Netflix_Movie_Recommendation_NN

December 12, 2022

[1]:
```
from google.colab import drive
```

[2]:
```
drive.mount('/content/drive/')
```

```
Drive already mounted at /content/drive/; to attempt to forcibly remount, call
drive.mount("/content/drive/", force_remount=True).
```

[3]:
```
!ln -s /content/gdrive/MyDrive/ /mydrive
!ls /mydrive
```

```
ln: failed to create symbolic link '/mydrive': File exists
/mydrive
```

[4]:
```
!ls
```

```
drive  sample_data
```

[5]:
```
%cd ..
```

```
/
```

[6]:
```
!ls
```

```
bin      dev   lib32  mydrive                   python-apt  srv    usr
boot     etc   lib64  NGC-DL-CONTAINER-LICENSE  root        sys    var
content  home  media  opt                       run         tmp
datalab  lib   mnt    proc                      sbin        tools
```

[7]:
```
%cd content/drive/MyDrive/Colab Notebooks/Netflix_Movie_Recommendation
```

```
/content/drive/MyDrive/Colab Notebooks/Netflix_Movie_Recommendation
```

[8]:
```
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 scipy.linalg import sqrtm

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

[ ]:
```
!ls
```

[ ]:
```
!unzip data_folder/archive.zip
```

```
Archive:  data_folder/archive.zip
  inflating: README
  inflating: combined_data_1.txt
  inflating: combined_data_2.txt
  inflating: combined_data_3.txt
  inflating: combined_data_4.txt
  inflating: movie_titles.csv
  inflating: probe.txt
  inflating: qualifying.txt
```

[ ]:
```
start = datetime.now()
if not os.path.isfile('data.csv'):
    # Creating 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=['data_folder/combined_data_1.txt','data_folder/combined_data_2.txt',
           'data_folder/combined_data_3.txt', 'data_folder/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[:] # We might not 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)
```

```
Time taken : 0:00:00.000698
```

[10]:
```
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)
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..
```

[ ]:
```
df['user'].describe()
```

[ ]:
```
count    1.004805e+08
mean     1.322489e+06
std      7.645368e+05
min      6.000000e+00
25%      6.611980e+05
50%      1.319012e+06
75%      1.984455e+06
max      2.649429e+06
Name: user, dtype: float64
```

[13]:
```
len(df2)
```

[13]: 364225

Spliting data into Train and Test(80:20)

[ ]:
```
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")
```

[ ]:
```
len(train_df2)
```

[ ]: 100480507

[35]:
```
from collections import defaultdict
import json
def create_movie_user_dict_train(df):

    if not os.path.isfile('movie_user_train.json'):
        movie_user = defaultdict(list)
        # count=0
        for iter, row in df.iterrows():
            # count+=1
            # if count%10000==0:
            #   print(count)
            movie_user[row[0]].append(row[1])
        my_json = json.dumps(movie_user)
        f = open("movie_user_train.json","w")
        f.write(my_json)
        f.close()
    else:
        print("opening json file")
        with open('movie_user_train.json') as json_file:
          movie_user = json.load(json_file)
    print('movie_user_train.json loaded')
    return movie_user

def create_user_movie_dict_train(df):

    if not os.path.isfile('user_movie_train.json'):
```

```
        user_movie = defaultdict(list)
        for iter, row in df.iterrows():
            user_movie[row[1]].append(row[0])
        my_json = json.dumps(user_movie)
        f = open("user_movie_train.json","w")
        f.write(my_json)
        f.close()
    else:
        print("opening json file")
        with open('user_movie_train.json') as json_file:
          user_movie = json.load(json_file)
    print('user_movie_train.json loaded')
    return user_movie

def create_movie_user_dict_test(df):

    if not os.path.isfile('movie_user_test.json'):
        movie_user = defaultdict(list)
        for iter, row in df.iterrows():
            movie_user[row[0]].append(row[1])
        my_json = json.dumps(movie_user)
        f = open("movie_user_test.json","w")
        f.write(my_json)
        f.close()
    else:
        print("opening json file")
        with open('movie_user_test.json') as json_file:
          movie_user = json.load(json_file)
    print('movie_user_test.json loaded')
    return movie_user

def create_user_movie_dict_test(df):

    if not os.path.isfile('user_movie_test.json'):
        user_movie = defaultdict(list)
        for iter, row in df.iterrows():
            user_movie[row[1]].append(row[0])
        my_json = json.dumps(user_movie)
        f = open("user_movie_test.json","w")
        f.write(my_json)
        f.close()
    else:
        print("opening json file")
        with open('user_movie_test.json') as json_file:
          user_movie = json.load(json_file)
    print('user_movie_test.json loaded')
    return user_movie
```

[33]:
```
import gc
gc.collect()
```

[33]: 31

[36]:
```
movie_user_train = create_movie_user_dict_train(train_df)
gc.collect()
```

```
movie_user_train.json loaded
```

[36]: 0

[37]:
```
movie_user_train['10341']
```

[37]: []

[38]:
```
user_movie_train = create_user_movie_dict_train(train_df)
gc.collect()
```

```
user_movie_train.json loaded
```

[38]: 0

[39]:
```
movie_user_test = create_movie_user_dict_test(test_df)
gc.collect()
```

```
movie_user_test.json loaded
```

[39]: 0

[40]:
```
user_movie_test = create_user_movie_dict_test(test_df)
gc.collect()
```

```
user_movie_test.json loaded
```

[40]: 0

[ ]:
```
df.head()
```

[ ]:

	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

[ ]:
```
result_comparision={'HR':[],'NDCG':[]}
```

[ ]:
```
train_df.head()
```

[ ]:
```
   movie    user  rating       date
0  10341  510180       4 1999-11-11
1   1798  510180       5 1999-11-11
2  10774  510180       3 1999-11-11
3   8651  510180       2 1999-11-11
4  14660  510180       2 1999-11-11
```

[75]:
```
from random import shuffle
import warnings
warnings.simplefilter('error', RuntimeWarning)
class SVD:
    def __init__(self,movie_user,user_movie,K=30):
        self.movie_user=movie_user
        self.user_movie=user_movie
        self.K=K
        self.bi={}
        self.bu={}
        self.qi={}
        self.pu={}
        for user_id in list(user_movie.keys()):
            uid=user_id
            self.bu.setdefault(uid,0)
            self.pu.setdefault(uid,np.random.random((self.K,1))/10*np.sqrt(self.
↪K))
        for movie_id in list(movie_user.keys()):
            iid=movie_id
            self.bi.setdefault(iid,0)
            self.qi.setdefault(iid,np.random.random((self.K,1))/10*np.sqrt(self.
↪K))

    def Sort_Tuple(self,tup,n): #sort according to n+1 th item, the scores␣
↪calculated
        tup.sort(key = lambda x: x[n], reverse=True)
        return tup

    def predict(self,uid,iid):  #
        #setdefault            bi,bu,qi,pu    0
        self.bi.setdefault(iid,0)
        self.bu.setdefault(uid,0)
        self.qi.setdefault(iid,np.zeros((self.K,1)))
        self.pu.setdefault(uid,np.zeros((self.K,1)))
        rating=self.bi[iid]+self.bu[uid]+np.sum(self.qi[iid]*self.pu[uid]) #  ␣
↪
        return 1/(1 + np.exp(-rating))
```

```
   def train(self,user_movie,movie_user,steps=20,gamma=0.01,Lambda=0.03): ␣
↪#   step
       num_user=len(list(user_movie.keys()))
       for step in range(steps):
           print('step',step+1,'is running')
           users_random=np.random.permutation(list(user_movie.keys()))␣
↪#     kk user_movie keys
           movies=list(movie_user.keys())
           HR_num=0
           NDCG_total=0
           for user_id in users_random:
             uid=user_id
             movie_list=[]
             watched_list=user_movie[uid].copy()
             watched_list=[str(i) for i in watched_list]
             the_one=watched_list.pop()
             unwatched_list=[]
             count=0
             while(count<100):
               selection=random.choice(movies)
               if selection in watched_list:
                 continue
               else:
                 unwatched_list.append(selection)
                 count+=1
             for movie in watched_list:
               movie_list.append((movie,1))
             for movie in unwatched_list:
               movie_list.append((movie,0))
             shuffle(movie_list)
             # print(movie_list)
             # print(" ")
             movie_list_new=[]
             for movie_rating in movie_list:
               iid=movie_rating[0]
               rating=movie_rating[1]
               y_proba=self.predict(uid, iid)
               movie_list_new.append((iid,rating,y_proba))
               eui=rating-y_proba
               self.bu[uid]+=gamma*(eui-Lambda*self.bu[uid])
               self.bi[iid]+=gamma*(eui-Lambda*self.bi[iid])
               tmp=self.qi[iid]
               self.qi[iid]+=gamma*(eui*self.pu[uid]-Lambda*self.qi[iid])
               self.pu[uid]+=gamma*(eui*tmp-Lambda*self.pu[uid])

             sorted_IDCG=movie_list_new.copy()
             self.Sort_Tuple(sorted_IDCG,1)
```

```
            sorted_DCG=movie_list_new.copy()
            self.Sort_Tuple(sorted_DCG,2)
            # print(user_id)
            # print(sorted_IDCG)
            # print(sorted_DCG)
            the_one_score=self.predict(uid, the_one)
            # print(the_one_score)
            if the_one_score>sorted_DCG[9][2]:
              HR_num+=1
              DCG=0
              IDCG=0
              for i in range(10):
                IDCG+=sorted_IDCG[i][1]/np.log(i+2)
              for i in range(10):
                DCG+=sorted_DCG[i][1]/np.log(i+2)
              if IDCG==0:
                NDCG_total+=0
              else:
                NDCG_total+=DCG/IDCG
            # print(HR_num)
            # print(DCG)
            # print(IDCG)
          gamma=0.93*gamma  #gamma 0.93
          HR=HR_num/num_user
          NDCG=NDCG_total/num_user
          print('HR is {0:3f}, NDCG is {1:3f}'.format(HR, NDCG))

  def test(self,user_movie,movie_user):
      HR_num=0
      NDCG_total=0
      num_user=len(list(user_movie.keys()))
      movies=list(movie_user.keys())
      for user_id in user_movie.keys():
        uid=user_id
        movie_list=[]
        watched_list=[]
        watched_list=user_movie[uid].copy()
        watched_list=[str(i) for i in watched_list]
        the_one=watched_list.pop()
        unwatched_list=[]
        count=0
        while(count<100):
          selection=random.choice(movies)
          if selection in watched_list:
            continue
          else:
            unwatched_list.append(selection)
```

```
            count+=1
          for movie in watched_list:
            movie_list.append((movie,1))
          for movie in unwatched_list:
            movie_list.append((movie,0))
          shuffle(movie_list)
          movie_list_new=[]
          for movie_rating in movie_list:
              iid=movie_rating[0]
              y_proba=self.predict(uid, iid)
              rating=movie_rating[1]
              movie_list_new.append((iid,rating,y_proba))

          sorted_IDCG=movie_list_new.copy()
          self.Sort_Tuple(sorted_IDCG,1)
          sorted_DCG=movie_list_new.copy()
          self.Sort_Tuple(sorted_DCG,2)
          the_one_score=self.predict(uid, the_one)
          if the_one_score>sorted_DCG[9][2]:
            HR_num+=1
            DCG=0
            IDCG=0
            for i in range(10):
              IDCG+=sorted_IDCG[i][1]/np.log(i+2)
            for i in range(10):
              DCG+=sorted_DCG[i][1]/np.log(i+2)
            if IDCG==0:
              NDCG_total+=0
            else:
              NDCG_total+=DCG/IDCG

        HR=HR_num/num_user
        NDCG=NDCG_total/num_user
        print(" ")
        print('HR is {0:3f}, NDCG is {1:3f}'.format(HR, NDCG))

if __name__=='__main__':

    b1=SVD(movie_user_train,user_movie_train,30)
    b1.train(user_movie_train,movie_user_train)
    b1.test(user_movie_test,movie_user_test)
```

```
step 1 is running
HR is 0.000000, NDCG is 0.000000
step 2 is running
HR is 0.006329, NDCG is 0.006329
step 3 is running
```

```
HR is 0.145570, NDCG is 0.142549
step 4 is running
HR is 0.177215, NDCG is 0.164557
step 5 is running
HR is 0.189873, NDCG is 0.177215
step 6 is running
HR is 0.177215, NDCG is 0.164557
step 7 is running
HR is 0.177215, NDCG is 0.164557
step 8 is running
HR is 0.177215, NDCG is 0.164557
step 9 is running
HR is 0.189873, NDCG is 0.177215
step 10 is running
HR is 0.183544, NDCG is 0.170886
step 11 is running
HR is 0.177215, NDCG is 0.164557
step 12 is running
HR is 0.177215, NDCG is 0.164557
step 13 is running
HR is 0.170886, NDCG is 0.158228
step 14 is running
HR is 0.177215, NDCG is 0.164557
step 15 is running
HR is 0.183544, NDCG is 0.170886
step 16 is running
HR is 0.183544, NDCG is 0.170886
step 17 is running
HR is 0.183544, NDCG is 0.170886
step 18 is running
HR is 0.183544, NDCG is 0.170886
step 19 is running
HR is 0.183544, NDCG is 0.170886
step 20 is running
HR is 0.177215, NDCG is 0.164557

HR is 0.345865, NDCG is 0.252831
```

[77]:
```python
from random import shuffle
import warnings
warnings.simplefilter('error', RuntimeWarning)
class SVD:
    def __init__(self,movie_user,user_movie,K=16):
        self.movie_user=movie_user
        self.user_movie=user_movie
        self.K=K
        self.bi={}
```

```
        self.bu={}
        self.qi={}
        self.pu={}
        for user_id in list(user_movie.keys()):
            uid=user_id
            self.bu.setdefault(uid,0)
            self.pu.setdefault(uid,np.random.random((self.K,1))/10*np.sqrt(self.
↪K))
        for movie_id in list(movie_user.keys()):
            iid=movie_id
            self.bi.setdefault(iid,0)
            self.qi.setdefault(iid,np.random.random((self.K,1))/10*np.sqrt(self.
↪K))

    def Sort_Tuple(self,tup,n): #sort according to n+1 th item, the scores␣
↪calculated
        tup.sort(key = lambda x: x[n], reverse=True)
        return tup

    def predict(self,uid,iid):  #
        #setdefault            bi,bu,qi,pu    0
        self.bi.setdefault(iid,0)
        self.bu.setdefault(uid,0)
        self.qi.setdefault(iid,np.zeros((self.K,1)))
        self.pu.setdefault(uid,np.zeros((self.K,1)))
        rating=self.bi[iid]+self.bu[uid]+np.sum(self.qi[iid]*self.pu[uid]) #   ␣
↪
        return 1/(1 + np.exp(-rating))

    def train(self,user_movie,movie_user,steps=20,gamma=0.01,Lambda=0.03): ␣
↪#   step
        num_user=len(list(user_movie.keys()))
        for step in range(steps):
            print('step',step+1,'is running')
            users_random=np.random.permutation(list(user_movie.keys()))␣
↪#     kk user_movie keys
            movies=list(movie_user.keys())
            HR_num=0
            NDCG_total=0
            for user_id in users_random:
              uid=user_id
              movie_list=[]
              watched_list=user_movie[uid].copy()
              watched_list=[str(i) for i in watched_list]
              the_one=watched_list.pop()
              unwatched_list=[]
```

```
            count=0
            while(count<100):
              selection=random.choice(movies)
              if selection in watched_list:
                continue
              else:
                unwatched_list.append(selection)
                count+=1
            for movie in watched_list:
              movie_list.append((movie,1))
            for movie in unwatched_list:
              movie_list.append((movie,0))
            shuffle(movie_list)
            # print(movie_list)
            # print(" ")
            movie_list_new=[]
            for movie_rating in movie_list:
              iid=movie_rating[0]
              rating=movie_rating[1]
              y_proba=self.predict(uid, iid)
              movie_list_new.append((iid,rating,y_proba))
              eui=rating-y_proba
              self.bu[uid]+=gamma*(eui-Lambda*self.bu[uid])
              self.bi[iid]+=gamma*(eui-Lambda*self.bi[iid])
              tmp=self.qi[iid]
              self.qi[iid]+=gamma*(eui*self.pu[uid]-Lambda*self.qi[iid])
              self.pu[uid]+=gamma*(eui*tmp-Lambda*self.pu[uid])

            sorted_IDCG=movie_list_new.copy()
            self.Sort_Tuple(sorted_IDCG,1)
            sorted_DCG=movie_list_new.copy()
            self.Sort_Tuple(sorted_DCG,2)
            # print(user_id)
            # print(sorted_IDCG)
            # print(sorted_DCG)
            the_one_score=self.predict(uid, the_one)
            # print(the_one_score)
            if the_one_score>sorted_DCG[9][2]:
              HR_num+=1
              DCG=0
              IDCG=0
              for i in range(10):
                IDCG+=sorted_IDCG[i][1]/np.log(i+2)
              for i in range(10):
                DCG+=sorted_DCG[i][1]/np.log(i+2)
              if IDCG==0:
                NDCG_total+=0
```

```
                else:
                  NDCG_total+=DCG/IDCG
                # print(HR_num)
                # print(DCG)
                # print(IDCG)
            gamma=0.93*gamma  #gamma 0.93
            HR=HR_num/num_user
            NDCG=NDCG_total/num_user
            print('HR is {0:3f}, NDCG is {1:3f}'.format(HR, NDCG))

    def test(self,user_movie,movie_user):
        HR_num=0
        NDCG_total=0
        num_user=len(list(user_movie.keys()))
        movies=list(movie_user.keys())
        for user_id in user_movie.keys():
          uid=user_id
          movie_list=[]
          watched_list=[]
          watched_list=user_movie[uid].copy()
          watched_list=[str(i) for i in watched_list]
          the_one=watched_list.pop()
          unwatched_list=[]
          count=0
          while(count<100):
            selection=random.choice(movies)
            if selection in watched_list:
              continue
            else:
              unwatched_list.append(selection)
              count+=1
          for movie in watched_list:
            movie_list.append((movie,1))
          for movie in unwatched_list:
            movie_list.append((movie,0))
          shuffle(movie_list)
          movie_list_new=[]
          for movie_rating in movie_list:
              iid=movie_rating[0]
              y_proba=self.predict(uid, iid)
              rating=movie_rating[1]
              movie_list_new.append((iid,rating,y_proba))

          sorted_IDCG=movie_list_new.copy()
          self.Sort_Tuple(sorted_IDCG,1)
          sorted_DCG=movie_list_new.copy()
          self.Sort_Tuple(sorted_DCG,2)
```

```
            the_one_score=self.predict(uid, the_one)
            if the_one_score>sorted_DCG[9][2]:
              HR_num+=1
              DCG=0
              IDCG=0
              for i in range(10):
                IDCG+=sorted_IDCG[i][1]/np.log(i+2)
              for i in range(10):
                DCG+=sorted_DCG[i][1]/np.log(i+2)
              if IDCG==0:
                NDCG_total+=0
              else:
                NDCG_total+=DCG/IDCG

          HR=HR_num/num_user
          NDCG=NDCG_total/num_user
          print(" ")
          print('HR is {0:3f}, NDCG is {1:3f}'.format(HR, NDCG))

if __name__=='__main__':

    b1=SVD(movie_user_train,user_movie_train,30)
    b1.train(user_movie_train,movie_user_train)
    b1.test(user_movie_test,movie_user_test)
```

```
step 1 is running
HR is 0.000000, NDCG is 0.000000
step 2 is running
HR is 0.012658, NDCG is 0.010846
step 3 is running
HR is 0.151899, NDCG is 0.133600
step 4 is running
HR is 0.196203, NDCG is 0.183544
step 5 is running
HR is 0.177215, NDCG is 0.164557
step 6 is running
HR is 0.183544, NDCG is 0.170886
step 7 is running
HR is 0.177215, NDCG is 0.164557
step 8 is running
HR is 0.177215, NDCG is 0.164557
step 9 is running
HR is 0.177215, NDCG is 0.164557
step 10 is running
HR is 0.177215, NDCG is 0.164557
step 11 is running
HR is 0.177215, NDCG is 0.164557
```

```
step 12 is running
HR is 0.177215, NDCG is 0.164557
step 13 is running
HR is 0.170886, NDCG is 0.158228
step 14 is running
HR is 0.170886, NDCG is 0.158228
step 15 is running
HR is 0.170886, NDCG is 0.158228
step 16 is running
HR is 0.170886, NDCG is 0.158228
step 17 is running
HR is 0.170886, NDCG is 0.158228
step 18 is running
HR is 0.170886, NDCG is 0.158228
step 19 is running
HR is 0.170886, NDCG is 0.158228
step 20 is running
HR is 0.170886, NDCG is 0.158228

HR is 0.345865, NDCG is 0.258432
```

1 GMF

[ ]:

[89]:
```
from random import shuffle
import warnings
# warnings.simplefilter('error', RuntimeWarning)
warnings.simplefilter('ignore')
class GMF:
    def __init__(self,movie_user,user_movie,K=30):
        self.movie_user=movie_user
        self.user_movie=user_movie
        self.K=K
        self.qi={}
        self.pu={}
        self.W1={}
        for user_id in list(user_movie.keys()):
            uid=user_id
            self.W1.setdefault(uid,np.random.random((self.K,1))/10*np.sqrt(self.
 ↪K))
            self.pu.setdefault(uid,np.random.random((self.K,1))/10*np.sqrt(self.
 ↪K))
        for movie_id in list(movie_user.keys()):
            iid=movie_id
```

```
            self.qi.setdefault(iid,np.random.random((self.K,1))/10*np.sqrt(self.
↪K))

    def Sort_Tuple(self,tup,n): #sort according to n+1 th item, the scores␣
↪calculated
        tup.sort(key = lambda x: x[n], reverse=True)
        return tup

    def predict(self,uid,iid):  #
        #setdefault            bi,bu,qi,pu    0
        self.W1.setdefault(uid,np.zeros((self.K,1)))
        self.qi.setdefault(iid,np.zeros((self.K,1)))
        self.pu.setdefault(uid,np.zeros((self.K,1)))
        rating=np.sum(self.qi[iid]*self.pu[uid]*self.W1[uid]) #
        return 1/(1 + np.exp(-rating))

    def train(self,user_movie,movie_user,steps=20,gamma=0.01,Lambda=0.02): ␣
↪#   step
        num_user=len(list(user_movie.keys()))
        for step in range(steps):
            print('step',step+1,'is running')
            users_random=np.random.permutation(list(user_movie.keys()))␣
↪#     kk user_movie keys
            movies=list(movie_user.keys())
            HR_num=0
            NDCG_total=0
            for user_id in users_random:
              uid=user_id
              movie_list=[]
              watched_list=user_movie[uid].copy()
              watched_list=[str(i) for i in watched_list]
              the_one=watched_list.pop()
              unwatched_list=[]
              count=0
              while(count<100):
                selection=random.choice(movies)
                if selection in watched_list:
                  continue
                else:
                  unwatched_list.append(selection)
                  count+=1
              for movie in watched_list:
                movie_list.append((movie,1))
              for movie in unwatched_list:
                movie_list.append((movie,0))
              shuffle(movie_list)
              # print(movie_list)
```

```
            # print(" ")
            movie_list_new=[]
            for movie_rating in movie_list:
              iid=movie_rating[0]
              rating=movie_rating[1]
              y_proba=self.predict(uid, iid)
              movie_list_new.append((iid,rating,y_proba))
              eui=rating-y_proba

              tmp=self.qi[iid]
              tmp1=self.W1[uid]
              self.qi[iid]+=gamma*(eui*self.pu[uid]-Lambda*self.qi[iid])
              self.pu[uid]+=gamma*(eui*tmp-Lambda*self.pu[uid])
              self.W1[uid]+=gamma*(eui*tmp1-Lambda*self.W1[uid])
            sorted_IDCG=movie_list_new.copy()
            self.Sort_Tuple(sorted_IDCG,1)
            sorted_DCG=movie_list_new.copy()
            self.Sort_Tuple(sorted_DCG,2)
            # print(user_id)
            # print(sorted_IDCG)
            # print(sorted_DCG)
            the_one_score=self.predict(uid, the_one)
            # print(the_one_score)
            if the_one_score>sorted_DCG[9][2]:
              HR_num+=1
              DCG=0
              IDCG=0
              for i in range(10):
                IDCG+=sorted_IDCG[i][1]/np.log(i+2)
              for i in range(10):
                DCG+=sorted_DCG[i][1]/np.log(i+2)
              if IDCG==0:
                NDCG_total+=0
              else:
                NDCG_total+=DCG/IDCG
              # print(HR_num)
              # print(DCG)
              # print(IDCG)
            # print(HR_num)
            # print(DCG)
            # print(IDCG)
          gamma=0.93*gamma  #gamma 0.93
          HR=HR_num/num_user
          NDCG=NDCG_total/num_user
          print('HR is {0:3f}, NDCG is {1:3f}'.format(HR, NDCG))

    def test(self,user_movie,movie_user):
```

```
        HR_num=0
        NDCG_total=0
        num_user=len(list(user_movie.keys()))
        movies=list(movie_user.keys())
        for user_id in user_movie.keys():
          uid=user_id
          movie_list=[]
          watched_list=[]
          watched_list=user_movie[uid].copy()
          watched_list=[str(i) for i in watched_list]
          the_one=watched_list.pop()
          unwatched_list=[]
          count=0
          while(count<100):
            selection=random.choice(movies)
            if selection in watched_list:
              continue
            else:
              unwatched_list.append(selection)
              count+=1
          for movie in watched_list:
            movie_list.append((movie,1))
          for movie in unwatched_list:
            movie_list.append((movie,0))
          shuffle(movie_list)
          movie_list_new=[]
          for movie_rating in movie_list:
              iid=movie_rating[0]
              rating=movie_rating[1]
              y_proba=self.predict(uid, iid)
              movie_list_new.append((iid,rating,y_proba))

          sorted_IDCG=movie_list_new.copy()
          self.Sort_Tuple(sorted_IDCG,1)
          sorted_DCG=movie_list_new.copy()
          self.Sort_Tuple(sorted_DCG,2)
          the_one_score=self.predict(uid, the_one)
          if the_one_score>sorted_DCG[9][2]:
            HR_num+=1
            DCG=0
            IDCG=0
            for i in range(10):
              IDCG+=sorted_IDCG[i][1]/np.log(i+2)
            for i in range(10):
              DCG+=sorted_DCG[i][1]/np.log(i+2)
            if IDCG==0:
              NDCG_total+=0
```

```
            else:
              NDCG_total+=DCG/IDCG
            # print(HR_num)
            # print(DCG)
            # print(IDCG)
        HR=HR_num/num_user
        NDCG=NDCG_total/num_user
        print('HR is {0:3f}, NDCG is {1:3f}'.format(HR, NDCG))

if __name__=='__main__':

    N1=GMF(movie_user_train,user_movie_train,30)
    N1.train(user_movie_train,movie_user_train)
    N1.test(user_movie_test,movie_user_test)
```

```
step 1 is running
HR is 0.000000, NDCG is 0.000000
step 2 is running
HR is 0.000000, NDCG is 0.000000
step 3 is running
HR is 0.113924, NDCG is 0.096536
step 4 is running
HR is 0.221519, NDCG is 0.208861
step 5 is running
HR is 0.177215, NDCG is 0.164557
step 6 is running
HR is 0.202532, NDCG is 0.189873
step 7 is running
HR is 0.183544, NDCG is 0.170886
step 8 is running
HR is 0.189873, NDCG is 0.177215
step 9 is running
HR is 0.183544, NDCG is 0.170886
step 10 is running
HR is 0.183544, NDCG is 0.170886
step 11 is running
HR is 0.177215, NDCG is 0.164557
step 12 is running
HR is 0.183544, NDCG is 0.170886
step 13 is running
HR is 0.183544, NDCG is 0.170886
step 14 is running
HR is 0.189873, NDCG is 0.177215
step 15 is running
HR is 0.158228, NDCG is 0.145570
step 16 is running
HR is 0.164557, NDCG is 0.151899
```

```
step 17 is running
HR is 0.170886, NDCG is 0.158228
step 18 is running
HR is 0.164557, NDCG is 0.151899
step 19 is running
HR is 0.164557, NDCG is 0.151899
step 20 is running
HR is 0.164557, NDCG is 0.151899
HR is 0.315789, NDCG is 0.241821
```

2 MLP

[115]:
```python
from random import shuffle
import warnings
# warnings.simplefilter('error', RuntimeWarning)
warnings.simplefilter('ignore')
class MLP:
    def __init__(self,movie_user,user_movie,K=16):
        self.movie_user=movie_user
        self.user_movie=user_movie
        self.K=K
        self.qi={}
        self.pu={}
        self.W1={}
        self.W2={}
        self.b1={}
        self.b2={}
        self.layer1={}
        self.output={}
        self.input={}
        for user_id in list(user_movie.keys()):
            uid=user_id
            self.W1.setdefault(uid,np.random.rand(self.K*2,4))
            self.W2.setdefault(uid,np.random.rand(4,1))
            self.layer1.setdefault(uid,np.random.rand(1,4))
            self.output.setdefault(uid,np.random.rand(1,1))
            self.b1.setdefault(uid,np.random.rand(1,4))
            self.b2.setdefault(uid,np.random.rand(1,1))
            self.pu.setdefault(uid,np.random.random((self.K,1))/10*np.sqrt(self.
 ↪K))
        for movie_id in list(movie_user.keys()):
            iid=movie_id

            self.qi.setdefault(iid,np.random.random((self.K,1))/10*np.sqrt(self.
 ↪K))
    def sigmoid(self,X):
```

```
    return 1/(1+np.exp(-X))

  def sigmoid_derivative(self,X):
    return 1/(1+np.exp(-X))*(1-1/(1+np.exp(-X)))

  def Sort_Tuple(self,tup,n): #sort according to n+1 th item, the scores␣
↪calculated
    tup.sort(key = lambda x: x[n], reverse=True)
    return tup

  def predict(self,uid,iid):  #
      #setdefault            bi,bu,qi,pu    0
      self.W1.setdefault(uid,np.random.rand(self.K*2,4))
      self.W2.setdefault(uid,np.random.rand(4,1))
      # self.layer1.setdefault(uid,np.random.rand(1,4))
      # self.output.setdefault(uid,np.random.rand(1,1))
      self.qi.setdefault(iid,np.zeros((self.K,1)))
      self.pu.setdefault(uid,np.zeros((self.K,1)))
      self.b1.setdefault(uid,np.random.rand(1,4))
      self.b2.setdefault(uid,np.random.rand(1,1))
      self.input[uid]=np.concatenate([self.pu[uid], self.qi[iid]])
      # print(self.input[uid])
      self.input[uid]=np.transpose(self.input[uid])
      # print(self.input[uid])
      # print(np.shape(self.input[uid]))
      # print(np.shape(self.W1[uid]))
      # print(np.dot(self.input[uid], self.W1[uid]))
      # print(self.b1[uid])
      self.layer1[uid] = self.sigmoid(np.dot(self.input[uid], self.
↪W1[uid])+self.b1[uid])
      self.output[uid] = self.sigmoid(np.dot(self.layer1[uid], self.
↪W2[uid])+self.b2[uid])
      y_proba=self.output[uid].flatten()
      y_proba=y_proba[0]
      return y_proba

  def train(self,user_movie,movie_user,steps=20,gamma=0.01,Lambda=0.02): ␣
↪#   step
      num_user=2*len(list(user_movie.keys()))
      for step in range(steps):
          print('step',step+1,'is running')
          users_random=np.random.permutation(list(user_movie.keys()))␣
↪#     kk user_movie keys
          movies=list(movie_user.keys())
          HR_num=0
          NDCG_total=0
          for user_id in users_random:
```

```
            uid=user_id
            movie_list=[]
            watched_list=user_movie[uid].copy()
            watched_list=[str(i) for i in watched_list]
            the_one=watched_list.pop()
            unwatched_list=[]
            count=0
            while(count<100):
              selection=random.choice(movies)
              if selection in watched_list:
                continue
              else:
                unwatched_list.append(selection)
                count+=1
            for movie in watched_list:
              movie_list.append((movie,1))
            for movie in unwatched_list:
              movie_list.append((movie,0))
            shuffle(movie_list)
            # print(movie_list)
            # print(" ")
            movie_list_new=[]
            for movie_rating in movie_list:
              iid=movie_rating[0]
              rating=movie_rating[1]
              y_proba=self.predict(uid, iid)

              movie_list_new.append((iid,rating,y_proba))
              eui=rating-y_proba
              d_W2 = np.dot(self.layer1[uid].T, (2*eui * self.
↪sigmoid_derivative(self.output[uid])))
              d_b2 = np.dot(1, (2*eui * self.sigmoid_derivative(self.
↪output[uid])))
              d_W1 = np.dot(self.input[uid].T,  (np.dot(2*eui * self.
↪sigmoid_derivative(self.output[uid]), self.W2[uid].T) * self.
↪sigmoid_derivative(self.layer1[uid])))
              d_b1 = np.dot(1,  (np.dot(2*eui * self.sigmoid_derivative(self.
↪output[uid]), self.W2[uid].T) * self.sigmoid_derivative(self.layer1[uid])))
              # update the weights with the derivative (slope) of the loss␣
↪function
              self.W1[uid] += d_W1
              self.W2[uid] += d_W2
              self.b1[uid] += d_b1
              self.b2[uid] += d_b2

            sorted_IDCG=movie_list_new.copy()
            self.Sort_Tuple(sorted_IDCG,1)
```

```
            sorted_DCG=movie_list_new.copy()
            self.Sort_Tuple(sorted_DCG,2)
            # print(user_id)
            #print(sorted_IDCG)
            # print(sorted_DCG)
            the_one_score=self.predict(uid, the_one)
            #print(the_one_score)
            if the_one_score>sorted_DCG[9][2]:
              HR_num+=1
              DCG=0
              IDCG=0
              for i in range(10):
                IDCG+=sorted_IDCG[i][1]/np.log(i+2)
              for i in range(10):
                DCG+=sorted_DCG[i][1]/np.log(i+2)
              if IDCG==0:
                NDCG_total+=0
              else:
                NDCG_total+=DCG/IDCG
          gamma=0.93*gamma  #gamma 0.93
          HR=HR_num/num_user
          NDCG=NDCG_total/num_user
          print('HR is {0:3f}, NDCG is {1:3f}'.format(HR, NDCG))

    def test(self,user_movie,movie_user):
        HR_num=0
        NDCG_total=0
        num_user=2*len(list(user_movie.keys()))
        movies=list(movie_user.keys())
        for user_id in user_movie.keys():
          uid=user_id
          movie_list=[]
          watched_list=[]
          watched_list=user_movie[uid].copy()
          watched_list=[str(i) for i in watched_list]
          the_one=watched_list.pop()
          unwatched_list=[]
          count=0
          while(count<100):
            selection=random.choice(movies)
            if selection in watched_list:
              continue
            else:
              unwatched_list.append(selection)
              count+=1
          for movie in watched_list:
            movie_list.append((movie,1))
```

```
            for movie in unwatched_list:
              movie_list.append((movie,0))
            shuffle(movie_list)
            movie_list_new=[]
            for movie_rating in movie_list:
                iid=movie_rating[0]
                rating=movie_rating[1]
                y_proba=self.predict(uid, iid)
                movie_list_new.append((iid,rating,y_proba))

            sorted_IDCG=movie_list_new.copy()
            self.Sort_Tuple(sorted_IDCG,1)
            #print(sorted_IDCG)
            sorted_DCG=movie_list_new.copy()
            self.Sort_Tuple(sorted_DCG,2)
            #print(sorted_DCG)
            the_one_score=self.predict(uid, the_one)
            #print(the_one_score)
            #print(sorted_DCG[9][2])
            if the_one_score>=sorted_DCG[9][2]:
              HR_num+=1
              DCG=0
              IDCG=0
              for i in range(10):
                IDCG+=sorted_IDCG[i][1]/np.log(i+2)
              for i in range(10):
                DCG+=sorted_DCG[i][1]/np.log(i+2)
              if IDCG==0:
                NDCG_total+=0
              else:
                NDCG_total+=DCG/IDCG
              #print(HR_num)

        HR=HR_num/num_user
        NDCG=NDCG_total/num_user
        print('HR is {0:3f}, NDCG is {1:3f}'.format(HR, NDCG))
if __name__=='__main__':

    N2=MLP(movie_user_train,user_movie_train,30)
    N2.train(user_movie_train,movie_user_train)
    N2.test(user_movie_test,movie_user_test)
```

```
step 1 is running
HR is 0.148734, NDCG is 0.107228
step 2 is running
HR is 0.322785, NDCG is 0.294731
step 3 is running
```

```
HR is 0.325949, NDCG is 0.320668
step 4 is running
HR is 0.325949, NDCG is 0.314544
step 5 is running
HR is 0.344937, NDCG is 0.344425
step 6 is running
HR is 0.300633, NDCG is 0.297468
step 7 is running
HR is 0.300633, NDCG is 0.298000
step 8 is running
HR is 0.281646, NDCG is 0.279596
step 9 is running
HR is 0.287975, NDCG is 0.285450
step 10 is running
HR is 0.291139, NDCG is 0.286255
step 11 is running
HR is 0.303797, NDCG is 0.302758
step 12 is running
HR is 0.275316, NDCG is 0.275316
step 13 is running
HR is 0.262658, NDCG is 0.261916
step 14 is running
HR is 0.306962, NDCG is 0.306962
step 15 is running
HR is 0.300633, NDCG is 0.300633
step 16 is running
HR is 0.322785, NDCG is 0.322785
step 17 is running
HR is 0.303797, NDCG is 0.303797
step 18 is running
HR is 0.281646, NDCG is 0.281646
step 19 is running
HR is 0.306962, NDCG is 0.303797
step 20 is running
HR is 0.322785, NDCG is 0.319620
HR is 0.417293, NDCG is 0.197008
```

3 Fusion of MLP and GMF

[111]:
```
from random import shuffle
import warnings
# warnings.simplefilter('error', RuntimeWarning)
warnings.simplefilter('ignore')
class Fusion:
    def __init__(self,movie_user,user_movie,K=16):
        self.movie_user=movie_user
```

```
        self.user_movie=user_movie
        self.K=K
        self.qi={}
        self.pu={}
        self.W1_G={}
        self.W1={}
        self.W2={}
        self.W3={}
        self.b1={}
        self.b2={}
        self.layer1={}
        self.output={}
        self.input={}
        for user_id in list(user_movie.keys()):
            uid=user_id
            self.W1.setdefault(uid,np.random.rand(self.K*2,4))
            self.W2.setdefault(uid,np.random.rand(34,1))

            self.layer1.setdefault(uid,np.random.rand(1,4))
            self.output.setdefault(uid,np.random.rand(1,1))
            self.b1.setdefault(uid,np.random.rand(1,4))
            self.b2.setdefault(uid,np.random.rand(1,1))
            self.pu.setdefault(uid,np.random.random((self.K,1))/10*np.sqrt(self.
↪K))
            self.W1_G.setdefault(uid,np.random.random((self.K,1))/10*np.
↪sqrt(self.K))
        for movie_id in list(movie_user.keys()):
            iid=movie_id

            self.qi.setdefault(iid,np.random.random((self.K,1))/10*np.sqrt(self.
↪K))
    def sigmoid(self,X):
      return 1/(1+np.exp(-X))

    def sigmoid_derivative(self,X):
      return 1/(1+np.exp(-X))*(1-1/(1+np.exp(-X)))

    def Sort_Tuple(self,tup,n): #sort according to n+1 th item, the scores␣
↪calculated
      tup.sort(key = lambda x: x[n], reverse=True)
      return tup



    def predict_MLP(self,uid,iid):  #
        #setdefault            bi,bu,qi,pu     0
        self.W1_G.setdefault(uid,np.zeros((self.K,1)))
```

```
        self.W1.setdefault(uid,np.random.rand(self.K*2,4))
        self.W2.setdefault(uid,np.random.rand(34,1))

        # self.layer1.setdefault(uid,np.random.rand(1,4))
        # self.output.setdefault(uid,np.random.rand(1,1))
        self.qi.setdefault(iid,np.zeros((self.K,1)))
        self.pu.setdefault(uid,np.zeros((self.K,1)))
        self.b1.setdefault(uid,np.random.rand(1,4))
        self.b2.setdefault(uid,np.random.rand(1,1))
        rating=self.qi[iid]*self.pu[uid]*self.W1_G[uid] #
        # print(rating)
        # print(" ")
        self.input[uid]=np.concatenate([self.pu[uid], self.qi[iid]])
        self.input[uid]=np.transpose(self.input[uid])
        # print(self.input[uid])
        # print(np.shape(self.sigmoid(np.dot(self.input[uid], self.
↪W1[uid])+self.b1[uid])))
        # np.concatenate([np.transpose(self.sigmoid(np.dot(self.input[uid],␣
↪self.W1[uid])+self.b1[uid])), rating])
        # print(np.shape(np.concatenate([np.transpose(self.sigmoid(np.dot(self.
↪input[uid], self.W1[uid])+self.b1[uid])), rating])))
        self.layer1[uid] = np.transpose(np.concatenate([np.transpose(self.
↪sigmoid(np.dot(self.input[uid], self.W1[uid])+self.b1[uid])), rating]))
        self.output[uid] = self.sigmoid(np.dot(self.layer1[uid], self.
↪W2[uid])+self.b2[uid])
        y_proba=self.output[uid].flatten()
        y_proba=y_proba[0]
        return y_proba

    def train(self,user_movie,movie_user,steps=20,gamma=0.01,Lambda=0.02): ␣
↪#   step
        num_user=len(list(user_movie.keys()))
        for step in range(steps):
            print('step',step+1,'is running')
            users_random=np.random.permutation(list(user_movie.keys()))␣
↪#     kk user_movie keys
            movies=list(movie_user.keys())
            HR_num=0
            NDCG_total=0
            for user_id in users_random:
              uid=user_id
              movie_list=[]
              watched_list=user_movie[uid].copy()
              watched_list=[str(i) for i in watched_list]
              the_one=watched_list.pop()
              unwatched_list=[]
```

```
            count=0
            while(count<100):
              selection=random.choice(movies)
              if selection in watched_list:
                continue
              else:
                unwatched_list.append(selection)
                count+=1
            for movie in watched_list:
              movie_list.append((movie,1))
            for movie in unwatched_list:
              movie_list.append((movie,0))
            shuffle(movie_list)
            # print(movie_list)
            # print(" ")
            movie_list_new=[]
            for movie_rating in movie_list:
              iid=movie_rating[0]
              rating=movie_rating[1]
              y_proba=self.predict_MLP(uid, iid)
              movie_list_new.append((iid,rating,y_proba))
              eui=rating-y_proba
              d_W2 = np.dot(self.layer1[uid].T, (2*eui * self.
↪sigmoid_derivative(self.output[uid])))
              d_b2 = np.dot(1, (2*eui * self.sigmoid_derivative(self.
↪output[uid])))
              d_W1 = np.dot(self.input[uid].T,  (np.dot(2*eui * self.
↪sigmoid_derivative(self.output[uid]), self.W2[uid].T) * self.
↪sigmoid_derivative(self.layer1[uid])))
              d_b1 = np.dot(1,  (np.dot(2*eui * self.sigmoid_derivative(self.
↪output[uid]), self.W2[uid].T) * self.sigmoid_derivative(self.layer1[uid])))
              # update the weights with the derivative (slope) of the loss
              # print(np.shape(d_b1))
              # print(np.shape(self.b1[uid]))
              self.W2[uid] += d_W2
              self.W1[uid] += d_W1[:,:4]
              self.b1[uid] += d_b1[:,:4]
              self.b2[uid] += d_b2
              tmp=self.qi[iid]
              self.qi[iid]+=gamma*(eui*self.pu[uid]-Lambda*self.qi[iid])
              self.pu[uid]+=gamma*(eui*tmp-Lambda*self.pu[uid])

            sorted_IDCG=movie_list_new.copy()
            self.Sort_Tuple(sorted_IDCG,1)
            sorted_DCG=movie_list_new.copy()
            self.Sort_Tuple(sorted_DCG,2)
            # print(user_id)
```

```
            # print(sorted_IDCG)
            # print(sorted_DCG)
            the_one_score=self.predict_MLP(uid, the_one)
            if the_one_score>sorted_DCG[9][2]:
              HR_num+=1
              DCG=0
              IDCG=0
              for i in range(10):
                IDCG+=sorted_IDCG[i][1]/np.log(i+2)
              for i in range(10):
                DCG+=sorted_DCG[i][1]/np.log(i+2)
              if IDCG==0:
                NDCG_total+=0
              else:
                NDCG_total+=DCG/IDCG
                # print(HR_num)
                # print(DCG)
                # print(IDCG)
          gamma=0.93*gamma  #gamma 0.93
          HR=HR_num/num_user
          NDCG=NDCG_total/num_user
          print('HR is {0:3f}, NDCG is {1:3f}'.format(HR, NDCG))

    def test(self,user_movie,movie_user):
        HR_num=0
        NDCG_total=0
        num_user=len(list(user_movie.keys()))
        movies=list(movie_user.keys())
        for user_id in user_movie.keys():
          uid=user_id
          movie_list=[]
          watched_list=[]
          watched_list=user_movie[uid].copy()
          watched_list=[str(i) for i in watched_list]
          the_one=watched_list.pop()
          unwatched_list=[]
          count=0
          while(count<100):
            selection=random.choice(movies)
            if selection in watched_list:
              continue
            else:
              unwatched_list.append(selection)
              count+=1
          for movie in watched_list:
            movie_list.append((movie,1))
          for movie in unwatched_list:
```

```
            movie_list.append((movie,0))
        shuffle(movie_list)
        movie_list_new=[]
        for movie_rating in movie_list:
            iid=movie_rating[0]
            rating=movie_rating[1]
            y_proba=self.predict_MLP(uid, iid)
            movie_list_new.append((iid,rating,y_proba))

        sorted_IDCG=movie_list_new.copy()
        self.Sort_Tuple(sorted_IDCG,1)
        sorted_DCG=movie_list_new.copy()
        self.Sort_Tuple(sorted_DCG,2)
        the_one_score=self.predict_MLP(uid, the_one)
        if the_one_score>=sorted_DCG[9][2]:
          HR_num+=1
          DCG=0
          IDCG=0
          for i in range(10):
            IDCG+=sorted_IDCG[i][1]/np.log(i+2)
          for i in range(10):
            DCG+=sorted_DCG[i][1]/np.log(i+2)
          if IDCG==0:
            NDCG_total+=0
          else:
            NDCG_total+=DCG/IDCG

      HR=HR_num/num_user
      NDCG=NDCG_total/num_user
      print('HR is {0:3f}, NDCG is {1:3f}'.format(HR, NDCG))

if __name__=='__main__':

    N2=Fusion(movie_user_train,user_movie_train,30)
    N2.train(user_movie_train,movie_user_train)
    N2.test(user_movie_test,movie_user_test)
```

```
step 1 is running
HR is 0.322785, NDCG is 0.258835
step 2 is running
HR is 0.575949, NDCG is 0.542128
step 3 is running
HR is 0.512658, NDCG is 0.489348
step 4 is running
HR is 0.411392, NDCG is 0.379987
step 5 is running
HR is 0.398734, NDCG is 0.383699
```

```
step 6 is running
HR is 0.341772, NDCG is 0.335894
step 7 is running
HR is 0.322785, NDCG is 0.315951
step 8 is running
HR is 0.297468, NDCG is 0.285899
step 9 is running
HR is 0.310127, NDCG is 0.301772
step 10 is running
HR is 0.379747, NDCG is 0.367579
step 11 is running
HR is 0.335443, NDCG is 0.328433
step 12 is running
HR is 0.335443, NDCG is 0.326139
step 13 is running
HR is 0.272152, NDCG is 0.270180
step 14 is running
HR is 0.291139, NDCG is 0.281342
step 15 is running
HR is 0.278481, NDCG is 0.271262
step 16 is running
HR is 0.322785, NDCG is 0.313672
step 17 is running
HR is 0.316456, NDCG is 0.311880
step 18 is running
HR is 0.310127, NDCG is 0.304308
step 19 is running
HR is 0.310127, NDCG is 0.306209
step 20 is running
HR is 0.297468, NDCG is 0.291079
HR is 0.293233, NDCG is 0.080145
```

4 Referenced Models

[15]:
```
df2
```

[15]:

	movie	user	rating	date
100423292	17764	544	4	2000-03-06
84285351	15057	544	3	2000-03-06
55061261	10055	544	4	2000-03-06
15307250	2940	544	3	2000-03-06
23553419	4402	544	3	2000-03-06
…	…	…	…	…
67060193	12232	785	4	2005-12-30
56579332	10358	785	3	2005-12-30
71950173	13042	307	5	2005-12-30

```
23935492    4472   576       5 2005-12-30
27409107    5071   199       4 2005-12-31

[31321 rows x 4 columns]
```

[16]:
```
columns_titles = ["user","movie","rating","date"]
df2=df2.reindex(columns=columns_titles)
```

[18]:
```
df2
```

[18]:
```
           user  movie  rating       date
58827304   1086  10809       4 1999-12-31
4302414    1086    829       3 1999-12-31
3547033    1086    682       4 1999-12-31
57353601   1086  10451       5 1999-12-31
82743775   1086  14755       4 1999-12-31
…           …     …          …          …
14869543   3321   2864       2 2005-12-31
89325107   3321  15871       2 2005-12-31
96644421   7613  17149       2 2005-12-31
73703374   2693  13384       3 2005-12-31
53546256   3321   9745       2 2005-12-31

[364225 rows x 4 columns]
```

[17]:
```
df2.columns = ['user_id', 'item_id', 'rating', 'timestamp']
df2
```

[17]:
```
            user_id  item_id  rating  timestamp
100423292       544    17764       4 2000-03-06
84285351        544    15057       3 2000-03-06
55061261        544    10055       4 2000-03-06
15307250        544     2940       3 2000-03-06
23553419        544     4402       3 2000-03-06
…               …       …          …          …
67060193        785    12232       4 2005-12-30
56579332        785    10358       3 2005-12-30
71950173        307    13042       5 2005-12-30
23935492        576     4472       5 2005-12-30
27409107        199     5071       4 2005-12-31

[31321 rows x 4 columns]
```

[ ]:
```
# df = df.iloc[1: , :]
```

[18]:
```
!pip install tensorboardX
```

```
Looking in indexes: https://pypi.org/simple, https://us-python.pkg.dev/colab-
wheels/public/simple/
Requirement already satisfied: tensorboardX in /usr/local/lib/python3.8/dist-
packages (2.5.1)
Requirement already satisfied: protobuf<=3.20.1,>=3.8.0 in
/usr/local/lib/python3.8/dist-packages (from tensorboardX) (3.19.6)
Requirement already satisfied: numpy in /usr/local/lib/python3.8/dist-packages
(from tensorboardX) (1.21.6)
```

[23]:
```
import os
import time
import argparse
import pandas as pd
import numpy as np
import random
import torch
import torch.nn as nn
import torch.optim as optim
import torch.utils.data as data
from tensorboardX import SummaryWriter
```

[19]:
```
def seed_everything(seed):
    random.seed(seed)
    os.environ['PYTHONHASHSEED'] = str(seed)
    np.random.seed(seed)
    torch.manual_seed(seed)
    torch.cuda.manual_seed(seed)
    torch.backends.cudnn.deterministic = True
    torch.backends.cudnn.benchmark = True
```

[20]:
```
import gc
gc.collect()
```

[20]:
```
0
```

[ ]:
```
gc.collect()
```

[ ]:
```
53
```

[21]:
```
import random
import numpy as np
import pandas as pd
import torch

class NCF_Data(object):

  def __init__(self, args, ratings):
```

```
    self.ratings = ratings
    self.num_ng = args.num_ng
    self.num_ng_test = args.num_ng_test
    self.batch_size = args.batch_size
    print('hello')
    self.preprocess_ratings = self._reindex(self.ratings)
    gc.collect()
    self.user_pool = set(self.ratings['user_id'].unique())
    gc.collect()
    self.item_pool = set(self.ratings['item_id'].unique())
    gc.collect()
    self.train_ratings, self.test_ratings = self._leave_one_out(self.
↪preprocess_ratings)
    gc.collect()
    self.negatives = self._negative_sampling(self.preprocess_ratings)
    gc.collect()
    random.seed(args.seed)

  def _reindex(self, ratings):
    user_list = list(ratings['user_id'].drop_duplicates())
    user2id = {w: i for i, w in enumerate(user_list)}

    item_list = list(ratings['item_id'].drop_duplicates())
    item2id = {w: i for i, w in enumerate(item_list)}

    ratings['user_id'] = ratings['user_id'].apply(lambda x: user2id[x])
    ratings['item_id'] = ratings['item_id'].apply(lambda x: item2id[x])
    print()
    ratings['rating'] = ratings['rating'].apply(lambda x: float(x > 0))
    return ratings

  def _leave_one_out(self, ratings):
    """
    leave-one-out evaluation protocol in paper https://www.comp.nus.edu.sg/
↪~xiangnan/papers/ncf.pdf
    """
    ratings['rank_latest'] = ratings.groupby(['user_id'])['timestamp'].
↪rank(method='first', ascending=False)
    test = ratings.loc[ratings['rank_latest'] == 1]
    train = ratings.loc[ratings['rank_latest'] > 1]
    # assert train['user_id'].nunique()==test['user_id'].nunique(), 'Not Match␣
↪Train User with Test User'
    return train[['user_id', 'item_id', 'rating']], test[['user_id', 'item_id',␣
↪'rating']]


  def _negative_sampling(self, ratings):
```

```
    interact_status = (
      ratings.groupby('user_id')['item_id']
      .apply(set)
      .reset_index()
      .rename(columns={'item_id': 'interacted_items'}))

    interact_status['negative_samples']=''
    for iter, row in interact_status.iterrows():
      negative_items=self.item_pool-interact_status['interacted_items'][iter]
      interact_status['negative_samples'][iter]=random.sample(negative_items,␣
↪min(len(negative_items),self.num_ng_test))
      # interact_status['negative_items'] = interact_status['interacted_items'].
↪apply(lambda x: self.item_pool - x)
      # interact_status['negative_samples'] = interact_status['negative_items'].
↪apply(lambda x: random.sample(x, min(len(x),self.num_ng_test)))
      if iter%100000==0:
        print(iter)
        gc.collect()
    interact_status[['user_id', 'interacted_items', 'negative_samples']].
↪to_csv('interact_status.csv')
    return interact_status[['user_id', 'interacted_items', 'negative_samples']]

  def get_train_instance(self):

    users, items, ratings = [], [], []
    print('0')
    train_ratings = pd.merge(self.train_ratings, self.negatives[['user_id',␣
↪'interacted_items']], on='user_id')
    print('1')
    print(len(train_ratings))
    # train_ratings['negatives']=''
    # print('2')
    # for i in range(len(train_ratings)):
    #   for iter, row in train_ratings.iterrows():
    #     negative_items=self.item_pool-train_ratings['interacted_items'][iter]
    #     train_ratings['negatives'][iter]=random.sample(negative_items, 4)
    #     # print(iter)
    #     if iter%100000==0:

    #       gc.collect()
    # print('3')
    # print('1')
    train_ratings['negative_items'] = train_ratings['interacted_items'].
↪apply(lambda x: self.item_pool - x)
    print('2')
```

```
    train_ratings['negatives'] = train_ratings['negative_items'].apply(lambda x:
↪ random.sample(x, self.num_ng))
    print('3')
    for row in train_ratings.itertuples():
      users.append(int(row.user_id))
      items.append(int(row.item_id))
      ratings.append(float(row.rating))
      for i in range(self.num_ng):
        users.append(int(row.user_id))
        # print(row.negatives[i])
        items.append(int(row.negatives[i]))
        ratings.append(float(0))  # negative samples get 0 rating
    dataset = Rating_Datset(
      user_list=users,
      item_list=items,
      rating_list=ratings)
    return torch.utils.data.DataLoader(dataset, batch_size=self.batch_size,␣
↪shuffle=True, num_workers=4)


  def get_test_instance(self):
    users, items, ratings = [], [], []
    test_ratings = pd.merge(self.test_ratings, self.negatives[['user_id',␣
↪'negative_samples']], on='user_id')
    for row in test_ratings.itertuples():
      users.append(int(row.user_id))
      items.append(int(row.item_id))
      ratings.append(float(row.rating))
      for i in getattr(row, 'negative_samples'):
        users.append(int(row.user_id))
        items.append(int(i))
        ratings.append(float(0))
      gc.collect()
    dataset = Rating_Datset(
      user_list=users,
      item_list=items,
      rating_list=ratings)
    gc.collect()
    return torch.utils.data.DataLoader(dataset, batch_size=self.num_ng_test+1,␣
↪shuffle=False, num_workers=4)

class Rating_Datset(torch.utils.data.Dataset):
  def __init__(self, user_list, item_list, rating_list):
    super(Rating_Datset, self).__init__()
    self.user_list = user_list
    self.item_list = item_list
    self.rating_list = rating_list
```

```
  def __len__(self):
    return len(self.user_list)

  def __getitem__(self, idx):
    user = self.user_list[idx]
    item = self.item_list[idx]
    rating = self.rating_list[idx]

    return (
      torch.tensor(user, dtype=torch.long),
      torch.tensor(item, dtype=torch.long),
      torch.tensor(rating, dtype=torch.float)
      )
```

[24]:
```
parser = argparse.ArgumentParser()
parser.add_argument("--seed",
        type=int,
        default=42,
        help="Seed")
parser.add_argument("--lr",
        type=float,
        default=0.001,
        help="learning rate")
parser.add_argument("--dropout",
        type=float,
        default=0.2,
        help="dropout rate")
parser.add_argument("--batch_size",
        type=int,
        default=256,
        help="batch size for training")
parser.add_argument("--epochs",
        type=int,
        default=30,
        help="training epoches")
parser.add_argument("--top_k",
        type=int,
        default=10,
        help="compute metrics@top_k")
parser.add_argument("--factor_num",
        type=int,
        default=32,
        help="predictive factors numbers in the model")
parser.add_argument("--layers",
    nargs='+',
```

```
    default=[64,32,16,8],
    help="MLP layers. Note that the first layer is the concatenation of user␣
 ↪and item embeddings. So layers[0]/2 is the embedding size.")
parser.add_argument("--num_ng",
        type=int,
        default=4,
        help="Number of negative samples for training set")
parser.add_argument("--num_ng_test",
        type=int,
        default=100,
        help="Number of negative samples for test set")
parser.add_argument("--out",
        default=True,
        help="save model or not")

# set device and parameters
args,none = parser.parse_known_args()
device = torch.device("cuda:0" if torch.cuda.is_available() else "cpu")
writer = SummaryWriter()

# seed for Reproducibility
seed_everything(args.seed)
```

[25]:
```
# set the num_users, items
num_users = df2['user_id'].nunique()+1
num_items = df2['item_id'].nunique()+1

# construct the train and test datasets
data = NCF_Data(args, df2)
```

```
hello


<ipython-input-21-0af864947c4a>:60: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame

See the caveats in the documentation: https://pandas.pydata.org/pandas-
docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
  interact_status['negative_samples'][iter]=random.sample(negative_items,
min(len(negative_items),self.num_ng_test))

0
```

[26]:
```
train_loader =data.get_train_instance()
test_loader =data.get_test_instance()
```

```
0
1
```

```
31141
2
3
```

5 R1

[27]:
```
class Generalized_Matrix_Factorization(nn.Module):
    def __init__(self, args, num_users, num_items):
        super(Generalized_Matrix_Factorization, self).__init__()
        self.num_users = num_users
        self.num_items = num_items
        self.factor_num = args.factor_num

        self.embedding_user = nn.Embedding(num_embeddings=self.num_users,␣
↪embedding_dim=self.factor_num)
        self.embedding_item = nn.Embedding(num_embeddings=self.num_items,␣
↪embedding_dim=self.factor_num)

        self.affine_output = nn.Linear(in_features=self.factor_num,␣
↪out_features=1)
        self.logistic = nn.Sigmoid()

    def forward(self, user_indices, item_indices):
        user_embedding = self.embedding_user(user_indices)
        item_embedding = self.embedding_item(item_indices)
        element_product = torch.mul(user_embedding, item_embedding)
        logits = self.affine_output(element_product)
        rating = self.logistic(logits)
        return rating

    def init_weight(self):
        pass
```

[ ]:
```

```

6 R2

[28]:
```
class Multi_Layer_Perceptron(nn.Module):
    def __init__(self, args, num_users, num_items):
        super(Multi_Layer_Perceptron, self).__init__()
        self.num_users = num_users
        self.num_items = num_items
        self.factor_num = args.factor_num
        self.layers = args.layers
```

```
        self.embedding_user = nn.Embedding(num_embeddings=self.num_users,␣
↪embedding_dim=self.factor_num)
        self.embedding_item = nn.Embedding(num_embeddings=self.num_items,␣
↪embedding_dim=self.factor_num)

        self.fc_layers = nn.ModuleList()
        for idx, (in_size, out_size) in enumerate(zip(self.layers[:-1], self.
↪layers[1:])):
            self.fc_layers.append(nn.Linear(in_size, out_size))

        self.affine_output = nn.Linear(in_features=self.layers[-1],␣
↪out_features=1)
        self.logistic = nn.Sigmoid()

    def forward(self, user_indices, item_indices):
        user_embedding = self.embedding_user(user_indices)
        item_embedding = self.embedding_item(item_indices)
        vector = torch.cat([user_embedding, item_embedding], dim=-1)  # the␣
↪concat latent vector
        for idx, _ in enumerate(range(len(self.fc_layers))):
            vector = self.fc_layers[idx](vector)
            vector = nn.ReLU()(vector)
            # vector = nn.BatchNorm1d()(vector)
            # vector = nn.Dropout(p=0.5)(vector)
        logits = self.affine_output(vector)
        rating = self.logistic(logits)
        return rating

    def init_weight(self):
        pass
```

[ ]:

7 R3

[29]:
```
class NeuMF(nn.Module):
    def __init__(self, args, num_users, num_items):
        super(NeuMF, self).__init__()
        self.num_users = num_users
        self.num_items = num_items
        self.factor_num_mf = args.factor_num
        self.factor_num_mlp =  int(args.layers[0]/2)
        self.layers = args.layers
        self.dropout = args.dropout
```

```
        self.embedding_user_mlp = nn.Embedding(num_embeddings=self.num_users,␣
↪embedding_dim=self.factor_num_mlp)
        self.embedding_item_mlp = nn.Embedding(num_embeddings=self.num_items,␣
↪embedding_dim=self.factor_num_mlp)

        self.embedding_user_mf = nn.Embedding(num_embeddings=self.num_users,␣
↪embedding_dim=self.factor_num_mf)
        self.embedding_item_mf = nn.Embedding(num_embeddings=self.num_items,␣
↪embedding_dim=self.factor_num_mf)

        self.fc_layers = nn.ModuleList()
        for idx, (in_size, out_size) in enumerate(zip(args.layers[:-1], args.
↪layers[1:])):
            self.fc_layers.append(torch.nn.Linear(in_size, out_size))
            self.fc_layers.append(nn.ReLU())

        self.affine_output = nn.Linear(in_features=args.layers[-1] + self.
↪factor_num_mf, out_features=1)
        self.logistic = nn.Sigmoid()
        self.init_weight()

    def init_weight(self):
        nn.init.normal_(self.embedding_user_mlp.weight, std=0.01)
        nn.init.normal_(self.embedding_item_mlp.weight, std=0.01)
        nn.init.normal_(self.embedding_user_mf.weight, std=0.01)
        nn.init.normal_(self.embedding_item_mf.weight, std=0.01)

        for m in self.fc_layers:
            if isinstance(m, nn.Linear):
                nn.init.xavier_uniform_(m.weight)

        nn.init.xavier_uniform_(self.affine_output.weight)

        for m in self.modules():
            if isinstance(m, nn.Linear) and m.bias is not None:
                m.bias.data.zero_()

    def forward(self, user_indices, item_indices):
        user_embedding_mlp = self.embedding_user_mlp(user_indices)
        item_embedding_mlp = self.embedding_item_mlp(item_indices)

        user_embedding_mf = self.embedding_user_mf(user_indices)
        item_embedding_mf = self.embedding_item_mf(item_indices)
```

```
        mlp_vector = torch.cat([user_embedding_mlp, item_embedding_mlp],␣
↪dim=-1)  # the concat latent vector
        mf_vector =torch.mul(user_embedding_mf, item_embedding_mf)

        for idx, _ in enumerate(range(len(self.fc_layers))):
            mlp_vector = self.fc_layers[idx](mlp_vector)

        vector = torch.cat([mlp_vector, mf_vector], dim=-1)
        logits = self.affine_output(vector)
        rating = self.logistic(logits)
        return rating.squeeze()
```

[30]:
```
import numpy as np
import torch


def hit(ng_item, pred_items):
        if ng_item in pred_items:
                return 1
        return 0


def ndcg(ng_item, pred_items):
        if ng_item in pred_items:
                index = pred_items.index(ng_item)
                return np.reciprocal(np.log2(index+2))
        return 0


def metrics(model, test_loader, top_k, device):
        HR, NDCG = [], []

        for user, item, label in test_loader:
                user = user.to(device)
                item = item.to(device)

                predictions = model(user, item)
                _, indices = torch.topk(predictions, top_k)
                recommends = torch.take(
                                item, indices).cpu().numpy().tolist()

                ng_item = item[0].item() # leave one-out evaluation has only␣
↪one item per user
                HR.append(hit(ng_item, recommends))
                NDCG.append(ndcg(ng_item, recommends))

        return np.mean(HR), np.mean(NDCG)
```

[31]:
```
model = NeuMF(args, num_users, num_items)
model = model.to(device)
loss_function = nn.BCELoss()
optimizer = optim.Adam(model.parameters(), lr=args.lr)

# train, evaluation
best_hr = 0
for epoch in range(1, args.epochs+1):
        model.train() # Enable dropout (if have).
        start_time = time.time()

        for user, item, label in train_loader:
                user = user.to(device)
                item = item.to(device)
                label = label.to(device)

                optimizer.zero_grad()
                prediction = model(user, item)
                loss = loss_function(prediction, label)
                loss.backward()
                optimizer.step()
                writer.add_scalar('loss/Train_loss', loss.item(), epoch)

        model.eval()
        HR, NDCG = metrics(model, test_loader, args.top_k, device)
        writer.add_scalar('Perfomance/HR@10', HR, epoch)
        writer.add_scalar('Perfomance/NDCG@10', NDCG, epoch)

        elapsed_time = time.time() - start_time
        print("The time elapse of epoch {:03d}".format(epoch) + " is: " +
                        time.strftime("%H: %M: %S", time.gmtime(elapsed_time)))
        print("HR: {:.3f}\tNDCG: {:.3f}".format(np.mean(HR), np.mean(NDCG)))

        if HR > best_hr:
                best_hr, best_ndcg, best_epoch = HR, NDCG, epoch
                if args.out:
                        if not os.path.exists('models/'):
                                os.mkdir('models/')
                        torch.save(model,
                                '{}{}.pth'.format('models/', 'ml-1m_Neu_MF'))

writer.close()
print("End. Best epoch {:03d}: HR = {:.3f}, NDCG = {:.3f}".format(
                                                                best_epoch,␣
 ↪best_hr, best_ndcg))
```

```
The time elapse of epoch 001 is: 00: 00: 06
```

```
HR: 0.444       NDCG: 0.212
The time elapse of epoch 002 is: 00: 00: 06
HR: 0.483       NDCG: 0.260
The time elapse of epoch 003 is: 00: 00: 06
HR: 0.494       NDCG: 0.277
The time elapse of epoch 004 is: 00: 00: 06
HR: 0.478       NDCG: 0.272
The time elapse of epoch 005 is: 00: 00: 06
HR: 0.467       NDCG: 0.279
The time elapse of epoch 006 is: 00: 00: 06
HR: 0.483       NDCG: 0.279
The time elapse of epoch 007 is: 00: 00: 06
HR: 0.472       NDCG: 0.274
The time elapse of epoch 008 is: 00: 00: 06
HR: 0.478       NDCG: 0.277
The time elapse of epoch 009 is: 00: 00: 06
HR: 0.494       NDCG: 0.284
The time elapse of epoch 010 is: 00: 00: 06
HR: 0.472       NDCG: 0.276
The time elapse of epoch 011 is: 00: 00: 07
HR: 0.478       NDCG: 0.267
The time elapse of epoch 012 is: 00: 00: 06
HR: 0.483       NDCG: 0.268
The time elapse of epoch 013 is: 00: 00: 06
HR: 0.472       NDCG: 0.264
The time elapse of epoch 014 is: 00: 00: 06
HR: 0.456       NDCG: 0.254
The time elapse of epoch 015 is: 00: 00: 06
HR: 0.472       NDCG: 0.270
The time elapse of epoch 016 is: 00: 00: 06
HR: 0.456       NDCG: 0.265
The time elapse of epoch 017 is: 00: 00: 06
HR: 0.472       NDCG: 0.268
The time elapse of epoch 018 is: 00: 00: 06
HR: 0.467       NDCG: 0.265
The time elapse of epoch 019 is: 00: 00: 06
HR: 0.478       NDCG: 0.269
The time elapse of epoch 020 is: 00: 00: 06
HR: 0.472       NDCG: 0.270
The time elapse of epoch 021 is: 00: 00: 06
HR: 0.472       NDCG: 0.271
The time elapse of epoch 022 is: 00: 00: 06
HR: 0.478       NDCG: 0.277
The time elapse of epoch 023 is: 00: 00: 06
HR: 0.489       NDCG: 0.270
The time elapse of epoch 024 is: 00: 00: 06
HR: 0.467       NDCG: 0.268
The time elapse of epoch 025 is: 00: 00: 06
```

```
HR: 0.478       NDCG: 0.271
The time elapse of epoch 026 is: 00: 00: 06
HR: 0.478       NDCG: 0.278
The time elapse of epoch 027 is: 00: 00: 06
HR: 0.478       NDCG: 0.275
The time elapse of epoch 028 is: 00: 00: 07
HR: 0.472       NDCG: 0.279
The time elapse of epoch 029 is: 00: 00: 07
HR: 0.483       NDCG: 0.284
The time elapse of epoch 030 is: 00: 00: 07
HR: 0.478       NDCG: 0.278
End. Best epoch 003: HR = 0.494, NDCG = 0.277
```

[127]:
```
list_HR=[0.3459,0.3158,0.4172,0.293233,0.494]
list_NDCG=[0.2584,0.2418,0.197,0.08,0.277]
list_model=['B1', 'N1', 'N2', 'N3', 'R3']
```

[128]:
```
table_result = pd.DataFrame({'HR': list_HR,
                 'NDCG': list_NDCG},
                   index=list_model)
```

[129]:
```
import matplotlib
matplotlib.use('nbagg')

import matplotlib.pyplot as plt
```

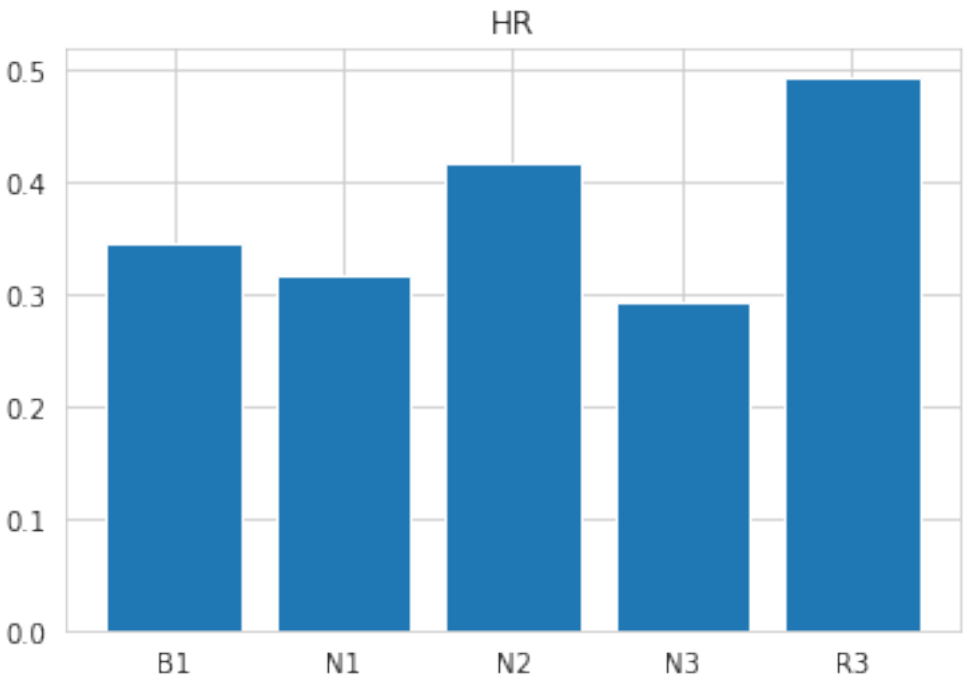
[ ]:
```

```

8 Result Summary

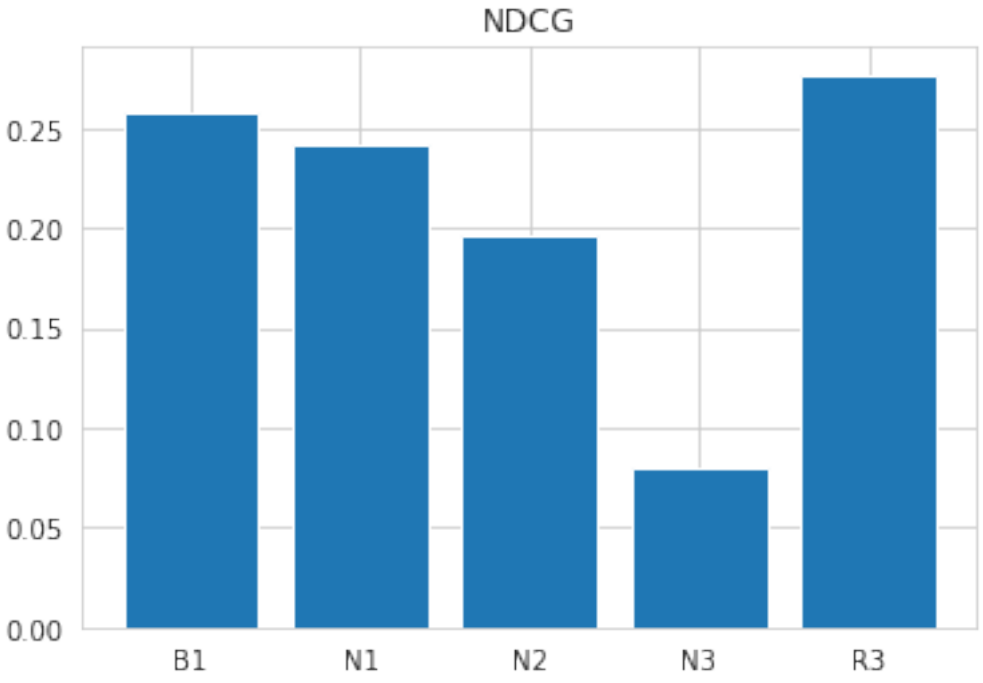
[130]:
```
%matplotlib inline
plt.bar(list_model, list_HR)
plt.title('HR')

plt.show()
```



[131]:
```
plt.bar(list_model, list_NDCG)
plt.title('NDCG')

plt.show()
```



[118]:
```
table_result
```

[118]:

	HR	NDCG
B1	0.3459	0.2584
N1	0.3158	0.2418
N2	0.4172	0.197
N3	0.293233	0.08
R3	0.494	0.277

The training of every model is taking more than 20 hours, so I only run one time with K=10 and Factors=16. It turns out that R3 is the best in both HR and NDCG, which is a referenced model - NeuMF implemented by the [3] reference on Github. Compared to my model, the referenced model used the torch library while my model is implemented from scratch. And there seems to be some errors in my impelmentations because the my implemented model is shallow and only have a few neurons in each layer. So my model is easier to overfit. In the coding part, I learned how to implement NeuMF from scratch and with torch library. And what I learned in tackling recommendation problem is that combining two methods sometimes can give us better performance. In this case, we combined GMF and Neural Network, and it turns out that with the the processing of both high-level and low-level features, our result is more comprehensive and thus have better performance over HR and NDCG. This is very innovating because similar ideas were submitted in the field of Computer Vision in Object Dection tasks with YOLO. YOLO get three different sizes feature map by doing up-sampling after the feature extraction network. By doing object detection on those three levels, it has a better performance detecting different size object than its predecessor who use a fixed size feature map. This tells me that this idea of combining different level's feature can be applied to many fields, not just Recommendation Systems or Computer Vision.

[ ]:
```

```