get  (actual_list , predicted_list) ratings given list
# of predictions (prediction is a class in Surprise).
##########################################################
def get_ratings(predictions):
    actual = np.array([pred.r_ui for pred in predictions])
    pred = np.array([pred.est for pred in predictions])
```

```
    return actual, pred

#################################################################
# get ''rmse'' and ''mape'' , given list of prediction objecs
#################################################################
def get_errors(predictions, print_them=False):

    actual, pred = get_ratings(predictions)
    rmse = np.sqrt(np.mean((pred - actual)**2))
    mape = np.mean(np.abs(pred - actual)/actual)

    return rmse, mape*100

###################################################################################
# It will return predicted ratings, rmse and mape of both train and test data   #
###################################################################################
def run_surprise(algo, trainset, testset, verbose=True):
    '''
        return train_dict, test_dict

        It returns two dictionaries, one for train and the other is for test
        Each of them have 3 key-value pairs, which specify ''rmse'', ''mape'', and ''predicted rat
ings''.
    '''
    start = datetime.now()
    # dictionaries that stores metrics for train and test..
    train = dict()
    test = dict()

    # train the algorithm with the trainset
    st = datetime.now()
    print('Training the model...')
    algo.fit(trainset)
    print('Done. time taken : {} \n'.format(datetime.now()-st))

    # ---------------- Evaluating train data--------------------#
    st = datetime.now()
    print('Evaluating the model with train data..')
    # get the train predictions (list of prediction class inside Surprise)
    train_preds = algo.test(trainset.build_testset())
    # get predicted ratings from the train predictions..
    train_actual_ratings, train_pred_ratings = get_ratings(train_preds)
    # get ''rmse'' and ''mape'' from the train predictions.
    train_rmse, train_mape = get_errors(train_preds)
    print('time taken : {}'.format(datetime.now()-st))

    if verbose:
        print('-'*15)
        print('Train Data')
        print('-'*15)
        print("RMSE : {}\n\nMAPE : {}\n".format(train_rmse, train_mape))

    #store them in the train dictionary
    if verbose:
        print('adding train results in the dictionary..')
    train['rmse'] = train_rmse
    train['mape'] = train_mape
    train['predictions'] = train_pred_ratings

    #------------ Evaluating Test data---------------#
    st = datetime.now()
    print('\nEvaluating for test data...')
    # get the predictions( list of prediction classes) of test data
    test_preds = algo.test(testset)
    # get the predicted ratings from the list of predictions
    test_actual_ratings, test_pred_ratings = get_ratings(test_preds)
    # get error metrics from the predicted and actual ratings
    test_rmse, test_mape = get_errors(test_preds)
    print('time taken : {}'.format(datetime.now()-st))

    if verbose:
        print('-'*15)
        print('Test Data')
        print('-'*15)
        print("RMSE : {}\n\nMAPE : {}\n".format(test_rmse, test_mape))
    # store them in test dictionary
    if verbose:
```

```
        print('storing the test results in test dictionary...')
    test['rmse'] = test_rmse
    test['mape'] = test_mape
    test['predictions'] = test_pred_ratings

    print('\n'+'-'*45)
    print('Total time taken to run this algorithm :', datetime.now() - start)

    # return two dictionaries train and test
    return train, test
```

4.4.1 XGBoost with initial 13 features

In [71]:

```
import xgboost as xgb
```

In [86]:

```
import warnings
warnings.filterwarnings('ignore')
from sklearn.model_selection import GridSearchCV
# prepare Train data
x_train = reg_train.drop(['user','movie','rating'], axis=1)
y_train = reg_train['rating']

# Prepare Test data
x_test = reg_test_df.drop(['user','movie','rating'], axis=1)
y_test = reg_test_df['rating']

# initialize Our first XGBoost model...
params={'n_estimators':[50,70,90,110,120,130,140,150,160,170,180,190,200]}
first_xgb = xgb.XGBRegressor(silent=1, n_jobs=13, random_state=15)
gs_13=GridSearchCV(first_xgb,param_grid=params)
gs_13.fit(x_train,y_train)
gs_13.best_estimator_
```

Out[86]:

```
XGBRegressor(base_score=0.5, booster='gbtree', colsample_bylevel=1,
       colsample_bytree=1, gamma=0, learning_rate=0.1, max_delta_step=0,
       max_depth=3, min_child_weight=1, missing=None, n_estimators=200,
       n_jobs=13, nthread=None, objective='reg:linear', random_state=15,
       reg_alpha=0, reg_lambda=1, scale_pos_weight=1, seed=None, silent=1,
       subsample=1)
```

In [87]:

```
# initialize Our first XGBoost model...
first_xgb = xgb.XGBRegressor(base_score=0.5, booster='gbtree', colsample_bylevel=1,
       colsample_bytree=1, gamma=0, learning_rate=0.1, max_delta_step=0,
       max_depth=3, min_child_weight=1, missing=None, n_estimators=200,
       n_jobs=13, nthread=None, objective='reg:linear', random_state=15,
       reg_alpha=0, reg_lambda=1, scale_pos_weight=1, seed=None, silent=1,
       subsample=1)
train_results, test_results = run_xgboost(first_xgb, x_train, y_train, x_test, y_test)

# store the results in models_evaluations dictionaries
models_evaluation_train['first_algo'] = train_results
models_evaluation_test['first_algo'] = test_results

xgb.plot_importance(first_xgb)
plt.show()
```

```
Training the model..
Done. Time taken : 0:00:16.542029

Done

Evaluating the model with TRAIN data...
Evaluating Test data
```

```
Evaluating Test data

TEST DATA
------------------------------
RMSE :  1.09487048205718
MAPE :  35.38743413034222
```

4.4.2 Suprise BaselineModel

In [146]:

```python
from surprise import BaselineOnly
```

In [147]:

```python
bsl_options = {'method': 'sgd',
               'learning_rate': .001
               }
bsl_algo = BaselineOnly(bsl_options=bsl_options)

# run this algorithm.., It will return the train and test results..
bsl_train_results, bsl_test_results = run_surprise(bsl_algo, trainset, testset, verbose=True)

# Just store these error metrics in our models_evaluation datastructure
models_evaluation_train['bsl_algo'] = bsl_train_results
models_evaluation_test['bsl_algo'] = bsl_test_results
```

```
Training the model...
Estimating biases using sgd...
Done. time taken : 0:00:00.904369

Evaluating the model with train data..
time taken : 0:00:01.442384
---------------
Train Data
---------------
RMSE : 0.9350205122246975

MAPE : 29.45464404577332

adding train results in the dictionary..
```

```
Evaluating for test data...
time taken : 0:00:00.154587
---------------
Test Data
---------------
RMSE : 1.089987756601425

MAPE : 36.072863508085426

storing the test results in test dictionary...

---------------------------------------------
Total time taken to run this algorithm : 0:00:02.519743
```

Predicted_rating : (baseline prediction)

```
-
http://surprise.readthedocs.io/en/stable/basic_algorithms.html#surprise.prediction_algorithm
seline_only.BaselineOnly
```

> $ \large {\hat{r}_{ui} = b_{ui} =\mu + b_u + b_i} $

- $\pmb \mu $: Average of all trainings in training data.
- $\pmb b_u$: User bias
- $\pmb b_i$: Item bias (movie biases)

Optimization function (Least Squares Problem)

```
- http://surprise.readthedocs.io/en/stable/prediction_algorithms.html#baselines-estimates-c
onfiguration
```

> $ \large \sum_{r_{ui} \in R_{train}} \left(r_{ui} - (\mu + b_u + b_i)\right)^2 + \lambda \left(b_u^2 + b_i^2 \right).\text { [mimimize } {b_u, b_i]}$

In [103]:

```
import sklearn
sklearn.metrics.SCORERS.keys()
```

Out[103]:

```
dict_keys(['explained_variance', 'r2', 'neg_median_absolute_error', 'neg_mean_absolute_error', 'ne
g_mean_squared_error', 'neg_mean_squared_log_error', 'accuracy', 'roc_auc', 'balanced_accuracy', '
average_precision', 'neg_log_loss', 'brier_score_loss', 'adjusted_rand_score',
'homogeneity_score', 'completeness_score', 'v_measure_score', 'mutual_info_score',
'adjusted_mutual_info_score', 'normalized_mutual_info_score', 'fowlkes_mallows_score',
'precision', 'precision_macro', 'precision_micro', 'precision_samples', 'precision_weighted',
'recall', 'recall_macro', 'recall_micro', 'recall_samples', 'recall_weighted', 'f1', 'f1_macro', '
f1_micro', 'f1_samples', 'f1_weighted'])
```

4.4.3 XGBoost with initial 13 features + Surprise Baseline predictor

Updating Train Data

In [148]:

```
# add our baseline_predicted value as our feature..
reg_train['bslpr'] = models_evaluation_train['bsl_algo']['predictions']
reg_train.head(2)
```

Out[148]:

	user	movie	GAvg	sur1	sur2	sur3	sur4	sur5	smr1	smr2	smr3	smr4	smr5	UAvg	MAvg	rating	bslpr
0	39297	33	3.575734	5.0	5.0	2.0	4.0	5.0	5.0	5.0	5.0	5.0	2.0	3.269565	4.143646	5	3.890715
1	53406	33	3.575734	4.0	5.0	4.0	5.0	4.0	2.0	5.0	5.0	3.0	3.0	3.370370	4.143646	4	2.975282

Updating Test Data

In [149]:

```
# add that baseline predicted ratings with Surprise to the test data as well
reg_test_df['bslpr']  = models_evaluation_test['bsl_algo']['predictions']

reg_test_df.head(2)
```

Out[149]:

	user	movie	GAvg	sur1	sur2	sur3	sur4	sur5	smr1	smr2	smr3	smr4	sr
0	808635	71	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.575
1	898730	71	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.575

In [127]:

```
# prepare train data
x_train = reg_train.drop(['user', 'movie','rating'], axis=1)
y_train = reg_train['rating']

# Prepare Test data
x_test = reg_test_df.drop(['user','movie','rating'], axis=1)
y_test = reg_test_df['rating']
params={'n_estimators':[50,70,90,110,120,130,140,150,160,170,180,190,200]}
first_xgb = xgb.XGBRegressor(silent=1, n_jobs=13, random_state=15)
gs_13=GridSearchCV(first_xgb,param_grid=params)
gs_13.fit(x_train,y_train)
gs_13.best_estimator_
# initialize Our first XGBoost model...
```

Out[127]:

```
XGBRegressor(base_score=0.5, booster='gbtree', colsample_bylevel=1,
       colsample_bytree=1, gamma=0, learning_rate=0.1, max_delta_step=0,
       max_depth=3, min_child_weight=1, missing=None, n_estimators=200,
       n_jobs=13, nthread=None, objective='reg:linear', random_state=15,
       reg_alpha=0, reg_lambda=1, scale_pos_weight=1, seed=None, silent=1,
       subsample=1)
```

In [128]:

```
xgb_bsl = xgb.XGBRegressor(base_score=0.5, booster='gbtree', colsample_bylevel=1,
       colsample_bytree=1, gamma=0, learning_rate=0.1, max_delta_step=0,
       max_depth=3, min_child_weight=1, missing=None, n_estimators=200,
       n_jobs=13, nthread=None, objective='reg:linear', random_state=15,
       reg_alpha=0, reg_lambda=1, scale_pos_weight=1, seed=None, silent=1,
       subsample=1)
train_results, test_results = run_xgboost(xgb_bsl, x_train, y_train, x_test, y_test)

# store the results in models_evaluations dictionaries
models_evaluation_train['xgb_bsl'] = train_results
models_evaluation_test['xgb_bsl'] = test_results

xgb.plot_importance(xgb_bsl)
plt.show()
```

```
Training the model..
Done. Time taken : 0:00:17.825034

Done

Evaluating the model with TRAIN data...
Evaluating Test data
```

```
TEST DATA
------------------------------
RMSE :  1.0952571679216956
MAPE :  35.35882675208906
```

4.4.4 Surprise KNNBaseline predictor

In [150]:

```python
from surprise import KNNBaseline
```

- KNN BASELINE
  - http://surprise.readthedocs.io/en/stable/knn_inspired.html#surprise.prediction_algorithms.knns.KNNBaseline

- PEARSON_BASELINE SIMILARITY
  - http://surprise.readthedocs.io/en/stable/similarities.html#surprise.similarities.pearson_baseline

- SHRINKAGE
  - *2.2 Neighborhood Models* in http://courses.ischool.berkeley.edu/i290-dm/s11/SECURE/a1-koren.pdf

- **predicted Rating** : (***based on User-User similarity***)

\begin{align} \hat{r}_{ui} = b_{ui} + \frac{ \sum\limits_{v \in N^k_i(u)} \text{sim}(u, v) \cdot (r_{vi} - b_{vi})} {\sum\limits_{v \in N^k_i(u)} \text{sim}(u, v)} \end{align}

- $\pmb{b_{ui}}$ - *Baseline prediction* of (user,movie) rating
- $ \pmb {N_i^k (u)}$ - Set of **K similar** users (neighbours) of **user (u)** who rated **movie(i)**
- *sim (u, v)* - **Similarity** between users **u and v**
  - Generally, it will be cosine similarity or Pearson correlation coefficient.
  - But we use **shrunk Pearson-baseline correlation coefficient**, which is based on the pearsonBaseline similarity (we take base line predictions instead of mean rating of user/item)

- **Predicted rating** (based on Item Item similarity): \begin{align} \hat{r}_{ui} = b_{ui} + \frac{ \sum\limits_{j \in

- **Predicted rating** (based on item item similarity): \begin{align} \hat{r}_{ui} = b_{ui} + \frac{ \sum\limits_{j \in N^k_u(i)}\text{sim}(i, j) \cdot (r_{uj} - b_{uj})} {\sum\limits_{j \in N^k_u(j)} \text{sim}(i, j)} \end{align}
    - ***Notations follows same as above (user user based predicted rating)***

4.4.4.1 Surprise KNNBaseline with user user similarities

In [151]:

```
# we specify , how to compute similarities and what to consider with sim_options to our algorithm
sim_options = {'user_based' : True,
               'name': 'pearson_baseline',
               'shrinkage': 100,
               'min_support': 2
              }
# we keep other parameters like regularization parameter and learning_rate as default values.
bsl_options = {'method': 'sgd'}

knn_bsl_u = KNNBaseline(k=40, sim_options = sim_options, bsl_options = bsl_options)
knn_bsl_u_train_results, knn_bsl_u_test_results = run_surprise(knn_bsl_u, trainset, testset,
verbose=True)

# Just store these error metrics in our models_evaluation datastructure
models_evaluation_train['knn_bsl_u'] = knn_bsl_u_train_results
models_evaluation_test['knn_bsl_u'] = knn_bsl_u_test_results
```

```
Training the model...
Estimating biases using sgd...
Computing the pearson_baseline similarity matrix...
Done computing similarity matrix.
Done. time taken : 0:05:44.918332

Evaluating the model with train data..
time taken : 0:05:27.369982
---------------
Train Data
---------------
RMSE : 0.3412600175696613

MAPE : 9.35413821052911

adding train results in the dictionary..

Evaluating for test data...
time taken : 0:00:00.737267
---------------
Test Data
---------------
RMSE : 1.0896400011629415

MAPE : 36.03579932018314

storing the test results in test dictionary...

---------------------------------------------
Total time taken to run this algorithm : 0:11:13.630935
```

4.4.4.2 Surprise KNNBaseline with movie movie similarities

In [152]:

```
# we specify , how to compute similarities and what to consider with sim_options to our algorithm

# 'user_based' : Fals => this considers the similarities of movies instead of users

sim_options = {'user_based' : False,
               'name': 'pearson_baseline',
               'shrinkage': 100,
               'min_support': 2
              }
# we keep other parameters like regularization parameter and learning_rate as default values.
bsl_options = {'method': 'sgd'}
```

```
knn_bsl_m = KNNBaseline(k=40, sim_options = sim_options, bsl_options = bsl_options)

knn_bsl_m_train_results, knn_bsl_m_test_results = run_surprise(knn_bsl_m, trainset, testset,
verbose=True)

# Just store these error metrics in our models_evaluation datastructure
models_evaluation_train['knn_bsl_m'] = knn_bsl_m_train_results
models_evaluation_test['knn_bsl_m'] = knn_bsl_m_test_results
```

```
Training the model...
Estimating biases using sgd...
Computing the pearson_baseline similarity matrix...
Done computing similarity matrix.
Done. time taken : 0:00:02.249488

Evaluating the model with train data..
time taken : 0:00:12.131193
---------------
Train Data
---------------
RMSE : 0.33379129916076966

MAPE : 8.719452699287773

adding train results in the dictionary..

Evaluating for test data...
time taken : 0:00:00.165793
---------------
Test Data
---------------
RMSE : 1.089638713949878

MAPE : 36.03392586028367

storing the test results in test dictionary...

---------------------------------------------
Total time taken to run this algorithm : 0:00:14.565506
```

4.4.5 XGBoost with initial 13 features + Surprise Baseline predictor + KNNBaseline predictor

- First we will run XGBoost with predictions from both KNN's (that uses User_User and Item_Item similarities along with our previous features.

- Then we will run XGBoost with just predictions form both knn models and preditions from our baseline model.

Preparing Train data

In [153]:

```
# add the predicted values from both knns to this dataframe
reg_train['knn_bsl_u'] = models_evaluation_train['knn_bsl_u']['predictions']
reg_train['knn_bsl_m'] = models_evaluation_train['knn_bsl_m']['predictions']

reg_train.head(2)
```

Out[153]:

	user	movie	GAvg	sur1	sur2	sur3	sur4	sur5	smr1	smr2	smr3	smr4	smr5	UAvg	MAvg	rating	bslpr
0	39297	33	3.575734	5.0	5.0	2.0	4.0	5.0	5.0	5.0	5.0	5.0	2.0	3.269565	4.143646	5	3.890715
1	53406	33	3.575734	4.0	5.0	4.0	5.0	4.0	2.0	5.0	5.0	3.0	3.0	3.370370	4.143646	4	2.975282

Preparing Test data

In [154]:

```
reg_test_df['knn_bsl_u'] = models_evaluation_test['knn_bsl_u']['predictions']
reg_test_df['knn_bsl_m'] = models_evaluation_test['knn_bsl_m']['predictions']

reg_test_df.head(2)
```

Out[154]:

	user	movie	GAvg	sur1	sur2	sur3	sur4	sur5	smr1	smr2	smr3	smr4	sı
0	808635	71	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.575
1	898730	71	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.575

In [156]:

```
# prepare the train data....
x_train = reg_train.drop(['user', 'movie', 'rating'], axis=1)
y_train = reg_train['rating']

# prepare the train data....
x_test = reg_test_df.drop(['user','movie','rating'], axis=1)
y_test = reg_test_df['rating']
params={'n_estimators':[50,70,90,110,120,130,140,150,160,170,180,190,200]}
first_xgb = xgb.XGBRegressor(silent=1, n_jobs=13, random_state=15)
gs_13=GridSearchCV(first_xgb,param_grid=params,scoring='neg_mean_squared_error')
gs_13.fit(x_train,y_train)
# declare the model
gs_13.best_estimator_
```

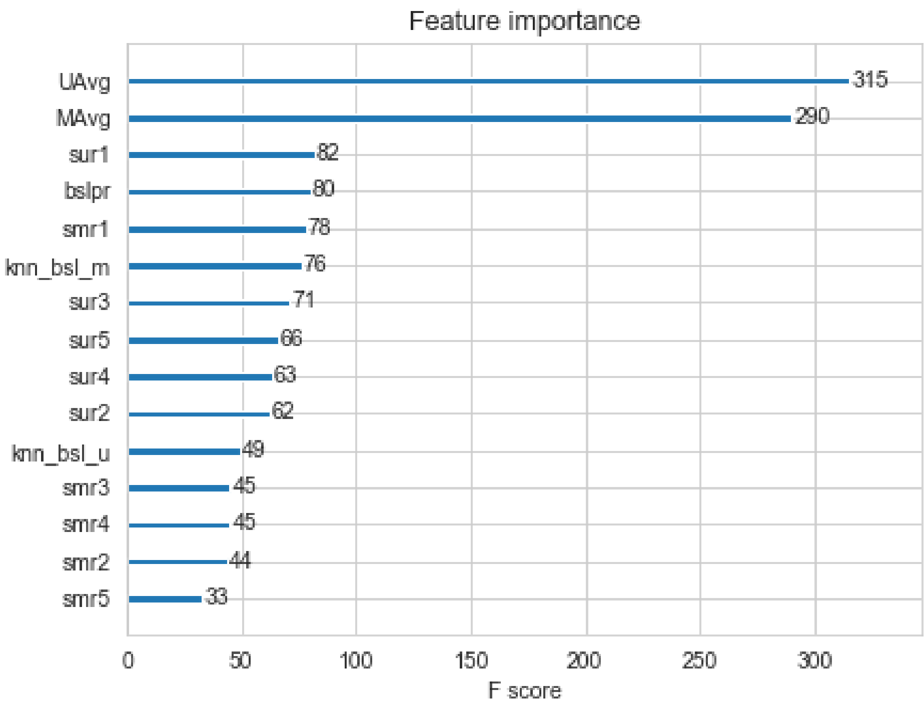
Out[156]:

```
XGBRegressor(base_score=0.5, booster='gbtree', colsample_bylevel=1,
       colsample_bytree=1, gamma=0, learning_rate=0.1, max_delta_step=0,
       max_depth=3, min_child_weight=1, missing=None, n_estimators=200,
       n_jobs=13, nthread=None, objective='reg:linear', random_state=15,
       reg_alpha=0, reg_lambda=1, scale_pos_weight=1, seed=None, silent=1,
       subsample=1)
```

In [157]:

```
xgb_knn_bsl = xgb.XGBRegressor(base_score=0.5, booster='gbtree', colsample_bylevel=1,
       colsample_bytree=1, gamma=0, learning_rate=0.1, max_delta_step=0,
       max_depth=3, min_child_weight=1, missing=None, n_estimators=200,
       n_jobs=13, nthread=None, objective='reg:linear', random_state=15,
       reg_alpha=0, reg_lambda=1, scale_pos_weight=1, seed=None, silent=1,
       subsample=1)
train_results, test_results = run_xgboost(xgb_knn_bsl, x_train, y_train, x_test, y_test)

# store the results in models_evaluations dictionaries
models_evaluation_train['xgb_knn_bsl'] = train_results
models_evaluation_test['xgb_knn_bsl'] = test_results


xgb.plot_importance(xgb_knn_bsl)
plt.show()
```

```
Training the model..
Done. Time taken : 0:00:20.561588

Done

Evaluating the model with TRAIN data...
Evaluating Test data

TEST DATA
------------------------------
RMSE :  1.094164865102673
MAPE :  35.44161901872462
```



4.4.6 Matrix Factorization Techniques

4.4.6.1 SVD Matrix Factorization User Movie intractions

In [158]:

```
from surprise import SVD
```

http://surprise.readthedocs.io/en/stable/matrix_factorization.html#surprise.prediction_algorithms.matrix_factorization.SVD

- Predicted Rating :

```
- $ \large  \hat r_{ui} = \mu + b_u + b_i + q_i^Tp_u $

    - $\pmb q_i$ - Representation of item(movie) in latent factor space

    - $\pmb p_u$ - Representation of user in new latent factor space
```

- A BASIC MATRIX FACTORIZATION MODEL in https://datajobs.com/data-science-repo/Recommender-Systems-[Netflix].pdf

- Optimization problem with user item interactions and regularization (to avoid overfitting)

```
- $\large \sum_{r_{ui} \in R_{train}} \left(r_{ui} - \hat{r}_{ui} \right)^2 +
```

\lambda\left(b_i^2 + b_u^2 + ||q_i||^2 + ||p_u||^2\right) $

In [159]:

```
# initiallize the model
svd = SVD(n_factors=100, biased=True, random_state=15, verbose=True)
svd_train_results, svd_test_results = run_surprise(svd, trainset, testset, verbose=True)

# Just store these error metrics in our models_evaluation datastructure
models_evaluation_train['svd'] = svd_train_results
models_evaluation_test['svd'] = svd_test_results
```

```
Training the model...
Processing epoch 0
Processing epoch 1
Processing epoch 2
Processing epoch 3
Processing epoch 4
Processing epoch 5
Processing epoch 6
Processing epoch 7
Processing epoch 8
Processing epoch 9
Processing epoch 10
Processing epoch 11
Processing epoch 12
Processing epoch 13
Processing epoch 14
Processing epoch 15
Processing epoch 16
Processing epoch 17
Processing epoch 18
Processing epoch 19
Done. time taken : 0:00:14.735999

Evaluating the model with train data..
time taken : 0:00:02.089944
---------------
Train Data
---------------
RMSE : 0.6599550156839991

MAPE : 19.832869899255765

adding train results in the dictionary..

Evaluating for test data...
time taken : 0:00:00.171999
---------------
Test Data
---------------
RMSE : 1.0895575335859022

MAPE : 36.03389911426933

storing the test results in test dictionary...

---------------------------------------------
Total time taken to run this algorithm : 0:00:17.035202
```

4.4.6.2 SVD Matrix Factorization with implicit feedback from user (user rated movies)

In [160]:

```
from surprise import SVDpp
```

- -----> 2.5 Implicit Feedback in http://courses.ischool.berkeley.edu/i290-dm/s11/SECURE/a1-koren.pdf

- Predicted Rating :

```
- $ \large \hat{r}_{ui} = \mu + b_u + b_i + q_i^T\left(p_u +
|I_u|^{-\frac{1}{2}} \sum_{j \in I_u}y_j\right) $
```

- $ \pmb{I_u}$ --- the set of all items rated by user u
- $\pmb{y_j}$ --- Our new set of item factors that capture implicit ratings.

- Optimization problem with user item interactions and regularization (to avoid

overfitting)

- $ \large \sum_{r_{ui} \in R_{train}} \left(r_{ui} - \hat{r}_{ui} \right)^2 +

\lambda\left(b_i^2 + b_u^2 + ||q_i||^2 + ||p_u||^2 + ||y_j||^2\right) $

In [161]:

```
# initiallize the model
svdpp = SVDpp(n_factors=50, random_state=15, verbose=True)
svdpp_train_results, svdpp_test_results = run_surprise(svdpp, trainset, testset, verbose=True)

# Just store these error metrics in our models_evaluation datastructure
models_evaluation_train['svdpp'] = svdpp_train_results
models_evaluation_test['svdpp'] = svdpp_test_results
```

```
Training the model...
 processing epoch 0
 processing epoch 1
 processing epoch 2
 processing epoch 3
 processing epoch 4
 processing epoch 5
 processing epoch 6
 processing epoch 7
 processing epoch 8
 processing epoch 9
 processing epoch 10
 processing epoch 11
 processing epoch 12
 processing epoch 13
 processing epoch 14
 processing epoch 15
 processing epoch 16
 processing epoch 17
 processing epoch 18
 processing epoch 19
Done. time taken : 0:03:08.830544

Evaluating the model with train data..
time taken : 0:00:08.814570
---------------
Train Data
---------------
RMSE : 0.6055768503411023

MAPE : 17.571545001485987

adding train results in the dictionary..

Evaluating for test data...
time taken : 0:00:00.164209
---------------
Test Data
---------------
RMSE : 1.089607032933482

MAPE : 36.037435340011555

storing the test results in test dictionary...

---------------------------------------------
Total time taken to run this algorithm : 0:03:17.846929
```

4.4.7 XgBoost with 13 features + Surprise Baseline + Surprise KNNbaseline + MF Techniques

Preparing Train data

In [162]:

```python
# add the predicted values from both knns to this dataframe
reg_train['svd'] = models_evaluation_train['svd']['predictions']
reg_train['svdpp'] = models_evaluation_train['svdpp']['predictions']

reg_train.head(2)
```

Out[162]:

	user	movie	GAvg	sur1	sur2	sur3	sur4	sur5	smr1	smr2	...	smr4	smr5	UAvg	MAvg	rating	bslpr	kn
0	39297	33	3.575734	5.0	5.0	2.0	4.0	5.0	5.0	5.0	...	5.0	2.0	3.269565	4.143646	5	3.890715	4.
1	53406	33	3.575734	4.0	5.0	4.0	5.0	4.0	2.0	5.0	...	3.0	3.0	3.370370	4.143646	4	2.975282	2.

2 rows × 21 columns

Preparing Test data

In [163]:

```python
reg_test_df['svd'] = models_evaluation_test['svd']['predictions']
reg_test_df['svdpp'] = models_evaluation_test['svdpp']['predictions']

reg_test_df.head(2)
```

Out[163]:

	user	movie	GAvg	sur1	sur2	sur3	sur4	sur5	smr1	smr2	...	smr4	smr5	
0	808635	71	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	...	3.575734	3.575734	3.5
1	898730	71	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	3.575734	...	3.575734	3.575734	3.5

2 rows × 21 columns

In [164]:

```python
# prepare x_train and y_train
x_train = reg_train.drop(['user', 'movie', 'rating',], axis=1)
y_train = reg_train['rating']

# prepare test data
x_test = reg_test_df.drop(['user', 'movie', 'rating'], axis=1)
y_test = reg_test_df['rating']

params={'n_estimators':[50,70,90,110,120,130,140,150,160,170,180,190,200]}
first_xgb = xgb.XGBRegressor(silent=1, n_jobs=13, random_state=15)
gs_13=GridSearchCV(first_xgb,param_grid=params,scoring='neg_mean_squared_error')
gs_13.fit(x_train,y_train)
# declare the model
gs_13.best_estimator_
```

Out[164]:

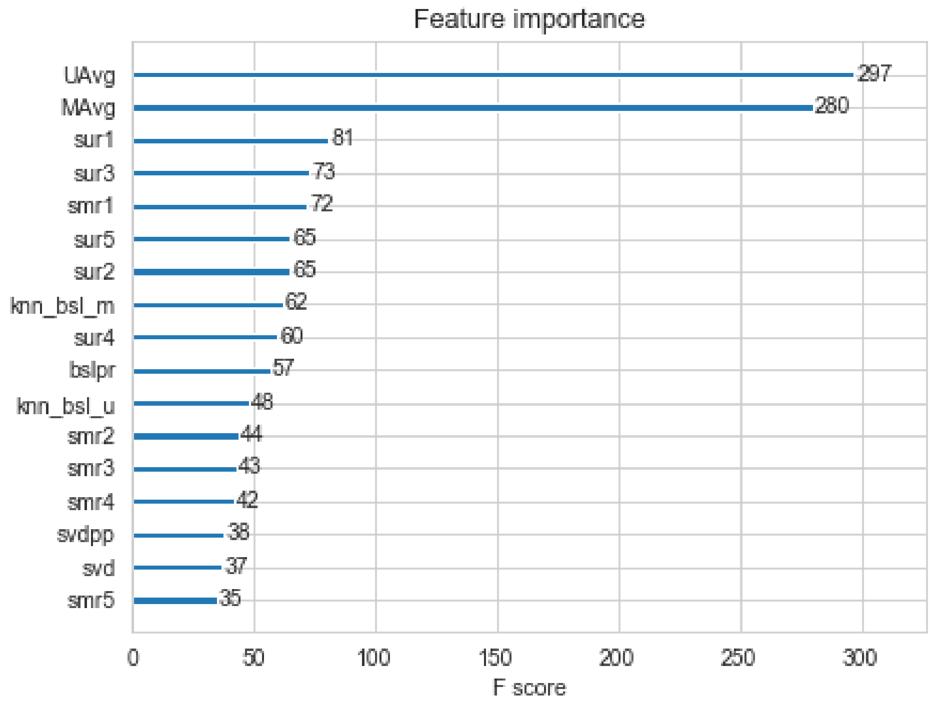
```
XGBRegressor(base_score=0.5, booster='gbtree', colsample_bylevel=1,
       colsample_bytree=1, gamma=0, learning_rate=0.1, max_delta_step=0,
       max_depth=3, min_child_weight=1, missing=None, n_estimators=200,
       n_jobs=13, nthread=None, objective='reg:linear', random_state=15,
       reg_alpha=0, reg_lambda=1, scale_pos_weight=1, seed=None, silent=1,
       subsample=1)
```

In [165]:

```python
xgb_final = xgb.XGBRegressor(base_score=0.5, booster='gbtree', colsample_bylevel=1,
       colsample_bytree=1, gamma=0, learning_rate=0.1, max_delta_step=0,
       max_depth=3, min_child_weight=1, missing=None, n_estimators=200,
       n_jobs=13, nthread=None, objective='reg:linear', random_state=15,
       reg_alpha=0, reg_lambda=1, scale_pos_weight=1, seed=None, silent=1,
       subsample=1)
train_results, test_results = run_xgboost(xgb_final, x_train, y_train, x_test, y_test)
```

```
train_results, test_results = run_xgboost(xgb_final, x_train, y_train, x_test, y_test)

# store the results in models_evaluations dictionaries
models_evaluation_train['xgb_final'] = train_results
models_evaluation_test['xgb_final'] = test_results


xgb.plot_importance(xgb_final)
plt.show()
```

```
Training the model..
Done. Time taken : 0:00:28.796185

Done

Evaluating the model with TRAIN data...
Evaluating Test data

TEST DATA
------------------------------
RMSE :  1.094091656041009
MAPE :  35.44812817393913
```



4.4.8 XgBoost with Surprise Baseline + Surprise KNNbaseline + MF Techniques

In [166]:

```
# prepare train data
x_train = reg_train[['knn_bsl_u', 'knn_bsl_m', 'svd', 'svdpp']]
y_train = reg_train['rating']

# test data
x_test = reg_test_df[['knn_bsl_u', 'knn_bsl_m', 'svd', 'svdpp']]
y_test = reg_test_df['rating']
params={'n_estimators':[50,70,90,110,120,130,140,150,160,170,180,190,200]}
first_xgb = xgb.XGBRegressor(silent=1, n_jobs=13, random_state=15)
gs_13=GridSearchCV(first_xgb,param_grid=params,scoring='neg_mean_squared_error')
gs_13.fit(x_train,y_train)
# declare the model
gs_13.best_estimator_
```

Out[166]:

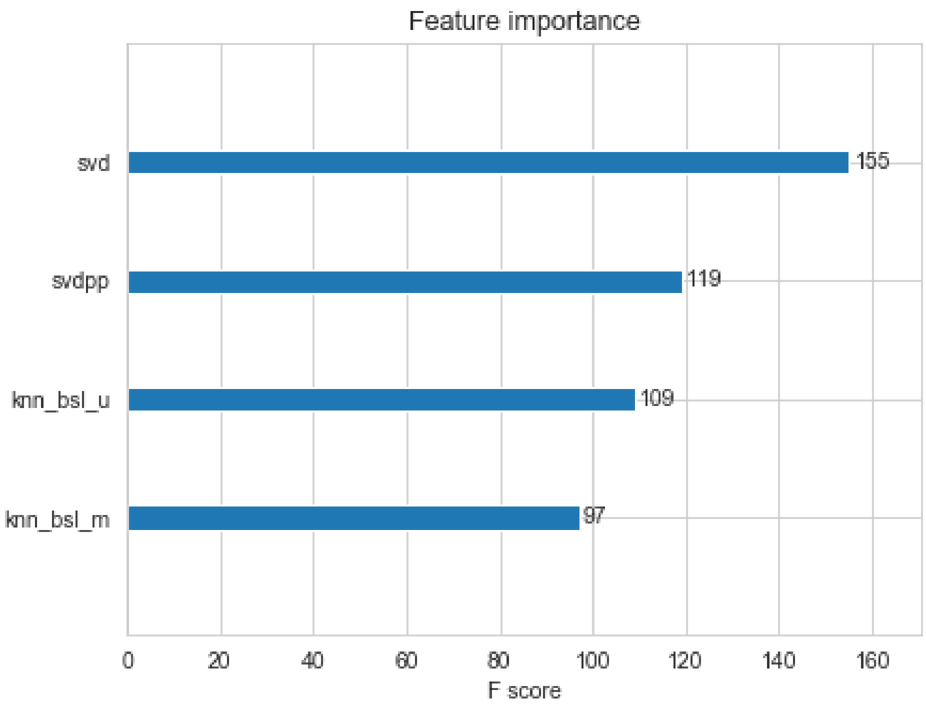
```
XGBRegressor(base_score=0.5, booster='gbtree', colsample_bylevel=1,
```

```
       colsample_bytree=1, gamma=0, learning_rate=0.1, max_delta_step=0,
       max_depth=3, min_child_weight=1, missing=None, n_estimators=70,
       n_jobs=13, nthread=None, objective='reg:linear', random_state=15,
       reg_alpha=0, reg_lambda=1, scale_pos_weight=1, seed=None, silent=1,
       subsample=1)
```

In [167]:

```
xgb_all_models = xgb.XGBRegressor(base_score=0.5, booster='gbtree', colsample_bylevel=1,
       colsample_bytree=1, gamma=0, learning_rate=0.1, max_delta_step=0,
       max_depth=3, min_child_weight=1, missing=None, n_estimators=70,
       n_jobs=13, nthread=None, objective='reg:linear', random_state=15,
       reg_alpha=0, reg_lambda=1, scale_pos_weight=1, seed=None, silent=1,
       subsample=1)
train_results, test_results = run_xgboost(xgb_all_models, x_train, y_train, x_test, y_test)

# store the results in models_evaluations dictionaries
models_evaluation_train['xgb_all_models'] = train_results
models_evaluation_test['xgb_all_models'] = test_results

xgb.plot_importance(xgb_all_models)
plt.show()
```

```
Training the model..
Done. Time taken : 0:00:04.642514

Done

Evaluating the model with TRAIN data...
Evaluating Test data

TEST DATA
------------------------------
RMSE :  1.0920848003234473
MAPE :  36.24175671847023
```



4.5 Comparision between all models

In [169]:

```python
# Saving our TEST_RESULTS into a dataframe so that you don't have to run it again
pd.DataFrame(models_evaluation_test).to_csv('small_sample_results.csv')
models = pd.read_csv('small_sample_results.csv', index_col=0)
models.loc['rmse'].sort_values()
```

Out[169]:

```
svd                1.0895575335859022
svdpp               1.089607032933482
knn_bsl_m           1.089638713949878
knn_bsl_u          1.0896400011629415
bsl_algo            1.089987756601425
xgb_all_models     1.0920848003234473
xgb_final           1.094091656041009
xgb_knn_bsl         1.094164865102673
first_algo           1.09487048205718
xgb_bsl            1.0952571679216956
Name: rmse, dtype: object
```

5. Conclusion

1)Merging all text files into a single csv file (data.csv) 2)Sorting the dataframe by date column and removing any duplicate and Nan values if present. 3)Splitting the data into train and test data and performing Exploratory Data Analysis on it. The various steps are shown below: 3.1 Finding no.of users, ratings and movies in train and test data 3.2 Distribution of ratings (0-5), Ratings per month, Max no. of ratings given by each user, quantiles of the ratings given, max no. of ratings given for a movie across all users etc. 4)Creating sparse matrix from train and test data and analysing the sparsity. 5)Finding Global average of all movie ratings, Average rating per user, and Average rating per movie and Analysing the cold start problem in Users and Movies (No. of users or movies that didn't appear in train data.) 6)Compute User-User Similarity matrix and Movie-Movie similarity matrix. 7)Getting sample sparse matrices from train and test data. 8)Featurizing the data by selecting the top 5 ratings given by similar users to a particular user and also top 5 ratings given to similar movies with respect to particular movie. 9)Run XGBoost on the 13 features that are obtained. 10)Run Surprise Baseline only model on train and test data and combine the train and test results with the 13 features and run XGBoost again on top of it. 11)Run Surprise KNNBaseline only model on train and test data and combine the train and test results with the 13 features,Baseline only model features and run XGBoost again on top of it. 12)Run Surprise SVD and SVD++ matrix factorization models on train and test data and combine the train and test results with the 13) features,Baseline only model, KNN Baseline model features and run XGBoost again on top of it. 14)Hyperparameter tune the above XGBoost models using GridSearch CV and plot the feature importance of each model. 15)Comparing all the models that are obtained. I have done this with 15000 x 1000 train data and 7500 of test data as 25k x 5k is taking nearly 80 hours to run.. Thanks