notebook

April 17, 2023

[1]:
```
from math import sqrt

import numpy as np
import warnings
import pandas as pd
import seaborn as sns
import tensorflow as tf
from keras.layers import BatchNormalization
from keras.preprocessing.text import Tokenizer
from keras.utils import pad_sequences
from matplotlib import pyplot as plt
from sklearn.metrics import mean_squared_error
from sklearn.model_selection import train_test_split, GridSearchCV
from sklearn.preprocessing import MinMaxScaler, LabelEncoder
from surprise import Reader, Dataset, SVD
from tensorflow.python.keras.callbacks import EarlyStopping,␣
 ↪LearningRateScheduler, ReduceLROnPlateau
from tensorflow.python.keras.layers import Embedding, LSTM, Dense, Dropout,␣
 ↪Input, Concatenate, Conv1D, \
    GlobalMaxPooling1D, Layer
from tensorflow.python.keras.models import Model

from nltk.tokenize import word_tokenize
from nltk.corpus import stopwords
from nltk.stem import WordNetLemmatizer
import nltk
import re
from unidecode import unidecode
import swifter

from xgboost import XGBClassifier, XGBRegressor
from sklearn.decomposition import PCA
from sklearn.preprocessing import StandardScaler
```

[2]:
```
# show complete dataframe in console
pd.set_option('display.max_columns', None)
```

```
warnings.filterwarnings('ignore')
%matplotlib inline
```

1 Import Data

[3]:
```
train = pd.read_csv("./dataset/train.csv")
test = pd.read_csv("./dataset/test.csv")
books = pd.read_csv("./dataset/cleaned_books.csv")
users = pd.read_csv("./dataset/user_info.csv")
```

2 EDA

2.0.1 Train

[4]:
```
train.head()
```

[4]:

	User_Id	Book_Id	Rating
0	206641	56067	6
1	96769	327469	10
2	149881	325723	5
3	104656	115894	8
4	107921	236817	10

[5]:
```
train.describe()
```

[5]:

	User_Id	Book_Id	Rating
count	303216.000000	303216.000000	303216.000000
mean	140831.385448	167938.250904	7.755072
std	79826.132368	96866.070691	86.018692
min	2.000000	2.000000	1.000000
25%	70374.000000	83937.000000	7.000000
50%	144550.000000	168286.000000	8.000000
75%	209352.000000	251473.000000	9.000000
max	278858.000000	334342.000000	47363.000000

[6]:
```
train['Rating'].value_counts()
```

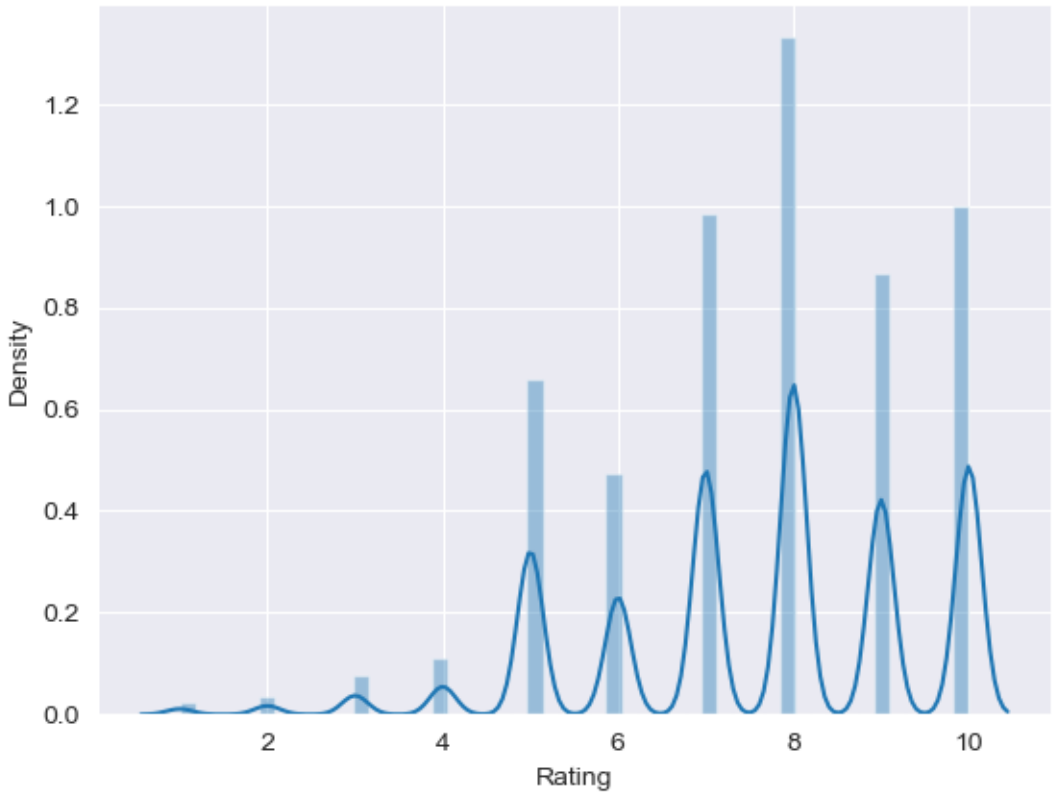
[6]:
```
8        72613
10       54613
7        53678
9        47240
5        35904
6        25786
4         6116
3         4149
2         1896
```

```
1          1220
47363         1
Name: Rating, dtype: int64
```

[7]:
```
train['Rating'] = train['Rating'].apply(lambda x: 10 if x > 10 else x)
```

[8]:
```
# distribution of rating
sns.distplot(train['Rating'])
```

[8]:
```
<Axes: xlabel='Rating', ylabel='Density'>
```



[9]:
```
# missing values
train.isnull().sum()
```

[9]:
```
User_Id    0
Book_Id    0
Rating     0
dtype: int64
```

2.0.2 Test

[10]:
```
test.head()
```

[10]:
```
   User_Id  Book_Id
0    51757   112562
1   167329   233532
2   115450    62910
3    71697    64447
4   255816    28554
```

[11]:
```
test.describe()
```

[11]:
```
             User_Id        Book_Id
count   47522.000000   47522.000000
mean   142520.973444  167381.549093
std     79456.934195   96927.857980
min        76.000000      11.000000
25%     71697.000000   83355.000000
50%    148556.000000  167235.000000
75%    210912.000000  251641.500000
max    278826.000000  334325.000000
```

[12]:
```
test.isnull().sum()
```

[12]:
```
User_Id    0
Book_Id    0
dtype: int64
```

2.0.3 Books

[13]:
```
books.head()
```

[13]:
```
   book_id                                              title  \
0     6036  Ecclesiastical History of the English People W…
1   248755   Rebecca of Sunnybrook Farm Wordsworth Collection
2   100080   No 2243 The Pregnant Mistress Harlequin Presents
3   216944                                               Izo
4    60313                                         Bad Blood

                author  year                          publisher  \
0                Bede  1991                      Penguin Books
1  Kate Douglas Wiggin  1999  NTCContemporary Publishing Company
2       Sandra Marton  2002                           Harlequin
3      Pascal de Duve  1994                                LGF
4         Debra Doyle  1993                  Berkley Pub Group

                                        image_url_s  \
```

```
0  http://images.amazon.com/images/P/014044565X.0…
1  http://images.amazon.com/images/P/1853261343.0…
2  http://images.amazon.com/images/P/0373122438.0…
3  http://images.amazon.com/images/P/2253135224.0…
4  http://images.amazon.com/images/P/0425139530.0…

                                          image_url_m  \
0  http://images.amazon.com/images/P/014044565X.0…
1  http://images.amazon.com/images/P/1853261343.0…
2  http://images.amazon.com/images/P/0373122438.0…
3  http://images.amazon.com/images/P/2253135224.0…
4  http://images.amazon.com/images/P/0425139530.0…

                                          image_url_l
0  http://images.amazon.com/images/P/014044565X.0…
1  http://images.amazon.com/images/P/1853261343.0…
2  http://images.amazon.com/images/P/0373122438.0…
3  http://images.amazon.com/images/P/2253135224.0…
4  http://images.amazon.com/images/P/0425139530.0…
```

[14]:
```
books.columns
```

[14]:
```
Index(['book_id', 'title', 'author', 'year', 'publisher', 'image_url_s',
       'image_url_m', 'image_url_l'],
      dtype='object')
```

[15]:
```
books = books[['book_id', 'title', 'author', 'year', 'publisher']]
```

[16]:
```
books.isnull().sum()
```

[16]:
```
book_id      0
title        0
author       1
year         0
publisher    5
dtype: int64
```

[17]:
```
# replace missing values with 'unknown'
books['author'] = books['author'].fillna('unknown')
books['publisher'] = books['publisher'].fillna('unknown')
```

[18]:
```
books.describe()
```

[18]:
```
             book_id           year
count  271379.000000  271379.000000
mean   167123.717734    1960.010653
std     96577.950048     275.531085
min         1.000000       0.000000
```

```
25%      83463.500000    1989.000000
50%     167091.000000    1995.000000
75%     250837.000000    2000.000000
max     334344.000000   37547.000000
```

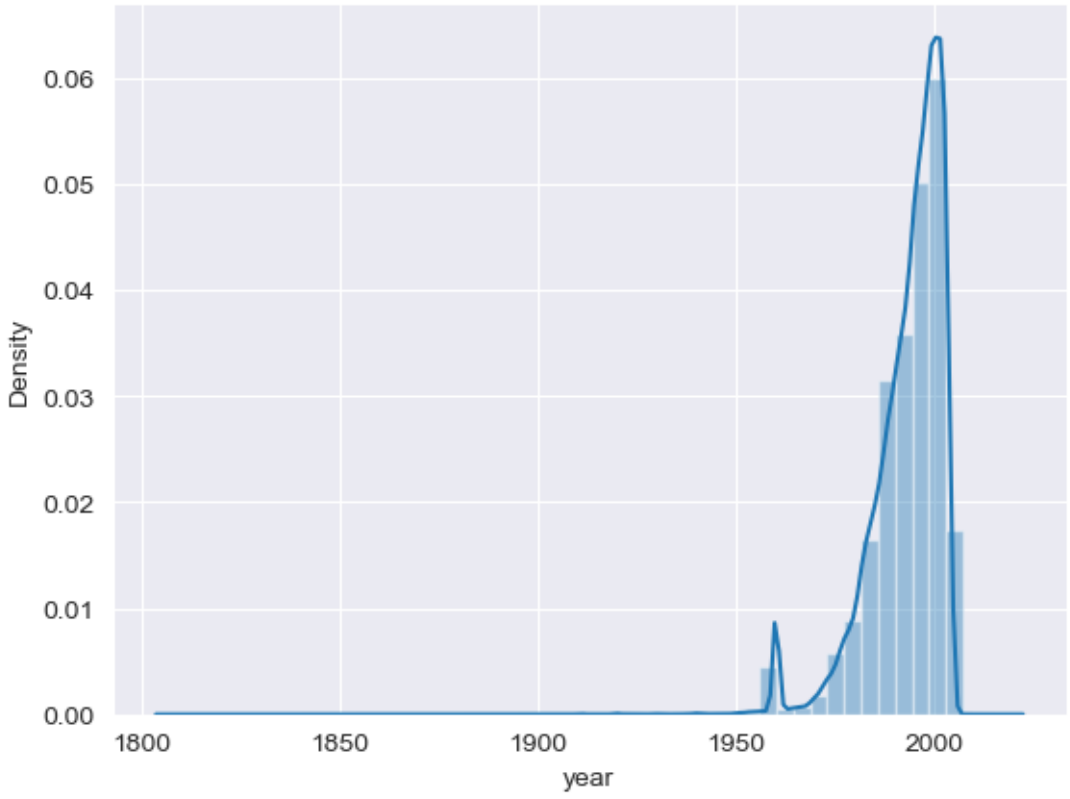
[19]:
```
# year
min_year = books['year'].min()
max_year = books['year'].max()
print(min_year, max_year)
```

```
0 37547
```

[20]:
```
# replace year < 1700 and year > 2020 with mean year
mean_year = books['year'].mean()
books['year'] = books['year'].apply(lambda x: mean_year if x < 1700 or x > 2020␣
 ↪else x)
```

[21]:
```
# distribution of year
sns.distplot(books['year'])
```

[21]:
```
<Axes: xlabel='year', ylabel='Density'>
```



[22]:
```
# unique values
print("Number of unique books: ", books['book_id'].nunique())
print("Number of unique authors: ", books['author'].nunique())
print("Number of unique publishers: ", books['publisher'].nunique())
```

```
Number of unique books:  271378
Number of unique authors:  100963
Number of unique publishers:  16623
```

[23]:
```
# Most books by author
books['author'].value_counts().head(10)
```

[23]:
```
Agatha Christie        632
William Shakespeare    567
Stephen King           524
Ann M Martin           428
Carolyn Keene          373
Francine Pascal        373
Isaac Asimov           330
Nora Roberts           315
Barbara Cartland       307
Charles Dickens        302
Name: author, dtype: int64
```

[24]:
```
# Most books by publisher
books['publisher'].value_counts().head(10)
```

[24]:
```
Harlequin                   7536
Silhouette                  4220
Pocket                      3905
Ballantine Books            3783
Bantam Books                3647
Scholastic                  3160
Simon amp Schuster          2971
Penguin Books               2845
Berkley Publishing Group    2771
Warner Books                2727
Name: publisher, dtype: int64
```

2.0.4 Users

[25]:
```
users.head()
```

[25]:

	User_Id	Location	Age
0	1	kawerau., bay of plenty., new zealand	65.0
1	2	austin, texas, usa	NaN
2	3	milpitas, california, usa	44.0
3	4	sao paulo, sao paulo, brazil	47.0

```
4        5                  verona, veneto, italy  38.0
```

[26]:
```
users.columns
```

[26]:
```
Index(['User_Id', 'Location', 'Age'], dtype='object')
```

[27]:
```
users.rename(columns={'User_Id': 'user_id', 'Location': 'location', 'Age':␣
 ↪'age'}, inplace=True)
```

[28]:
```
users.isnull().sum()
```

[28]:
```
user_id          0
location         0
age         110762
dtype: int64
```

[29]:
```
# create a new column country by splitting the location column on commas and␣
 ↪taking the last element
users['country'] = users['location'].str.split(',').str[-1]

# replace quotes in the country column with nothing
users['country'] = users['country'].str.replace('"', '')
users['country'] = users['country'].str.strip()
```

[30]:
```
users['country'].value_counts()
```

[30]:
```
usa                  139712
canada                21658
united kingdom        18556
germany               17073
spain                 13258
                      …
jackson                   1
&#32654;&#22269;          1
brunei darussalam         1
orense                    1
c.a.                      1
Name: country, Length: 630, dtype: int64
```

[31]:
```
# Source: https://github.com/lukes/ISO-3166-Countries-with-Regional-Codes/blob/
 ↪master/all/all.csv
# read in the countries csv file from the above url
countries = pd.read_csv("https://raw.githubusercontent.com/lukes/
 ↪ISO-3166-Countries-with-Regional-Codes/master/all/all.csv")
# convert all the column values to lowercase if they are strings
countries = countries.applymap(lambda x: x.lower().strip() if type(x) == str␣
 ↪else x)
```

```
countries_names =  countries['name'].values
countries_alpha2 = countries['alpha-2'].values
countries_alpha3 = countries['alpha-3'].values
```

[32]:
```
# rename the country column of df to name if the value matches name, alpha-2,␣
 ↪or alpha-3 in the countries dataframe else set it to other

users['temp_country'] = users['country'].str.replace('united states', 'united␣
 ↪states of america')

users['temp_country'] = users['temp_country'].apply(lambda x:␣
 ↪countries[countries['alpha-2'] == x]['name'].values[0] if x in␣
 ↪countries_alpha2 else x)

users['temp_country'] = users['temp_country'].apply(lambda x:␣
 ↪countries[countries['alpha-3'] == x]['name'].values[0] if x in␣
 ↪countries_alpha3 else x)

users['temp_country'] = users['temp_country'].apply(lambda x: 'other' if x not␣
 ↪in countries_names else x)

# delete the country column
users.drop(columns=['country'], inplace=True)
users.drop(columns=['location'], inplace=True)

# rename the country2 column to country
users.rename(columns={'temp_country': 'country'}, inplace=True)

users['country'].value_counts()
```

[32]:
```
united states of america    139729
other                         25833
canada                        21659
germany                       17074
spain                         13258
                              …
comoros                           1
madagascar                        1
brunei darussalam                 1
somalia                           1
kiribati                          1
Name: country, Length: 179, dtype: int64
```

[33]:
```
# add a new column region by mapping the country column to the region column in␣
 ↪the countries dataframe if the country is in the countries dataframe else␣
 ↪set it to other
```

```
users['region'] = users['country'].apply(lambda x: countries[countries['name']
 ↪== x]['region'].values[0] if x in countries_names else 'other')

users['region'].value_counts()
```

[33]:
```
americas    166417
europe       62217
other        25833
oceania      14947
asia          8320
africa        1097
Name: region, dtype: int64
```

[34]:
```
print("Missing age percentage: ", users['age'].isna().sum() / users.shape[0] *
 ↪100, "%")
```

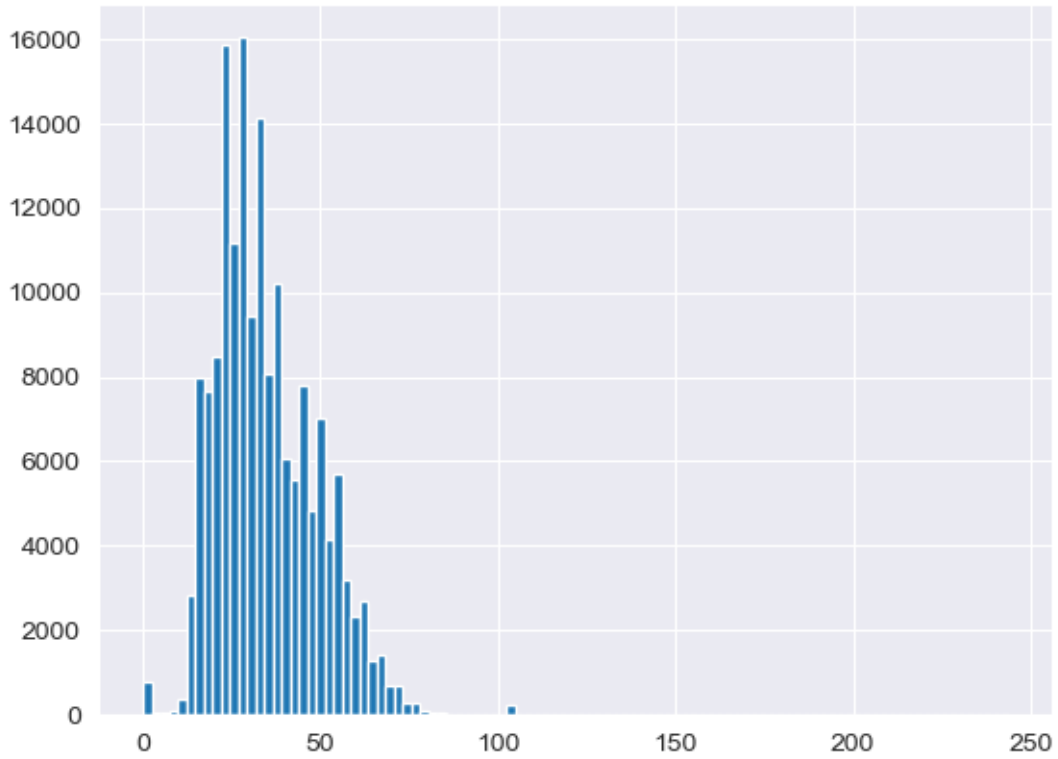
```
Missing age percentage:  39.71985741847105 %
```

[35]:
```
# Mean average age by country
users.groupby('country')['age'].mean().sort_values(ascending=False)
```

[35]:
```
country
chad                                                    75.500000
bhutan                                                  56.666667
tonga                                                   56.000000
isle of man                                             53.000000
antigua and barbuda                                     52.125000
                                                             ...
mauritania                                                   NaN
myanmar                                                      NaN
russian federation                                           NaN
somalia                                                      NaN
united kingdom of great britain and northern ireland         NaN
Name: age, Length: 179, dtype: float64
```

[36]:
```
users['age'].hist(bins=100)
```

[36]:
```
<Axes: >
```



[37]:
```
# min and max age
print("Min age: ", users['age'].min())
print("Max age: ", users['age'].max())
```

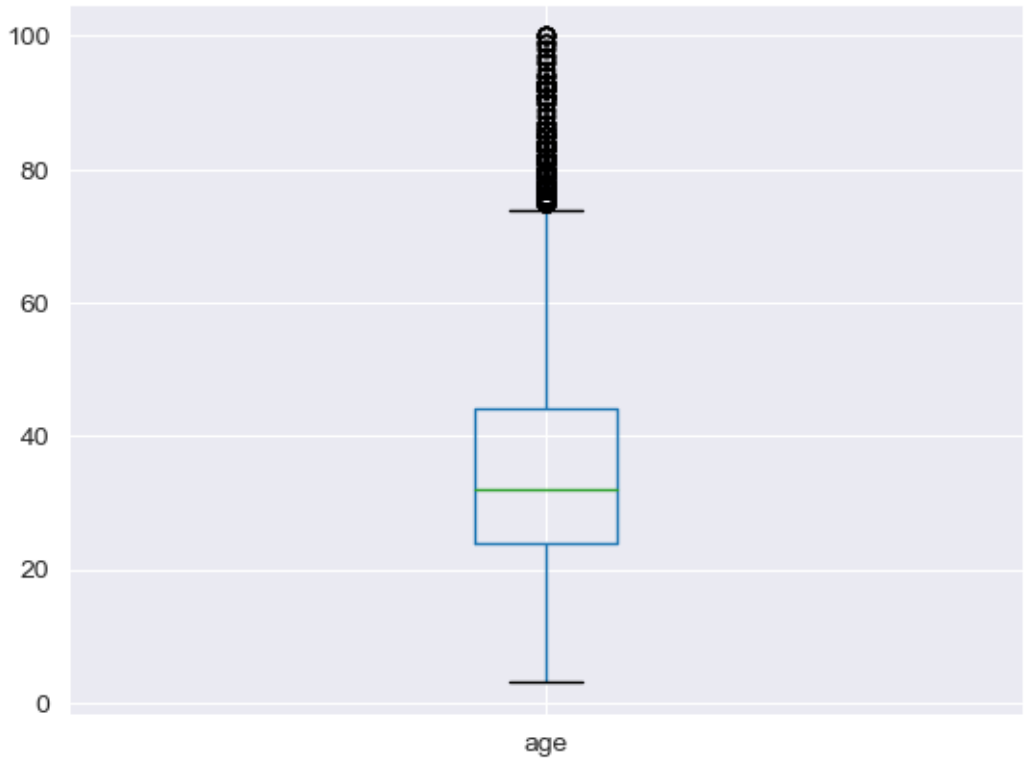
```
Min age:  0.0
Max age:  244.0
```

[38]:
```
# replace age > 100 with mean age
mean_age = users['age'].mean()
users['age'] = users['age'].apply(lambda x: mean_age if x > 100 else x)
```

[39]:
```
# replace age < 3 with 5
users['age'] = users['age'].apply(lambda x: 5 if x < 3 else x)
```

[40]:
```
users.boxplot(column=['age'])
```

[40]: <Axes: >



[41]:
```
# fill the missing values in the age column with 0 and another column for age missing
users['age_missing'] = users['age'].isna()
users['age'] = users['age'].fillna(0)
```

[42]:
```
users.head()
```

[42]:

	user_id	age	country	region	age_missing
0	1	65.0	new zealand	oceania	False
1	2	0.0	united states of america	americas	True
2	3	44.0	united states of america	americas	False
3	4	47.0	brazil	americas	False
4	5	38.0	italy	europe	False

[43]:
```
train = train.rename(columns={'User_Id': 'user_id', 'Rating': 'rating', 'Book_Id': 'book_id'})
test = test.rename(columns={'User_Id': 'user_id', 'Book_Id': 'book_id'})
users = users.rename(columns={'User_Id': 'user_id', 'Location': 'location', 'Age': 'age'})
```

3 Merge train with meta data

[44]:
```
print("Train shape: ", train.shape)
data = pd.merge(train, books, on='book_id', how='left')
print("Train shape after merging with books: ", data.shape)
data = pd.merge(data, users, on='user_id', how='left')
print("Train shape after merging with users: ", data.shape)
```

```
Train shape:  (303216, 3)
Train shape after merging with books:  (303219, 7)
Train shape after merging with users:  (303219, 11)
```

[45]:
```
data.head()
```

[45]:

	user_id	book_id	rating	title	author	year	publisher	age	country	region	age_missing
0	206641	56067	6	Geography Of Nowhere The Rise And Declineof Am…	James Howard Kunstler	1994.0	Free Press	100.0	united states of america	americas	False
1	96769	327469	10	Harry Potter and the Order of the Phoenix Book 5	J K Rowling	2003.0	Scholastic	0.0	other	other	True
2	149881	325723	5	Medinoche El Barco De Vapor	Randolph Stow	1985.0	Lectorum Pubns J	27.0	spain	europe	False
3	104656	115894	8	Gotta Get Next to You	Lynn Emery	2001.0	HarperTorch	22.0	united states of america	americas	False
4	107921	236817	10	Free	Paul Vincent	2003.0	Upfront Publishing	29.0	other	other	False

[46]:
```
data.isnull().sum()
```

[46]:
```
user_id           0
book_id           0
rating            0
title         34998
```

```
author          34998
year            34998
publisher       34998
age                 0
country             0
region             40
age_missing         0
dtype: int64
```

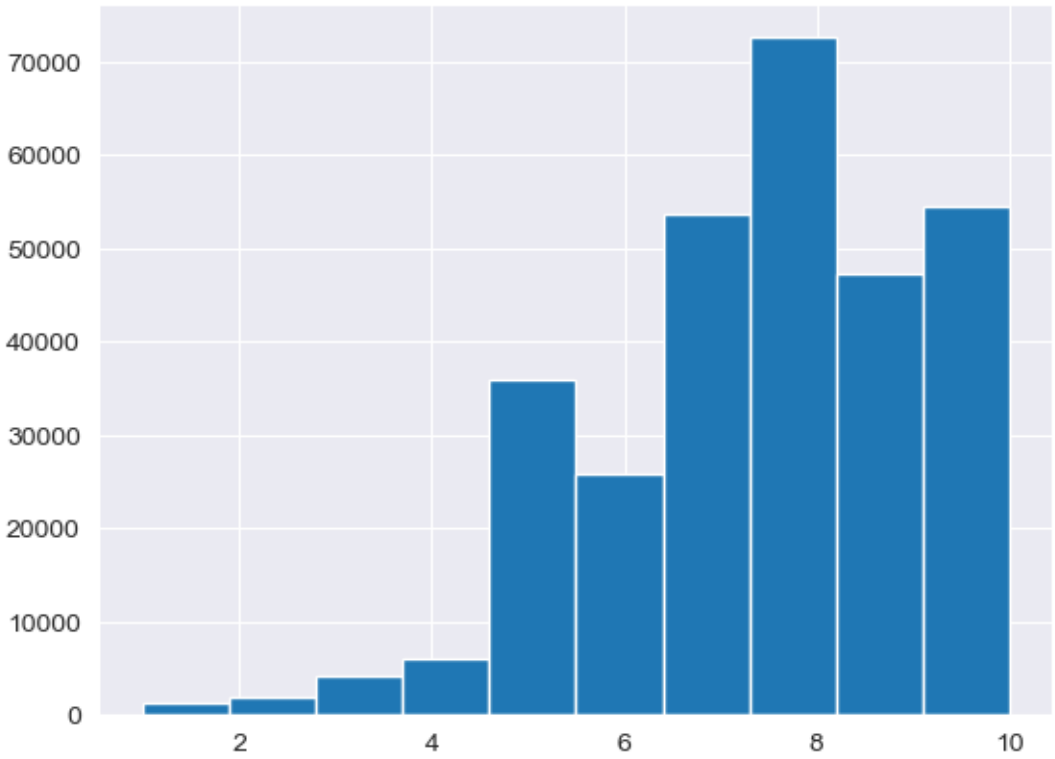
[47]:
```
data.describe()
```

[47]:
```
              user_id        book_id         rating           year  \
count  303219.000000  303219.000000  303219.000000  268221.000000
mean   140831.571996  167937.006494       7.598897    1995.155620
std     79825.762444   96866.399400       1.839927       8.477624
min         2.000000       2.000000       1.000000    1806.000000
25%     70374.000000   83937.000000       7.000000    1992.000000
50%    144550.000000  168286.000000       8.000000    1997.000000
75%    209352.000000  251473.000000       9.000000    2001.000000
max    278858.000000  334342.000000      10.000000    2020.000000

                 age
count  303219.000000
mean       25.685753
std        19.699771
min         0.000000
25%         0.000000
50%        29.000000
75%        40.000000
max       100.000000
```

[48]:
```
data['rating'].hist(bins=10)
```

[48]:
```
<Axes: >
```



[49]:
```
# top rated books
data.groupby('title')['rating'].mean().sort_values(ascending=False).head(10)
```

[49]:
```
title
Sport Stretch                                                    10.0
Emilys Black Mail Fold and Mail Stationery Emily the Strange     10.0
The Enchanted Castle Wordsworth Collection Childrens Library     10.0
The Enchanted Hill The story of Hearst Castle at San Simeon      10.0
The Enchanted Tarot Book and Cards                               10.0
The Enchanted World of RankinBass                                10.0
EmilyS Captain  March Madness Harlequin Historical               10.0
The Encyclopaedia of Celtic Wisdom The Celtic Shamans Sourcebook 10.0
The Encyclopedia of Ancient Civilizations                        10.0
The Encyclopedia of Healing Plants                               10.0
Name: rating, dtype: float64
```

[50]:
```
# top rated authors
data.groupby('author')['rating'].mean().sort_values(ascending=False).head(10)
```

[50]:
```
author
 17111776 Hume      10.0
Laura Berkeley      10.0
```

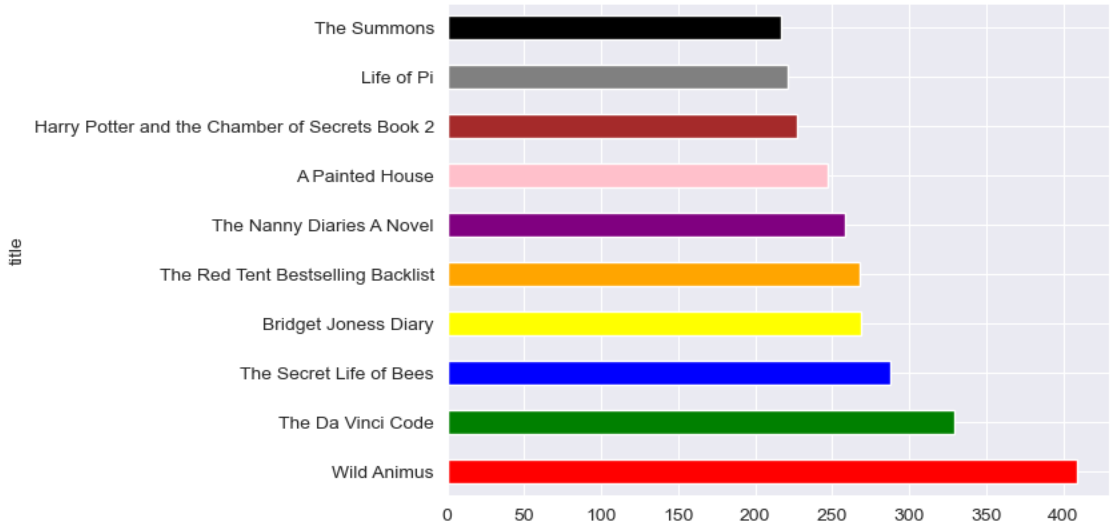
```
Candlewick Press    10.0
Candie Frankel      10.0
Lan Cao             10.0
Lance Morrow        10.0
Lance Parkin        10.0
Lanier Graham       10.0
Lao Tsu             10.0
Lara Owen           10.0
Name: rating, dtype: float64
```

[51]:
```
# most rated books
data.groupby('title')['rating'].count().sort_values(ascending=False).head(10)
```

[51]:
```
title
The Lovely Bones A Novel                          491
Wild Animus                                       409
The Da Vinci Code                                 329
The Secret Life of Bees                           288
Bridget Joness Diary                              269
The Red Tent Bestselling Backlist                 268
The Nanny Diaries A Novel                         258
A Painted House                                   247
Harry Potter and the Chamber of Secrets Book 2    227
Life of Pi                                        221
Name: rating, dtype: int64
```

[52]:
```
# plot the top 10 most rated books, X-axis = count and y-axis movie, and add␣
 ↪colors to the bars
data.groupby('title')['rating'].count().sort_values(ascending=False).iloc[1:11].
 ↪plot(kind='barh', color=['red', 'green', 'blue', 'yellow', 'orange',␣
 ↪'purple', 'pink', 'brown', 'grey', 'black'])
```

[52]:
```
<Axes: ylabel='title'>
```



[53]:
```
# top rated books by region
data.groupby(['region', 'title'])['rating'].mean().
 ↪sort_values(ascending=False)[1:11]
```

[53]:
```
region    title
americas  Tickets A Play in One Act
10.0
          Tibetan Folk Tales
10.0
          Joey Pigza Swallowed the Key Joey Pigza Books Hardcover
10.0
          Tibet
10.0
          An Album of Memories
10.0
          Thursday Next in the Well Of Lost Plots Thursday Next Novels Penguin
Books     10.0
          John Adams and the American Revolution
10.0
          An African Prayer Book
10.0
          Thunderstick Spanish Bit Saga of the Plains Indians
10.0
          John C Ordinary Enlightenment
10.0
Name: rating, dtype: float64
```

[54]:
```
# replace missing title, author, publisher with unknown
data['title'] = data['title'].fillna('unknown')
data['author'] = data['author'].fillna('unknown')
data['publisher'] = data['publisher'].fillna('unknown')
data['region'] = data['region'].fillna('unknown')
```

[55]:
```
# replace missing year with mean year
data['year'] = data['year'].fillna(data['year'].mean())
```

[56]:
```
data.isna().sum()
```

[56]:
```
user_id        0
book_id        0
rating         0
title          0
author         0
year           0
publisher      0
age            0
country        0
region         0
age_missing    0
dtype: int64
```

4 Merge test with meta data

[57]:
```
print("Test shape: ", test.shape)
test_data = pd.merge(test, books, on='book_id', how='left')
print("Test shape after merging with books: ", test_data.shape)
test_data = pd.merge(test_data, users, on='user_id', how='left')
print("Test shape after merging with users: ", test_data.shape)
```

```
Test shape:  (47522, 2)
Test shape after merging with books:  (47522, 6)
Test shape after merging with users:  (47522, 10)
```

[58]:
```
test_data.head()
```

[58]:

	user_id	book_id	title	author	year	publisher	age
0	51757	112562	The Mists of Avalon	MARION ZIMMER BRADLEY	1987.0	Del Rey	43.0
1	167329	233532	The BLACK ALBUM				
2	115450	62910	Harry Potter and the Chamber of Secrets Book 2				
3	71697	64447	The Wicca Handbook				
4	255816	28554	Lily White				

```
1         Hanif Kureishi  1996.0      Scribner  27.0
2            J K Rowling  2000.0    Scholastic  38.0
3         Eileen Holland  2000.0  Weiser Books  63.0
4           Susan Isaacs  1997.0   HarperTorch  46.0

                    country    region  age_missing
0  united states of america  americas        False
1                  portugal    europe        False
2  united states of america  americas        False
3                     other     other        False
4  united states of america  americas        False
```

[59]:
```
test_data.isnull().sum()
```

[59]:
```
user_id          0
book_id          0
title         4600
author        4600
year          4600
publisher     4600
age              0
country          0
region          12
age_missing      0
dtype: int64
```

[60]:
```
test_data.describe()
```

[60]:
```
             user_id        book_id          year           age
count   47522.000000   47522.000000  42922.000000  47522.000000
mean   142520.973444  167381.549093   1994.890276     27.463484
std     79456.934195   96927.857980      8.552716     19.054430
min        76.000000      11.000000   1902.000000      0.000000
25%     71697.000000   83355.000000   1992.000000      0.000000
50%    148556.000000  167235.000000   1997.000000     30.000000
75%    210912.000000  251641.500000   2001.000000     42.000000
max    278826.000000  334325.000000   2005.000000    100.000000
```

[61]:
```
# replace missing title, author, publisher and region with unknown
test_data['title'] = test_data['title'].fillna('unknown')
test_data['author'] = test_data['author'].fillna('unknown')
test_data['publisher'] = test_data['publisher'].fillna('unknown')
test_data['region'] = test_data['region'].fillna('unknown')
```

[62]:
```
# replace missing year with mean year
test_data['year'] = test_data['year'].fillna(data['year'].mean())
```

[63]:
```
test_data.isna().sum()
```

[63]:
```
user_id        0
book_id        0
title          0
author         0
year           0
publisher      0
age            0
country        0
region         0
age_missing    0
dtype: int64
```

5 Modeling

[64]:
```
# split the data into train and validation
from sklearn.model_selection import train_test_split
train_data, val_data = train_test_split(data, test_size=0.2, random_state=42)
```

[65]:
```
print("Train data shape: ", train_data.shape)
print("Validation data shape: ", val_data.shape)
```

```
Train data shape:  (242575, 11)
Validation data shape:  (60644, 11)
```

5.1 SVD

[66]:
```
svd = SVD(n_epochs=200, n_factors=15, lr_all=0.001, reg_all=0.05)
reader = Reader(rating_scale=(1, 10))
train_data_svd = Dataset.load_from_df(train_data[['user_id', 'book_id',␣
↪'rating']], reader)
```

[67]:
```
svd.fit(train_data_svd.build_full_trainset())
```

[67]:
```
<surprise.prediction_algorithms.matrix_factorization.SVD at 0x28b777220>
```

[68]:
```
# predict the ratings for the validation data
predictions = val_data.apply(lambda x: svd.predict(x['user_id'], x['book_id']).
↪est, axis=1)
```

[69]:
```
# Calculate the RMSE
from sklearn.metrics import mean_squared_error
from math import sqrt
rmse = sqrt(mean_squared_error(val_data['rating'], predictions))
```

[70]:
```
print("RMSE: ", rmse)
```

```
RMSE:  1.639888805960191
```

[71]:
```
# predict the ratings for the test data
predictions = test_data.apply(lambda x: svd.predict(x['user_id'], x['book_id']).
 ↪est, axis=1)
```

[72]:
```
predictions
```

[72]:
```
0        9.670121
1        8.346019
2        6.593337
3        9.198099
4        7.183357
           …
47517    9.292715
47518    6.692180
47519    7.759949
47520    7.729147
47521    8.755297
Length: 47522, dtype: float64
```

[73]:
```
submission = pd.read_csv("./dataset/sample_submission.csv")
```

[74]:
```
submission['Rating'] = predictions
```

[75]:
```
submission.to_csv('submission_svd.csv', index=False)
```

[76]:
```
# Grid search for best parameters
param_grid = {'n_epochs': [10, 100, 500], 'lr_all': [0.0005, 0.001, 0.005],␣
 ↪'reg_all': [0.01, 0.05, 0.1]}
```

[77]:
```
from surprise.model_selection import GridSearchCV as GridSearchCVSurprise

gs = GridSearchCVSurprise(SVD, param_grid, measures=['rmse'], cv=2, n_jobs=-1,␣
 ↪joblib_verbose=10)
```

[78]:
```
gs.fit(train_data_svd)
```

```
[Parallel(n_jobs=-1)]: Using backend LokyBackend with 10 concurrent workers.
[Parallel(n_jobs=-1)]: Done   5 tasks      | elapsed:    2.9s
[Parallel(n_jobs=-1)]: Done  12 tasks      | elapsed:    4.4s
[Parallel(n_jobs=-1)]: Done  21 tasks      | elapsed:   11.2s
[Parallel(n_jobs=-1)]: Done  30 tasks      | elapsed:   18.1s
[Parallel(n_jobs=-1)]: Done  41 out of  54 | elapsed:   48.1s remaining:   15.3s
[Parallel(n_jobs=-1)]: Done  47 out of  54 | elapsed:  1.1min remaining:   10.2s
[Parallel(n_jobs=-1)]: Done  54 out of  54 | elapsed:  1.2min finished
```

[79]:
```
# Get the best set of hyperparameters
best_params = gs.best_params['rmse']
print('Best RMSE:', gs.best_score['rmse'])
print('Best hyperparameters:', best_params)
```

```
Best RMSE: 1.6695733178557475
Best hyperparameters: {'n_epochs': 500, 'lr_all': 0.0005, 'reg_all': 0.1}
```

6 XGBoost

[80]:
```
train_data.head()
```

[80]:

	user_id	book_id	rating	title	author	year	publisher	age	country	region	age_missing
144978	49019	48902	5	unknown	unknown	1995.15562	unknown	0.0	malaysia	asia	True
52814	259486	83781	10	The Brethren	John Grisham	2000.00000	Island	30.0	portugal	europe	False
229011	75302	293333	9	Summerland	Michael Chabon	2002.00000	Miramax Kids	40.0	united states of america	americas	False
157957	137736	211866	8	paper Junie B Jones and the Yucky Blucky Frui…	Barbara Park	1995.00000	Random House Childrens Books	34.0	united states of america	americas	False
263928	59875	284366	9	Phantom Leader	Mark Berent	1992.00000	Jove Books	0.0	united states of america	americas	True

[81]:
```
test_data.head()
```

[81]:

	user_id	book_id	title
0	51757	112562	The Mists of Avalon
1	167329	233532	The BLACK ALBUM
2	115450	62910	Harry Potter and the Chamber of Secrets Book 2
3	71697	64447	The Wicca Handbook

```
4   255816    28554                                        Lily White

                  author    year     publisher   age  \
0  MARION ZIMMER BRADLEY  1987.0       Del Rey  43.0
1         Hanif Kureishi  1996.0      Scribner  27.0
2            J K Rowling  2000.0    Scholastic  38.0
3         Eileen Holland  2000.0  Weiser Books  63.0
4           Susan Isaacs  1997.0   HarperTorch  46.0

                    country    region  age_missing
0  united states of america  americas        False
1                  portugal    europe        False
2  united states of america  americas        False
3                     other     other        False
4  united states of america  americas        False
```

[82]:
```
train_xgb = train_data.copy()
test_xgb = test_data.copy()
```

[83]:
```
# convert the categorical columns to category type
encoder = LabelEncoder()
cat_cols = ['author', 'publisher', 'year', 'region', 'age_missing', 'country',␣
 ↪'user_id', 'book_id']
```

[84]:
```
scaler = MinMaxScaler()
num_cols = ['age']
```

[85]:
```
for col in cat_cols:
    train_xgb[col] = encoder.fit_transform(train_xgb[col])
    test_xgb[col] = encoder.fit_transform(test_xgb[col])
```

[86]:
```
train_xgb[num_cols] = scaler.fit_transform(train_xgb[num_cols])
test_xgb[num_cols] = scaler.fit_transform(test_xgb[num_cols])
```

[87]:
```
train_xgb.head()
```

[87]:
```
        user_id  book_id  rating  \
144978     9084    18000       5
52814     48384    30684      10
229011    13975   107905       9
157957    25491    77769       8
263928    11072   104616       9

                                                  title  author  year  \
144978                                          unknown   43578    80
52814                                      The Brethren   20927    85
229011                                       Summerland   29324    87
```

```
157957   paper Junie B Jones and the Yucky Blucky Frui…    3660    79
263928                                   Phantom Leader   27848    76

        publisher   age  country  region  age_missing
144978       8607  0.00       66       2            1
52814        4146  0.30       90       3            0
229011       5197  0.40      112       1            0
157957       6485  0.34      112       1            0
263928       4285  0.00      112       1            1
```

[88]:
```
X_train_xgb = train_xgb[['author', 'publisher', 'year', 'region',␣
 ↪'age_missing', 'country', 'user_id', 'book_id', 'age']]
y_train_xgb = train_xgb['rating']

X_test_xgb = test_xgb[['author', 'publisher', 'year', 'region', 'age_missing',␣
 ↪'country', 'user_id', 'book_id', 'age']]
```

[89]:
```
# train test split
X_train, X_val, y_train, y_val = train_test_split(X_train_xgb, y_train_xgb,␣
 ↪test_size=0.2, random_state=42)
```

[90]:
```
# train the model
xgb_model = XGBRegressor()
```

[91]:
```
xgb_model.fit(X_train, y_train)
```

[91]:
```
XGBRegressor(base_score=None, booster=None, callbacks=None,
             colsample_bylevel=None, colsample_bynode=None,
             colsample_bytree=None, early_stopping_rounds=None,
             enable_categorical=False, eval_metric=None, feature_types=None,
             gamma=None, gpu_id=None, grow_policy=None, importance_type=None,
             interaction_constraints=None, learning_rate=None, max_bin=None,
             max_cat_threshold=None, max_cat_to_onehot=None,
             max_delta_step=None, max_depth=None, max_leaves=None,
             min_child_weight=None, missing=nan, monotone_constraints=None,
             n_estimators=100, n_jobs=None, num_parallel_tree=None,
             predictor=None, random_state=None, …)
```

[92]:
```
# predict the ratings for the validation data
predictions = xgb_model.predict(X_val)
```

[93]:
```
predictions
```

[93]:
```
array([7.317499 , 7.210125 , 7.6401668, …, 7.540548 , 7.6343794,
       8.009657 ], dtype=float32)
```

[94]:
```
# Calculate the RMSE
rmse = sqrt(mean_squared_error(y_val, predictions))

print("RMSE: ", rmse)
```

```
RMSE:  1.7404442219110507
```

[95]:
```
# predict the ratings for the test data
predictions = xgb_model.predict(X_test_xgb)
```

[96]:
```
predictions
```

[96]:
```
array([7.3578234, 7.87281  , 7.331409 , …, 6.976823 , 7.3718224,
       7.229645 ], dtype=float32)
```

[97]:
```
submission = pd.read_csv("./dataset/sample_submission.csv")

submission['Rating'] = predictions

submission.to_csv('submission_xgb.csv', index=False)
```

7 XBG Classifier

[98]:
```
train_xgb.head()
```

[98]:

	user_id	book_id	rating	\
144978	9084	18000	5	
52814	48384	30684	10	
229011	13975	107905	9	
157957	25491	77769	8	
263928	11072	104616	9	

	title	author	year	\
144978	unknown	43578	80	
52814	The Brethren	20927	85	
229011	Summerland	29324	87	
157957	paper Junie B Jones and the Yucky Blucky Frui…	3660	79	
263928	Phantom Leader	27848	76	

	publisher	age	country	region	age_missing
144978	8607	0.00	66	2	1
52814	4146	0.30	90	3	0
229011	5197	0.40	112	1	0
157957	6485	0.34	112	1	0
263928	4285	0.00	112	1	1

[99]:
```
test_xgb.head()
```

[99]:
```
   user_id  book_id                                          title  author  \
0      723    11823                          The Mists of Avalon    9779
1     2268    24515                              The BLACK ALBUM    5588
2     1601     6629  Harry Potter and the Chamber of Secrets Book 2    6181
3      992     6836                          The Wicca Handbook    4137
4     3544     3053                                  Lily White   14481

   year  publisher   age  country  region  age_missing
0    56        982  0.43       40       1            0
1    66       3037  0.27       32       3            0
2    70       3013  0.38       40       1            0
3    70       3651  0.63       29       5            0
4    67       1599  0.46       40       1            0
```

[100]:
```
xgb_clf = XGBClassifier()
```

[101]:
```
xgb_clf.fit(X_train, y_train-1) # subtract 1 to make the ratings start from 0 instead of 1 for the classifier
```

[101]:
```
XGBClassifier(base_score=None, booster=None, callbacks=None,
              colsample_bylevel=None, colsample_bynode=None,
              colsample_bytree=None, early_stopping_rounds=None,
              enable_categorical=False, eval_metric=None, feature_types=None,
              gamma=None, gpu_id=None, grow_policy=None, importance_type=None,
              interaction_constraints=None, learning_rate=None, max_bin=None,
              max_cat_threshold=None, max_cat_to_onehot=None,
              max_delta_step=None, max_depth=None, max_leaves=None,
              min_child_weight=None, missing=nan, monotone_constraints=None,
              n_estimators=100, n_jobs=None, num_parallel_tree=None,
              objective='multi:softprob', predictor=None, …)
```

[102]:
```
# predict the ratings for the validation data
predictions = xgb_clf.predict(X_val) + 1 # add 1 to make the ratings start from 1 instead of 0 for the classifier

predictions
```

[102]:
```
array([ 8,  8,  8, …,  8, 10,  8])
```

[103]:
```
# Calculate the RMSE

rmse = sqrt(mean_squared_error(y_val, predictions))

print("RMSE: ", rmse)
```

```
RMSE:  1.9821890632399612
```

[104]:
```
# predict the ratings for the test data
predictions = xgb_clf.predict(X_test_xgb) + 1

predictions
```

[104]:
```
array([ 7,  8, 10, …,  8,  7,  8])
```

[105]:
```
submission = pd.read_csv("./dataset/sample_submission.csv")

submission['Rating'] = predictions

submission.to_csv('submission_xgb_clf.csv', index=False)
```

8 Using the XGBClassifier output as input to the XGBRegressor

[106]:
```
X_train['xgb_rating'] = xgb_clf.predict(X_train) + 1
X_val['xgb_rating'] = xgb_clf.predict(X_val) + 1
```

[107]:
```
X_train.head()
```

[107]:

	author	publisher	year	region	age_missing	country	user_id	book_id	age	xgb_rating
88509	8349	6483	82	1	1	112	35991	73472	0.00	8
6464	37461	1078	76	1	1	112	22464	120683	0.00	5
132134	43578	8607	80	3	0	74	3697	75252	0.48	8
282212	35999	3617	83	5	0	81	29449	86671	0.29	10
127022	31093	3308	85	3	0	39	43404	46488	0.21	8

[108]:
```
X_val.head()
```

[108]:

	author	publisher	year	region	age_missing	country	user_id	book_id	age	xgb_rating
171815	23301	6651	81	1	1	112	4543	23449	0.00	8
221523	34788	6310	78	1	1	112	17226	100589	0.00	8
290984	20563	992	75	3	0	102	32045	41002	0.41	8
290734	34709	360	84	1	0	21	40066			
215368	34762	8081	84	1	0	112	30635			

```
290734    20077  0.49          10
215368    33782  0.49           8
```

[109]:
```
# train the model
xgb_model = XGBRegressor()
```

[110]:
```
xgb_model.fit(X_train, y_train)
```

[110]:
```
XGBRegressor(base_score=None, booster=None, callbacks=None,
             colsample_bylevel=None, colsample_bynode=None,
             colsample_bytree=None, early_stopping_rounds=None,
             enable_categorical=False, eval_metric=None, feature_types=None,
             gamma=None, gpu_id=None, grow_policy=None, importance_type=None,
             interaction_constraints=None, learning_rate=None, max_bin=None,
             max_cat_threshold=None, max_cat_to_onehot=None,
             max_delta_step=None, max_depth=None, max_leaves=None,
             min_child_weight=None, missing=nan, monotone_constraints=None,
             n_estimators=100, n_jobs=None, num_parallel_tree=None,
             predictor=None, random_state=None, …)
```

[111]:
```
# predict the ratings for the validation data
predictions = xgb_model.predict(X_val)
predictions
```

[111]:
```
array([7.3600583, 7.3082237, 7.437581 , …, 7.210776 , 8.069264 ,
       7.552676 ], dtype=float32)
```

[112]:
```
# Calculate the RMSE
rmse = sqrt(mean_squared_error(y_val, predictions))
print("RMSE: ", rmse)
```

```
RMSE:  1.7510146228534578
```

[113]:
```
X_test_xgb['xgb_rating'] = xgb_clf.predict(X_test_xgb) + 1
```

[114]:
```
# predict the ratings for the test data
predictions = xgb_model.predict(X_test_xgb)
```

[115]:
```
predictions
```

[115]:
```
array([7.47733  , 7.6546597, 8.46654  , …, 7.0320435, 7.406923 ,
       7.650448 ], dtype=float32)
```

[116]:
```
submission = pd.read_csv("./dataset/sample_submission.csv")
```

[117]:
```
submission['Rating'] = predictions

submission.to_csv('submission_xgb_clf_xgb_reg.csv', index=False)
```

9 Grid search for best parameters for the XGBRegressor

[118]:
```
# drop the xgb_rating column
X_train.drop('xgb_rating', axis=1, inplace=True)
X_val.drop('xgb_rating', axis=1, inplace=True)
```

[119]:
```
param_grid = {'n_estimators': [1000, 5000], 'learning_rate': [0.05, 0.1, 0.15],␣
↪'max_depth': [7]}
```

[120]:
```
gs = GridSearchCV(xgb_model, param_grid, scoring='neg_mean_squared_error',␣
↪cv=2, n_jobs=-1, verbose=10)
```

[121]:
```
gs.fit(X_train, y_train)
```

```
Fitting 2 folds for each of 6 candidates, totalling 12 fits
[CV 2/2; 5/6] START learning_rate=0.15, max_depth=7, n_estimators=1000…
[CV 2/2; 5/6] END learning_rate=0.15, max_depth=7, n_estimators=1000;,
score=-3.002 total time= 1.3min
[CV 1/2; 5/6] START learning_rate=0.15, max_depth=7, n_estimators=1000…
[CV 1/2; 5/6] END learning_rate=0.15, max_depth=7, n_estimators=1000;,
score=-3.000 total time= 1.3min
[CV 1/2; 3/6] START learning_rate=0.1, max_depth=7, n_estimators=1000…
[CV 1/2; 3/6] END learning_rate=0.1, max_depth=7, n_estimators=1000;,
score=-2.984 total time= 1.3min
[CV 2/2; 3/6] START learning_rate=0.1, max_depth=7, n_estimators=1000…
[CV 2/2; 3/6] END learning_rate=0.1, max_depth=7, n_estimators=1000;,
score=-2.990 total time= 1.3min
```

[121]:
```
GridSearchCV(cv=2,
             estimator=XGBRegressor(base_score=None, booster=None,
                                    callbacks=None, colsample_bylevel=None,
                                    colsample_bynode=None,
                                    colsample_bytree=None,
                                    early_stopping_rounds=None,
                                    enable_categorical=False, eval_metric=None,
                                    feature_types=None, gamma=None, gpu_id=None,
                                    grow_policy=None, importance_type=None,
                                    interaction_constraints=None,
                                    learning_rate=None, m…
                                    max_cat_to_onehot=None, max_delta_step=None,
                                    max_depth=None, max_leaves=None,
                                    min_child_weight=None, missing=nan,
                                    monotone_constraints=None, n_estimators=100,
                                    n_jobs=None, num_parallel_tree=None,
                                    predictor=None, random_state=None, …),
             n_jobs=-1,
             param_grid={'learning_rate': [0.05, 0.1, 0.15], 'max_depth': [7],
                         'n_estimators': [1000, 5000]},
```

```
                    scoring='neg_mean_squared_error', verbose=10)
```

[122]:
```
# Get the best set of hyperparameters
best_params = gs.best_params_
print('Best RMSE:', sqrt(-gs.best_score_))
print('Best hyperparameters:', best_params)
```

```
Best RMSE: 1.7283323784695503
Best hyperparameters: {'learning_rate': 0.1, 'max_depth': 7, 'n_estimators':
1000}
```

[123]:
```
# train the model
xgb_model = XGBRegressor(n_estimators=best_params['n_estimators'],␣
 ↪learning_rate=best_params['learning_rate'],␣
 ↪max_depth=best_params['max_depth'])
```

[124]:
```
X_train['xgb_clf_rating'] = xgb_clf.predict(X_train) + 1
X_val['xgb_clf_rating'] = xgb_clf.predict(X_val) + 1

X_train['svd_rating'] = X_train.apply(lambda row: svd.predict(row['user_id'],␣
 ↪row['book_id']).est, axis=1)
X_val['svd_rating'] = X_val.apply(lambda row: svd.predict(row['user_id'],␣
 ↪row['book_id']).est, axis=1)
```

[125]:
```
# scale the ratings
X_train['svd_rating'] = scaler.fit_transform(X_train['svd_rating'].values.
 ↪reshape(-1, 1))
X_val['svd_rating'] = scaler.fit_transform(X_val['svd_rating'].values.
 ↪reshape(-1, 1))

X_train['xgb_clf_rating'] = scaler.fit_transform(X_train['xgb_clf_rating'].
 ↪values.reshape(-1, 1))
X_val['xgb_clf_rating'] = scaler.fit_transform(X_val['xgb_clf_rating'].values.
 ↪reshape(-1, 1))
```

[126]:
```
xgb_model.fit(X_train, y_train)
```

[126]:
```
XGBRegressor(base_score=None, booster=None, callbacks=None,
             colsample_bylevel=None, colsample_bynode=None,
             colsample_bytree=None, early_stopping_rounds=None,
             enable_categorical=False, eval_metric=None, feature_types=None,
             gamma=None, gpu_id=None, grow_policy=None, importance_type=None,
             interaction_constraints=None, learning_rate=0.1, max_bin=None,
             max_cat_threshold=None, max_cat_to_onehot=None,
             max_delta_step=None, max_depth=7, max_leaves=None,
             min_child_weight=None, missing=nan, monotone_constraints=None,
             n_estimators=1000, n_jobs=None, num_parallel_tree=None,
             predictor=None, random_state=None, …)
```

[127]:
```
# predict the ratings for the validation data
predictions = xgb_model.predict(X_val)
predictions
```

[127]:
```
array([7.2960134, 7.071744 , 8.0080805, …, 7.3103766, 7.946098 ,
       7.6988373], dtype=float32)
```

[128]:
```
# Calculate the RMSE
rmse = sqrt(mean_squared_error(y_val, predictions))
print("RMSE: ", rmse)
```

```
RMSE:  1.732692037237727
```

[129]:
```
X_test_xgb.drop('xgb_rating', axis=1, inplace=True)
```

[130]:
```
X_test_xgb['xgb_clf_rating'] = xgb_clf.predict(X_test_xgb) + 1
X_test_xgb['svd_rating'] = X_test_xgb.apply(lambda row: svd.
 ↪predict(row['user_id'], row['book_id']).est, axis=1)
```

[131]:
```
# scale the ratings
X_test_xgb['svd_rating'] = scaler.fit_transform(X_test_xgb['svd_rating'].values.
 ↪reshape(-1, 1))
X_test_xgb['xgb_clf_rating'] = scaler.
 ↪fit_transform(X_test_xgb['xgb_clf_rating'].values.reshape(-1, 1))
```

[132]:
```
# predict the ratings for the test data
predictions = xgb_model.predict(X_test_xgb)
predictions
```

[132]:
```
array([6.276332 , 7.56016  , 8.276598 , …, 6.1802816, 7.1553493,
       7.3081765], dtype=float32)
```

[133]:
```
submission = pd.read_csv("./dataset/sample_submission.csv")

submission['Rating'] = predictions

submission.to_csv('submission_xgb_clf_svd_xgb_reg.csv', index=False)
```

[134]:
```
# average rating of SVD and XGBRegressor
submission_xgb = pd.read_csv('submission_xgb.csv')
submission_svd = pd.read_csv('submission_svd.csv')

submission['Rating'] = (submission_xgb['Rating'] + submission_svd['Rating']) / 2

submission.to_csv('submission_xgb_svd_avg.csv', index=False)
```

[135]:
```
# average rating of SVD, XGBClassifier and XGBRegressor
submission_xgb_clf = pd.read_csv('submission_xgb_clf.csv')
```

```
submission['Rating'] = (submission_xgb['Rating'] * 0.3 +␣
 ↪submission_svd['Rating'] * 0.4 + submission_xgb_clf['Rating'] * 0.3)

submission.to_csv('submission_xgb_svd_xgb_clf_avg.csv', index=False)
```

[136]:
```
# average rating of SVD, XGBClassifier
submission_xgb_clf = pd.read_csv('submission_xgb_clf.csv')

submission['Rating'] = (submission_svd['Rating'] * 0.6 +␣
 ↪submission_xgb_clf['Rating'] * 0.4)

submission.to_csv('submission_svd_xgb_clf_weighted_avg.csv', index=False)
```

[137]:
```
# average rating of SVD, XGBClassifier
submission_xgb_clf = pd.read_csv('submission_xgb_clf.csv')

submission['Rating'] = (submission_svd['Rating'] +␣
 ↪submission_xgb_clf['Rating']) / 2

submission.to_csv('submission_svd_xgb_clf_avg.csv', index=False)
```

[138]:
```
from math import floor, ceil

def round_rating_to_nearest_even(rating):
    """
    7.36 -> 7
    7.64 -> 7.5
    7.5 -> 7.5
    6.5 -> 6.5
    6.4 -> 6
    6.6 -> 7
    """
    if rating % 1 == 0:
        return rating
    elif 0 < rating % 1 <= 0.25:
        return floor(rating)
    elif 0.25 < rating % 1 <= 0.75:
        return floor(rating) + 0.5
    else:
        return ceil(rating)
```

[139]:
```
submission['Rating'] = submission_svd['Rating'].
 ↪apply(round_rating_to_nearest_even)

submission.to_csv('submission_svd_rounded.csv', index=False)
```

[139]: