Adding library

```
#adding library
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
#import random for random between a and b (not include a, b)
import random
```

Pull data directly and unzip from grouplens website

```
DATASET_LINK='http://files.grouplens.org/datasets/movielens/ml-100k.zip'
!wget -nc http://files.grouplens.org/datasets/movielens/ml-100k.zip
!unzip -n ml-100k.zip
```

```
File ‘ml-100k.zip’ already there; not retrieving.

Archive:  ml-100k.zip
```

Describe data, statistics data in general way

Describe

```
# Viewing u.data file
column_names1 = ['user id','movie id','rating','timestamp']
df = pd.read_csv('ml-100k/u.data', sep='\t',header=None,names=column_names1)
df.head()
```

	user id	movie id	rating	timestamp
0	196	242	3	881250949
1	186	302	3	891717742
2	22	377	1	878887116
3	244	51	2	880606923
4	166	346	1	886397596

```
#check min, max rating and count how many the distincts value
print("rating:")
print(df.rating.max())
print(df.rating.min())
print(df.rating.value_counts())

#check how many the distincts value of users id
print("user:")
print(df["user id"].value_counts())
#check how many the distincts value of video
print("video:")
print(df["movie id"].value_counts())
```

```
rating:
5
1
4    34174
3    27145
5    21201
2    11370
1     6110
Name: rating, dtype: int64
user:
405    737
655    685
13     636
450    540
```

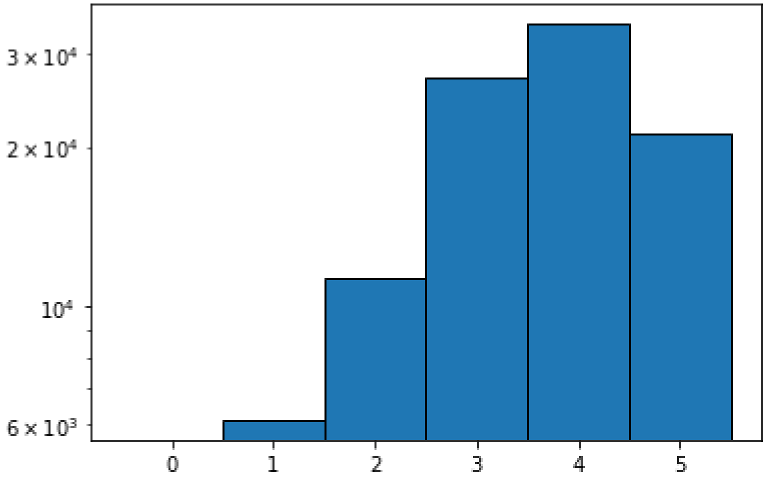
```
276    518
      ...
441     20
36      20
812     20
895     20
93      20
Name: user id, Length: 943, dtype: int64
video:
50      583
258     509
100     508
181     507
294     485
       ...
852       1
1505      1
1653      1
1452      1
1641      1
Name: movie id, Length: 1682, dtype: int64
```

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

```
count    100000.000000
mean          3.529860
std           1.125674
min           1.000000
25%           3.000000
50%           4.000000
75%           4.000000
max           5.000000
Name: rating, dtype: float64
```

Statistics and charts

```
plt.hist(df['rating'], bins=np.arange(7)-0.5, ec="k",log=True);
plt.plot();
plt.show();
```



Offline phase

Build matrix factorization using svd++

```
#@title Default title text
class SVDpp:
# Khởi tạo các biến cho class SVDpp
# matrixDataSet là tập dữ liệu đưa vào (tập train), numFactor là số factor ẩn
# bi là bias của item i, bu là bias của item u
# qi là dictionary chứa những key (id item) và giá trị của key là ma trận (1 cột)
#   numFactor số random trong nữa khoảng [0,1)
# qu là dictionary chứa những key (id user) và giá trị của key là ma trận (1 cột)
#   numFactor số random trong nữa khoảng [0,1)
# yi là dictionary chứa những key (id item) và giá trị của key là ma trận (1 cột)
#   numFactor số 0.1; đây là ma trận những nhân tố ẩn.
# avg là trung bình rating của matrixDataSet đưa vào.
# u_dict là dictionary chứa các key là user id và value là danh sách các item id
#   mà user đó đã rate.
```

```
    def __init__(self, matrixDataSet, numFactor=20):
        self.matrixDataSet = np.array(matrixDataSet)
        self.numFactor = numFactor
        self.bi = {}
        self.bu = {}
        self.qi = {}
        self.pu = {}
        self.avg = np.mean(self.matrixDataSet[:, 2])
        self.yi = {}
        self.u_dict = {}
        for i in range(self.matrixDataSet.shape[0]):
            user_id = self.matrixDataSet[i, 0]
            item_id = self.matrixDataSet[i, 1]
            self.u_dict.setdefault(user_id, [])
            self.u_dict[user_id].append(item_id)
            self.bi.setdefault(item_id, 0)
            self.bu.setdefault(user_id, 0)
            self.qi.setdefault(item_id, np.random.random((self.numFactor, 1)))
            self.pu.setdefault(user_id, np.random.random((self.numFactor, 1)))
            self.yi.setdefault(item_id, np.zeros((self.numFactor, 1)) + .1)

# Tính căn bậc 2 của Nu và Σyj. It used for predict, train method
# Nu is the amount of item which user rated. Get from u_dict
# userImplicitFactor is the result of sqrt(Nu) multiply Σyj
    def getNuYj(self, user_id, item_id):
            Nu = self.u_dict[user_id]
            numItemOfNu = len(Nu)
            sqrt_Nu = np.sqrt(numItemOfNu)
            y_u = np.zeros((self.numFactor, 1))
            if numItemOfNu == 0:
                userImplicitFactor = y_u
            else:
                for idItem in Nu:
                    y_u += self.yi[idItem]
                userImplicitFactor = y_u / sqrt_Nu

            return userImplicitFactor, sqrt_Nu

```

```
# Hàm predict để predict rating
# Phương thức setdefault là dành cho những item, user mới vào hệ thống
#   và thiết lập bi, bu, qi, pu và yi bằng 0. Khởi tạo mảng item rỗng mà user id
#   đã rate (chưa có gì)
# Bởi vì score nằm trong đoạn từ 1 đến 5, khi điểm lớn hơn 5 trả về 5
# hoặc nhỏ hơn 1, 1 sẽ được trả về.
    def predict(self, user_id, item_id):
        self.bi.setdefault(item_id, 0)
        self.bu.setdefault(user_id, 0)
        self.qi.setdefault(item_id, np.zeros((self.numFactor, 1)))
        self.pu.setdefault(user_id, np.zeros((self.numFactor, 1)))
        self.yi.setdefault(item_id, np.zeros((self.numFactor, 1)))
        self.u_dict.setdefault(user_id, [])
        userImplicitFactor, sqrt_Nu = self.getNuYj(user_id, item_id)
        rating = self.avg + self.bi[item_id] + self.bu[user_id] + np.sum(
            self.qi[item_id] * (self.pu[user_id] + userImplicitFactor))
        if rating > 5:
            rating = 5
        if rating < 1:
            rating = 1
        return rating

# Train function which is build by the matrix factorization and the svd++
# Lambda thay cho lambda vì bị lỗi do trùng với anonymous function (lambda).
# At the step 2 of docx, we get all pair of user, item, but here, we use number
#   of the rating in dataset source and random to take by np.random.permutation()
#   method which references n number and return an contigent array of the n number from 0 to n-1
# Get all of rating in dataset: self.matrixDataSet.shape[0]
    def train(self, epochs=20, alpha=0.005, Lambda=0.02):
        for epoch in range(epochs):
            print('epoch', epoch + 1, 'is running')
            Yui = np.random.permutation(self.matrixDataSet.shape[0])
            # Stochastic Gradient Descent
            rmse = 0.0
            for i in range(self.matrixDataSet.shape[0]):
                j = Yui[i]
                user_id = self.matrixDataSet[j, 0]
                item_id = self.matrixDataSet[j, 1]
                rating = self.matrixDataSet[j, 2]
                predict = self.predict(user_id, item_id)
                userImplicitFactor, sqrt_Nu = self.getNuYj(user_id, item_id)
                eui = rating - predict #step 7
                rmse += eui ** 2
                tempPu = self.pu[user_id] - alpha * (Lambda * self.pu[user_id] - eui * self.qi[item_id])
                tempQi = self.qi[item_id] - alpha * (Lambda * self.qi[item_id] - eui * (self.pu[user_id] + userImplicitFa
                self.bu[user_id] -= alpha * (Lambda * self.bu[user_id] - eui) #step 10
                self.bi[item_id] -= alpha * (Lambda * self.bi[item_id] - eui)
                self.pu[user_id] = tempPu
                self.qi[item_id] = tempQi
                for j in self.u_dict[user_id]: #step 14
                    self.yi[j] -= alpha * (Lambda * self.yi[j] - eui * self.qi[j] / sqrt_Nu)
            print('rmse: ', np.sqrt(rmse / self.matrixDataSet.shape[0]))


    def test(self, test_data):
        test_data = np.array(test_data)
        print('test data size: ', test_data.shape)
        rmse = 0.0
        for i in range(test_data.shape[0]):
            user_id = test_data[i, 0]
            item_id = test_data[i, 1]
            rating = test_data[i, 2]
            eui = rating - self.predict(user_id, item_id)
            rmse += eui ** 2
        print('rmse of test data is: ', np.sqrt(rmse / test_data.shape[0]))
        return np.sqrt(rmse / test_data.shape[0])
```

Preparing data to train

- Random (or load if right) data to train and test

```
column_names1 = ['user id','movie id','rating','timestamp']
```

```
datatrain = pd.read_csv('/content/ml-100k/u1.base', sep='\t',header=None,names=column_names1)
datatest = pd.read_csv('/content/ml-100k/u1.test', sep='\t',header=None,names=column_names1)
```

- Check, filter data

```
## Lấy dữ liệu và lọc dữ liệu (xóa duplicate, null, NaN)
datatrain.dropna(inplace=True)
datatrain.drop_duplicates(inplace=True)
datatest.dropna(inplace=True)
datatest.drop_duplicates(inplace=True)


## Lấy dữ liệu gồm title, id phim từ u.item và lọc
col = 'movie id | movie title | release date | video release date | IMDb URL | unknown | Action '
col+= '| Adventure | Animation | Children | Comedy | Crime | Documentary | Drama | Fantasy | Film-Noir '
col+= '| Horror | Musical | Mystery | Romance | Sci-Fi | Thriller | War | Western'
colItem = col.split(' | ')
movieItem = pd.read_csv('ml-100k/u.item',
                        sep='|',header=None,names=colItem,encoding='latin-1')
movieItem = movieItem[['movie id','movie title']]
movieItem.dropna(inplace=True)
movieItem.drop_duplicates(inplace=True)
```

Training

1. Predict before train (testing)

```
numFactor = 20
beforetrain = SVDpp(datatrain, numFactor)
```

```
#196    242 3   881250949
```

```
#186    302 3   891717742
#22 377 1   878887116
print (beforetrain.predict(196, 242))
print (beforetrain.predict(186  ,302))
print (beforetrain.predict(22,  377))
```

```
5
5
5
```

2. To train

epochs=20, numFactor=10, times~=40'

```
numFactor = 10
model = SVDpp(datatrain, numFactor)
model.train(epochs=5)
```

```
epoch 1 is running
rmse:  1.1418633334993153
epoch 2 is running
rmse:  1.0078133215799512
epoch 3 is running
rmse:  0.975830914253232
epoch 4 is running
rmse:  0.9569562249880843
epoch 5 is running
rmse:  0.9437353513493676
```

3. After trained (testing)

```
print (datatest.shape[0])
test_data = np.array(datatest)
print('test data size', datatest.shape[0])
table={}
```

```
table[numFactor] = [model.test(datatest)]
# Create DataFrame
df = pd.DataFrame(table)

# Print the output.
print(df)
```

```
20000
test data size 20000
test data size:  (20000, 4)
rmse of test data is:  1.0033410661590405
         10
0  1.003341
```

```
# predict rating
#196    242 3
#186    302 3
#22 377 1
print (model.predict(196, 242))
print (model.predict(186    ,302))
print (model.predict(22,    377))

#1  6   5   887431973
#1  10  3   875693118
print("===================")
print (model.predict(1  ,6))
print (model.predict(1, 10))

#247    50  5   893097024
#328    470 4   885046537
print("===================")
print (model.predict(247    ,50))
print (model.predict(328,   470))
```

```
4.261731867950952
3.6691783734742396
2.730751065208784
===================
4.1063066705884195
4.107204435499964
===================
4.355582033975845
3.7932378729185645
```

Cho thấy việc predict ngày càng chính xác hơn nếu chúng ta build với epoch, numfactor cao hơn (không quá cao). Epoch cỡ 100-200, numFactor cỡ 20!?

Train more

Train thay đổi epochs, numFactor trên 1 tập dữ liệu train u1.base

epochs=50, numFactor=20 => times ~= 1h30

```
modelFifTwe = SVDpp(datatrain, numFactor=20)
modelFifTwe.train(epochs=50)
```

```
epoch 1 is running
rmse:  1.2127756322517043
epoch 2 is running
rmse:  1.0403626458905162
epoch 3 is running
rmse:  0.9966144720109955
epoch 4 is running
rmse:  0.9689930278485509
epoch 5 is running
rmse:  0.9493579319364884
epoch 6 is running
rmse:  0.9340799476830878
epoch 7 is running
rmse:  0.9213990170670386
epoch 8 is running
rmse:  0.9102606720777253
```

```
epoch 9 is running
rmse:  0.9003509134253267
epoch 10 is running
rmse:  0.8918298720004196
epoch 11 is running
rmse:  0.8835142120594934
epoch 12 is running
rmse:  0.8753327946592122
epoch 13 is running
rmse:  0.8678003686575411
epoch 14 is running
rmse:  0.8602283844580954
epoch 15 is running
rmse:  0.8529303925159406
epoch 16 is running
rmse:  0.8453384530210101
epoch 17 is running
rmse:  0.8385642309939273
epoch 18 is running
rmse:  0.8307618013909703
epoch 19 is running
rmse:  0.8239128102961274
epoch 20 is running
rmse:  0.8166723778914584
epoch 21 is running
rmse:  0.8091798190573646
epoch 22 is running
rmse:  0.8024496419796235
epoch 23 is running
rmse:  0.7951928681525029
epoch 24 is running
rmse:  0.7882633879611802
epoch 25 is running
rmse:  0.7815436001629945
epoch 26 is running
rmse:  0.7750248447476693
epoch 27 is running
rmse:  0.7679901922795981
epoch 28 is running
rmse:  0.7618268230656972
epoch 29 is running
rmse:  0.7556118256627662
```

```
# predict rating
#196    242 3
#186    302 3
#22 377 1
print (modelFifTwe.predict(196, 242))
print (modelFifTwe.predict(186  ,302))
print (modelFifTwe.predict(22,  377))

#1  6   5
#1  10  3
print("===================")
print (modelFifTwe.predict(1    ,6))
print (modelFifTwe.predict(1,   10))

#247    50  5
#328    470 4
print("===================")
print (modelFifTwe.predict(247  ,50))
print (modelFifTwe.predict(328, 470))
```

```
3.8358237744887047
2.9166611662620197
2.6927850006931315
===================
3.607549634044278
3.062126955587438
===================
4.400828893820662
3.8912683263094645
```

epochs=100 numFactor=20

```
modelHundFif = SVDpp(datatrain, numFactor=20)
modelHundFif.train(epochs=100)
```

```
epoch 1 is running
rmse:  1.2098767865103766
epoch 2 is running
rmse:  1.0367281571458218
epoch 3 is running
rmse:  0.9933641436948908
epoch 4 is running
rmse:  0.966272277918801
epoch 5 is running
rmse:  0.9468591932015173
epoch 6 is running
rmse:  0.9315970173059981
epoch 7 is running
rmse:  0.9195135965814174
epoch 8 is running
rmse:  0.9080633188939393
epoch 9 is running
rmse:  0.8985438584164058
epoch 10 is running
rmse:  0.889806933962878
epoch 11 is running
rmse:  0.8810481209947766
epoch 12 is running
rmse:  0.8730353331801601
epoch 13 is running
rmse:  0.8650391225096681
epoch 14 is running
rmse:  0.8574074469429468
epoch 15 is running
rmse:  0.8497473224204901
epoch 16 is running
rmse:  0.84235440392463
epoch 17 is running
rmse:  0.8347225271701153
epoch 18 is running
rmse:  0.8274305428979001
epoch 19 is running
rmse:  0.8199427241921706
epoch 20 is running
rmse:  0.8128495620162429
epoch 21 is running
rmse:  0.8055256601842096
```

```
epoch 22 is running
rmse:  0.798356097030288
epoch 23 is running
rmse:  0.7912215986991809
epoch 24 is running
rmse:  0.7845070447279319
epoch 25 is running
rmse:  0.7776915422759539
epoch 26 is running
rmse:  0.7710288176403494
epoch 27 is running
rmse:  0.7647372444264824
epoch 28 is running
```

```
# predict rating
#196    242 3
#186    302 3
#22 377 1
print (modelHundFif.predict(196, 242))
print (modelHundFif.predict(186 ,302))
print (modelHundFif.predict(22, 377))

#1  6   5
#1  10  3
print("===================")
print (modelHundFif.predict(1   ,6))
print (modelHundFif.predict(1,  10))

#247    50  5
#328    470 4
print("===================")
print (modelHundFif.predict(247 ,50))
print (modelHundFif.predict(328,    470))
```

```
3.6272367747277787
3.3581318071006887
1.7370827321949707
===================
2.6245754557217977
3.9029981473726507
===================
4.334241515462834
3.0536613892789966

epoch 45 is running
```

Cho thấy build với epochs lớn, và factor lớn thì độ chính xác càng lớn. Nhưng trái lại thời gian build rất lâu; 85 epoch, 20 factor ~= 3h

```
rmse:  0.6741126099852922
```

A testing chains

```
rmse:  0.6675400178845552
```

```
modelTwTwChains = SVDpp(datatrain, numFactor=20)
modelTwTwChains.train(epochs=10)
modelTwTwChains.train(epochs=20)
modelTwTwChains.train(epochs=20)
```

```
epoch 53 is running
```

```
# predict rating
#196    242 3
#186    302 3
#22 377 1
print (modelTwTwChains.predict(196, 242))
print (modelTwTwChains.predict(186  ,302))
print (modelTwTwChains.predict(22,  377))

#1  6   5
#1  10  3
print("==================")
print (modelTwTwChains.predict(1    ,6))
print (modelTwTwChains.predict(1,   10))

#247    50  5
#328    470 4
print("==================")
print (modelTwTwChains.predict(247  ,50))
print (modelTwTwChains.predict(328, 470))
```

```
epoch 63 is running
```

Online phase - Recommend films

```
rmse:  0.6253844670434823
```

```
#model = SDVpp(), above
userid=1
amountMovie=3

def checkItemRated(itemid, userid, model):
  listItem = model.u_dict[userid]
  for item in listItem:
    if item == itemid:
      return True
  return False

def recommendFilm(model, userid, amountMovieSystem=1682, amountMovie=3):
  i=1
  countItemRated=0
  bestMovies = {}
  while i <= amountMovieSystem:
    if checkItemRated(i, userid, model):
      #print("item is rated: ", i)
      i+=1
      countItemRated+=1
      continue
    bestMovies[i]=model.predict(userid, i)
    #print("item is not rated", i, " with predict", bestMovies[i])
    i += 1
  sortedBestMovies = sorted(bestMovies.items(), key=lambda x: x[1], reverse=True)
  print("======================================")
  print("bias:", model.bu[userid])
  print("number of rated:", countItemRated)
  return sortedBestMovies[0:amountMovie]

```

```
rmse:  0.598971810167066
```

```
print("model", recommendFilm(model, 1))
print("modelFifTwe",recommendFilm(modelFifTwe, 1))
#print("modelTwTwChains",recommendFilm(modelTwTwChains, 1))
print("modelHundFif",recommendFilm(modelHundFif, 1))
```

```
=======================================
bias: 0.023871366793141384
number of rated: 135
model [(12, 4.7880036310767125), (483, 4.755237093815905), (318, 4.727831206760823)]
=======================================
bias: 0.23620157297312752
number of rated: 135
modelFifTwe [(56, 5), (64, 5), (92, 5)]
=======================================
bias: 0.029071557066634456
number of rated: 135
modelHundFif [(64, 5), (98, 5), (100, 5)]
KeyboardInterrupt:
```

SEARCH STACK OVERFLOW