Quora Question Pairs

Introduction

Quora is a platform for Q&A, just like StackOverflow. But quora is more of a general-purpose Q&A platform that means there is not much code like in StackOverflow.

One of the many problems that quora face is the duplication of questions. Duplication of question ruins the experience for both the questioner and the answerer. Since the questioner is asking a duplicate question, we can just show him/her the answers to the previous question. And the answerer doesn't have to repeat his/her answer for essentially the same questions.

For example, we have a question like "How can I be a good geologist?" and there are some answers to that question. Later someone else asks another question like "What should I do to be a great geologist?". We can see that both the questions are asking the same thing. Even though the wordings for the question are different, the intention of both questions is same. So the answers will be same for both questions. That means we can just show the answers of the first question. That way the person who is asking the question will get the answers immediately and people who have answered already the first question don't have to repeat themselves.

This problem is available on Kaggle as a competition. https://www.kaggle.com/c/quora-question-pairs

Business Objectives and Constraints

- There is no strict latency requirement.
- We would like to have interpretability but it is not absolutely mandatory.
- The cost of misclassification is medium.
- Both classes (duplicate or not) are equally important.

Data Overview

```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
import os
from nltk.corpus import stopwords
from nltk.stem import WordNetLemmatizer
from bs4 import BeautifulSoup
import re
from fuzzywuzzy import fuzz
```

```
from sklearn.feature_extraction.text import TfidfVectorizer
from scipy import sparse
from sklearn.preprocessing import StandardScaler
from imblearn.over_sampling import RandomOverSampler
from sklearn.model_selection import train_test_split
from sklearn.linear_model import LogisticRegression
from sklearn.metrics import confusion_matrix, log_loss
from sklearn.calibration import CalibratedClassifierCV
import xgboost as xgb
import nltk
import time
from matplotlib.pyplot import figure
from sentence_transformers import SentenceTransformer
from sklearn.preprocessing import MinMaxScaler
from joblib import dump, load
from sklearn.experimental import enable_halving_search_cv
from sklearn.model_selection import HalvingGridSearchCV
from sklearn.model_selection import ShuffleSplit
from sklearn.svm import LinearSVC
from sklearn.ensemble import RandomForestClassifier
import xgboost as xgb
# import optuna
import hyperopt
from hyperopt import fmin, tpe, hp, STATUS_OK, Trials
import warnings
import gc
from sklearn.model_selection import cross_val_score
nltk.download('wordnet')
nltk.download('stopwords')
nltk.download('punkt')
```

```
[nltk_data] Downloading package wordnet to /home/sanjay/nltk_data...
[nltk_data]   Package wordnet is already up-to-date!
[nltk_data] Downloading package stopwords to /home/sanjay/nltk_data...
[nltk_data]   Package stopwords is already up-to-date!
[nltk_data] Downloading package punkt to /home/sanjay/nltk_data...
[nltk_data]   Package punkt is already up-to-date!
```

```
True
```

```
!pip install -U -q PyDrive
```

```
from pydrive.auth import GoogleAuth
from pydrive.drive import GoogleDrive
from google.colab import auth
from oauth2client.client import GoogleCredentials
```

```
auth.authenticate_user()
gauth= GoogleAuth()
gauth.credentials = GoogleCredentials.get_application_default()
drive = GoogleDrive(gauth)
```

```
downloaded = drive.CreateFile({'id': '1X_iFz5blnMDEs0PoaPjaW4D-
fG_WnSVQ'})
downloaded.GetContentFile('train.csv')

data = pd.read_csv('train.csv')

print(data.columns)
print(data.is_duplicate.unique())
print(data.is_duplicate.value_counts())
print(data.shape)
```

```
Index(['id', 'qid1', 'qid2', 'question1', 'question2',
'is_duplicate'], dtype='object')
[0 1]
0    255027
1    149263
Name: is_duplicate, dtype: int64
(404290, 6)
```

Available Columns : id, qid1, qid2, question1, question2, is_duplicate Class labels : 0, 1 Total training data / No. of rows : 404290 No. of columns : 6 **is_duplicate** is the dependent variable. No. of non-duplicate data points is 255027 No. of duplicate data points is 149263

We have **404290** training data points. And only **36.92%** are positive. That means it is an imbalanced dataset.

Business Metrics

It is a binary classification.

- We need to minimize the log loss for this challenge.

Basic EDA

```
testdata = pd.read_csv('test.csv')
print(testdata.shape)
```

```
(2345796, 3)
```

```
data.head(5)
```

```
   id  qid1  qid2
question1  \
0   0     1     2  What is the step by step guide to invest in sh...

1   1     3     4  What is the story of Kohinoor (Koh-i-Noor) Dia...

2   2     5     6  How can I increase the speed of my internet co...

3   3     7     8  Why am I mentally very lonely? How can I solve...
```

```
4   4     9    10  Which one dissolve in water quikly sugar, salt...
```

```
                                           question2  is_duplicate
0  What is the step by step guide to invest in sh...             0
1  What would happen if the Indian government sto...             0
2  How can Internet speed be increased by hacking...             0
3  Find the remainder when [math]23^{24}[/math] i...             0
4           Which fish would survive in salt water?              0
```

```
testdata.head(5)
```

```
   test_id                                          question1  \
0        0  How does the Surface Pro himself 4 compare wit...
1        1  Should I have a hair transplant at age 24? How...
2        2  What but is the best way to send money from Ch...
3        3                         Which food not emulsifiers?
4        4                  How "aberystwyth" start reading?

                                           question2
0  Why did Microsoft choose core m3 and not core ...
1        How much cost does hair transplant require?
2                     What you send money to China?
3                                What foods fibre?
4                    How their can I start reading?
```

Test data don't have question ids. So the independent variables are **question1**, **question2** and the dependent variable is **is_duplicate**.

```
data.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 404290 entries, 0 to 404289
Data columns (total 6 columns):
 #   Column        Non-Null Count   Dtype 
---  ------        --------------   ----- 
 0   id            404290 non-null  int64 
 1   qid1          404290 non-null  int64 
 2   qid2          404290 non-null  int64 
 3   question1     404289 non-null  object
 4   question2     404288 non-null  object
 5   is_duplicate  404290 non-null  int64 
dtypes: int64(4), object(2)
memory usage: 18.5+ MB
```

```
data = data.dropna()
print(data.shape)
```

```
(404287, 6)
```

```
print(data.duplicated(('question1', 'question2')).sum())
```

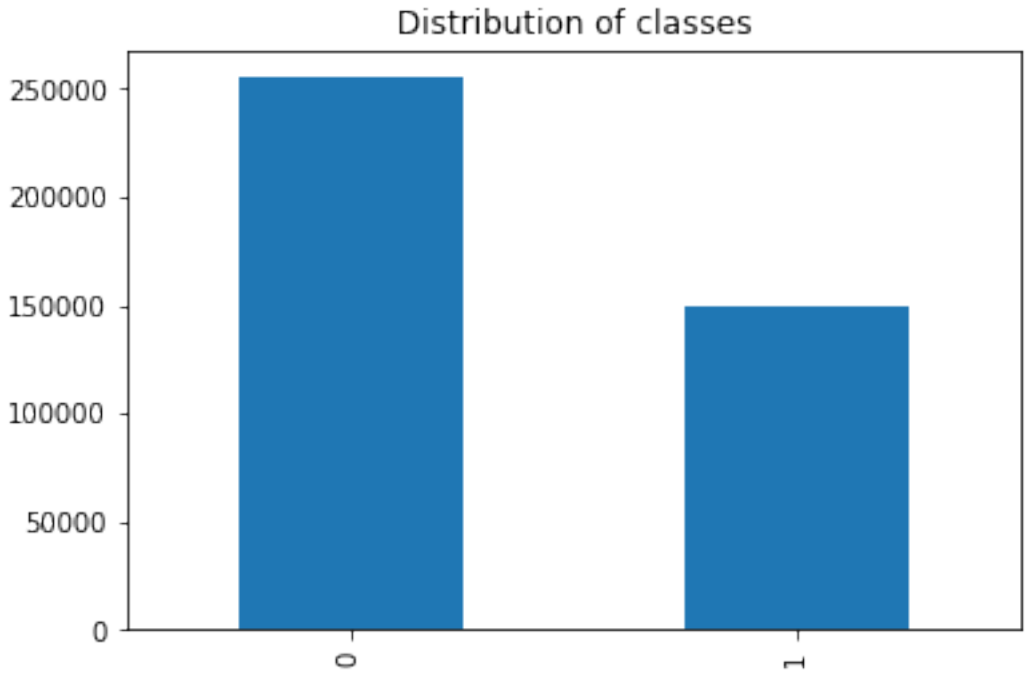
```
0
```

3 rows had null values. So We removed them and now We have **404287** question pairs.

```
duplicate_value_counts = data.is_duplicate.value_counts()
print(duplicate_value_counts/duplicate_value_counts.sum())
plt.title('Distribution of classes')
duplicate_value_counts.plot.bar()
```

```
0    0.630799
1    0.369201
Name: is_duplicate, dtype: float64
```

```
<AxesSubplot:title={'center':'Distribution of classes'}>
```



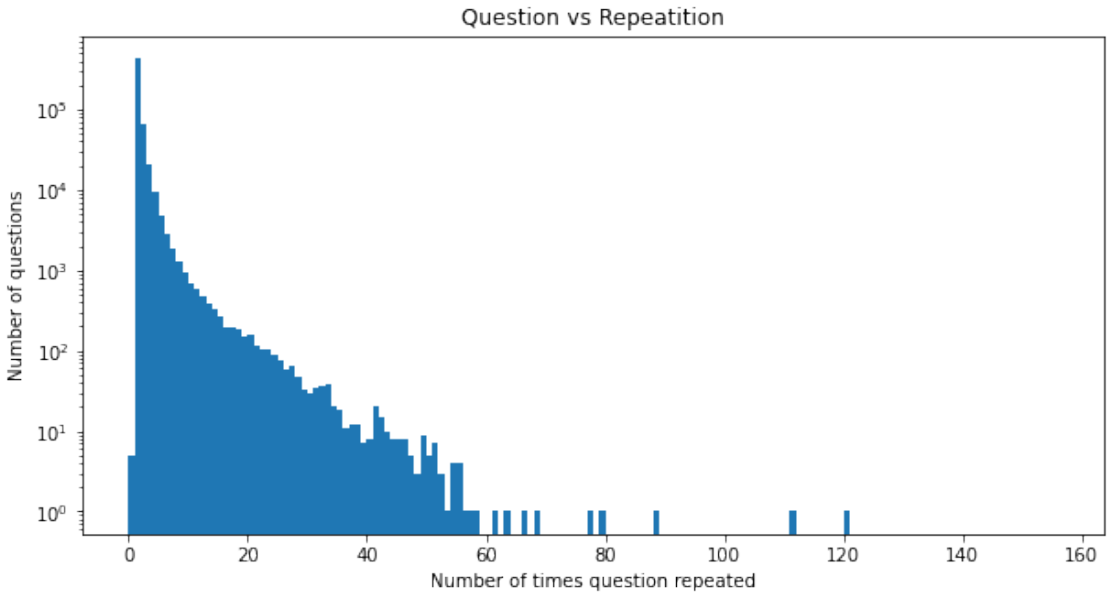
36.92% of question pairs are duplicates and **63.08%** of questions pair non-duplicate.

```
qids = np.append(data.qid1.values,data.qid2.values)
print(len(set(qids)))
print(len(qids))
```

```
537929
808574
```

```
occurences = np.bincount(qids)
plt.figure(figsize=(10,5))
plt.hist(occurences, bins=range(0,np.max(occurences)))
plt.yscale('log')
plt.xlabel('Number of times question repeated')
```

```
plt.ylabel('Number of questions')
plt.title('Question vs Repeatition')
plt.show()
print(np.min(occurences), np.max(occurences))
```




```
0 157
```

- Out of **808574** total questions (including both question1 and question2), **537929** are unique.
- Most of the questions are repeated very few times. Only a few of them are repeated multiple times.
- One question is repeated **157** times which is the max number of repetitions.

```
print(data.question1.apply(len).min())
print(data.loc[data.question1.apply(len).argmin()])
print(data.question2.apply(len).min())
print(data.loc[data.question2.apply(len).argmin()])
```

```
1
id                                                          3306
qid1                                                        6553
qid2                                                        6554
question1                                                      .
question2       Why is Cornell's endowment the lowest in the I...
is_duplicate                                                   0
Name: 3306, dtype: object
1
id                                                         47056
qid1                                                       84067
qid2                                                       84068
question1       Is there anywhere in the world offering pain m...
question2                                                      ?
```

```
is_duplicate                                                    0
Name: 47056, dtype: object
```

There are some questions with very few characters, which does not make sense. It will be taken care of later with Data Cleaning.

Data Cleaning

```
def preprocess_text(x):
    x = str(x).lower()
    x = x.replace(",000,000", "m").replace(",000", "k").replace("´",
"'").replace("’", "'")\
                           .replace("won't", "will
not").replace("cannot", "can not").replace("can't", "can not")\
                           .replace("n't", " not").replace("what's",
"what is").replace("it's", "it is")\
                           .replace("'ve", " have").replace("i'm", "i
am").replace("'re", " are")\
                           .replace("he's", "he is").replace("she's",
"she is").replace("'s", " own")\
                           .replace("%", " percent ").replace("₹", "
rupee ").replace("$", " dollar ")\
                           .replace("€", " euro ").replace("'ll", "
will")
    x = re.sub(r"([0-9]+)000000", r"\1m", x)
    x = re.sub(r"([0-9]+)000", r"\1k", x)
    x = re.sub(r"http\S+", "", x)
    x = re.sub('\W', ' ', x)

    lemmatizer = WordNetLemmatizer()
    x = lemmatizer.lemmatize(x)
    bfs = BeautifulSoup(x)
    x = bfs.get_text()
    x = x.strip()
    return x

def data_cleaning(data):
    newdata = pd.DataFrame()
    newdata['question1_final'] = data.question1.apply(preprocess_text)
    newdata['question2_final'] = data.question2.apply(preprocess_text)
    return newdata

traindata = data_cleaning(data)

testdata = data_cleaning(testdata)

print(data.head())
```

```
   id  qid1  qid2
question1  \
0   0     1     2  What is the step by step guide to invest in sh...
```

```
1   1     3     4  What is the story of Kohinoor (Koh-i-Noor) Dia...

2   2     5     6  How can I increase the speed of my internet co...

3   3     7     8  Why am I mentally very lonely? How can I solve...

4   4     9    10  Which one dissolve in water quikly sugar, salt...


                                                 question2  is_duplicate
0  What is the step by step guide to invest in sh...             0
1  What would happen if the Indian government sto...             0
2  How can Internet speed be increased by hacking...             0
3  Find the remainder when [math]23^{24}[/math] i...             0
4           Which fish would survive in salt water?              0

print(traindata.head())

                                      question1_final  \
0  what is the step by step guide to invest in sh...
1  what is the story of kohinoor  koh i noor  dia...
2  how can i increase the speed of my internet co...
3  why am i mentally very lonely  how can i solve it
4  which one dissolve in water quikly sugar  salt...

                                      question2_final
0  what is the step by step guide to invest in sh...
1  what would happen if the indian government sto...
2  how can internet speed be increased by hacking...
3  find the remainder when  math 23  24   math  i...
4            which fish would survive in salt water
```

- We have converted everything to lower case.
- We have removed contractions.
- We have replaced currency symbols with currency names.
- We have also removed hyperlinks.
- We have removed non-alphanumeric characters.
- We have removed inflections with word lemmatizer.
- We have also removed HTML tags.

Feature Extraction

```
def doesMatch (q, match):
    q1, q2 = q['question1_final'], q['question2_final']
    q1 = q1.split()
    q2 = q2.split()
    if len(q1)>0 and len(q2)>0 and q1[match]==q2[match]:
```

```
        return 1
    else:
        return 0

def feature_extract(data):
    data['q1_char_num'] = data.question1_final.apply(len)
    data['q2_char_num'] = data.question2_final.apply(len)
    data['q1_word_num'] = data.question1_final.apply(lambda x:
len(x.split()))
    data['q2_word_num'] = data.question2_final.apply(lambda x:
len(x.split()))

    data['total_word_num'] = data['q1_word_num'] + data['q2_word_num']
    data['differ_word_num'] = abs(data['q1_word_num'] -
data['q2_word_num'])
    data['same_first_word'] = data.apply(lambda x: doesMatch(x,
0) ,axis=1)
    data['same_last_word'] = data.apply(lambda x: doesMatch(x, -
1) ,axis=1)
    data['total_unique_word_num'] = data.apply(lambda x:
len(set(x.question1_final.split()).union(set(x.question2_final.split()
))) ,axis=1)
    data['total_unique_word_withoutstopword_num'] = data.apply(lambda
x:
len(set(x.question1_final.split()).union(set(x.question2_final.split()
)) - set(stopwords.words('english'))) ,axis=1)
    data['total_unique_word_num_ratio'] =
data['total_unique_word_num'] / data['total_word_num']

    data['common_word_num'] = data.apply(lambda x:
len(set(x.question1_final.split()).intersection(set(x.question2_final.
split()))) ,axis=1)
    data['common_word_ratio'] = data['common_word_num'] /
data['total_unique_word_num']
    data['common_word_ratio_min'] = data['common_word_num'] /
data.apply(lambda x: min(len(set(x.question1_final.split())),
len(set(x.question2_final.split()))) ,axis=1)
    data['common_word_ratio_max'] = data['common_word_num'] /
data.apply(lambda x: max(len(set(x.question1_final.split())),
len(set(x.question2_final.split()))) ,axis=1)

    data['common_word_withoutstopword_num'] = data.apply(lambda x:
len(set(x.question1_final.split()).intersection(set(x.question2_final.
split())) - set(stopwords.words('english'))) ,axis=1)
    data['common_word_withoutstopword_ratio'] =
data['common_word_withoutstopword_num'] /
data['total_unique_word_withoutstopword_num']
    data['common_word_withoutstopword_ratio_min'] =
data['common_word_withoutstopword_num'] / data.apply(lambda x:
min(len(set(x.question1_final.split()) -
```

```
set(stopwords.words('english'))), len(set(x.question2_final.split()) -
set(stopwords.words('english')))) ,axis=1)
    data['common_word_withoutstopword_ratio_max'] =
data['common_word_withoutstopword_num'] / data.apply(lambda x:
max(len(set(x.question1_final.split()) -
set(stopwords.words('english'))), len(set(x.question2_final.split()) -
set(stopwords.words('english')))) ,axis=1)

    data["fuzz_ratio"] = data.apply(lambda x:
fuzz.ratio(x.question1_final, x.question2_final), axis=1)
    data["fuzz_partial_ratio"] = data.apply(lambda x:
fuzz.partial_ratio(x.question1_final, x.question2_final), axis=1)
    data["fuzz_token_set_ratio"] = data.apply(lambda x:
fuzz.token_set_ratio(x.question1_final, x.question2_final), axis=1)
    data["fuzz_token_sort_ratio"] = data.apply(lambda x:
fuzz.token_sort_ratio(x.question1_final, x.question2_final), axis=1)
    data.fillna(0, inplace=True)
    return data
```

FuzzyWuzzy uses Levenshtein Distance to calculate the differences between sequences.
https://github.com/seatgeek/fuzzywuzzy

```
traindata = feature_extract(traindata)

testdata = feature_extract(testdata)

traindata.head()
```

```
                                    question1_final  \
0  what is the step by step guide to invest in sh...
1  what is the story of kohinoor  koh i noor  dia...
2  how can i increase the speed of my internet co...
3  why am i mentally very lonely  how can i solve it
4  which one dissolve in water quikly sugar  salt...

                                    question2_final  q1_char_num  \
0  what is the step by step guide to invest in sh...           65
1  what would happen if the indian government sto...           50
2  how can internet speed be increased by hacking...           72
3  find the remainder when  math 23  24   math  i...           49
4            which fish would survive in salt water            75

   q2_char_num  q1_word_num  q2_word_num  total_word_num
differ_word_num  \
0           56           14           12              26
2
1           87           10           15              25
5
2           58           14           10              24
4
3           64           11           13              24
```

```
2
4           38           13            7              20
6

   same_first_word  same_last_word  ...  common_word_ratio_min  \
0                1               0  ...               1.000000
1                1               0  ...               0.700000
2                1               0  ...               0.400000
3                0               0  ...               0.000000
4                1               0  ...               0.571429

   common_word_ratio_max  common_word_withoutstopword_num  \
0               0.916667                                5
1               0.500000                                4
2               0.285714                                2
3               0.000000                                0
4               0.307692                                2

   common_word_withoutstopword_ratio
common_word_withoutstopword_ratio_min  \
0                           0.833333
1.0
1                           0.363636
0.8
2                           0.222222
0.4
3                           0.000000
0.0
4                           0.153846
0.4

   common_word_withoutstopword_ratio_max  fuzz_ratio
fuzz_partial_ratio  \
0                               0.833333          93
100
1                               0.400000          66
74
2                               0.333333          54
53
3                               0.000000          35
39
4                               0.200000          46
55

   fuzz_token_set_ratio  fuzz_token_sort_ratio
0                   100                     93
1                    86                     63
2                    66                     66
3                    36                     36
4                    67                     47
```

```
[5 rows x 25 columns]
```

```
traindata.shape
```

```
(404287, 25)
```

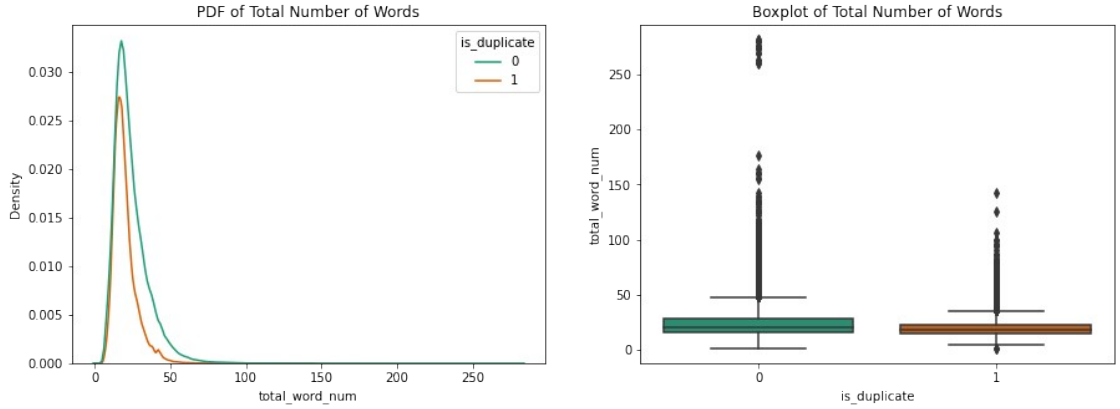
We have created **23** features from the questions.

- We have created features q1_word_num, q2_word_num with count of characters for both questions.
- We have created total_word_num feature which is equal to sum of q1_word_num and q2_word_num.
- We have created differ_word_num feature which is absolute difference between q1_word_num and q2_word_num.
- We have created same_first_word feature which is 1 if both questions have same first word otherwise 0.
- We have created same_last_word feature which is 1 if both questions have same last word otherwise 0.
- We have created total_unique_word_num feature which is equal to total number of unique words in both questions.
- We have created total_unique_word_withoutstopword_num feature which is equal to total number of unique words in both questions without the stop words.
- The total_unique_word_num_ratio is equal to total_unique_word_num divided by total_word_num.
- We have created common_word_num feature which is count of total common words in both questions.
- The common_word_ratio feature is equal to common_word_num divided by total_unique_word_num.
- The common_word_ratio_min is equal to common_word_num divided by minimum number of words between question 1 and question 2.
- The common_word_ratio_max is equal to common_word_num divided by maximum number of words between question 1 and question 2.
- We have created common_word_withoutstopword_num feature which is count of total common words in both questions excluding the stopwords.
- The common_word_withoutstopword_ratio feature is equal to common_word_withoutstopword_num divided by total_unique_word_withoutstopword_num.
- The common_word_withoutstopword_ratio_min is equal to common_word_withoutstopword_num divided by minimum number of words between question 1 and question 2 excluding the stopwords.
- The common_word_withoutstopword_ratio_max is equal to common_word_withoutstopword_num divided by maximum number of words between question 1 and question 2 excluding the stopwords.

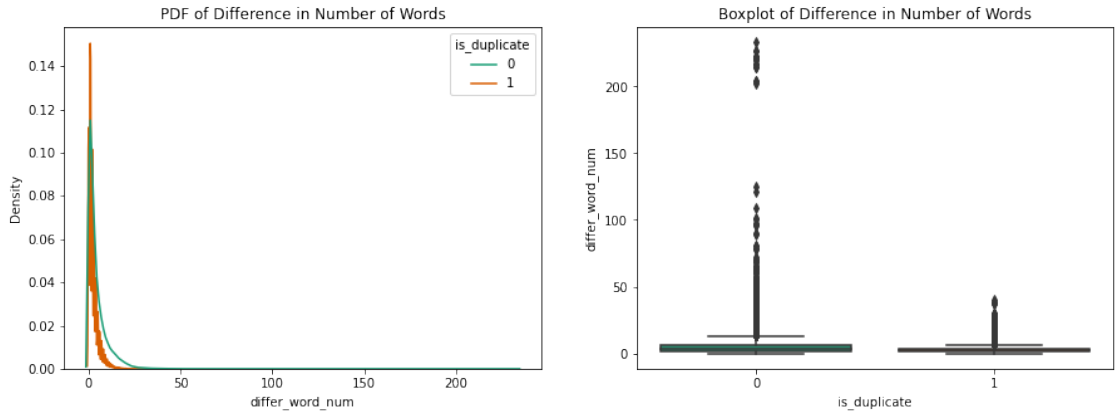
- Then we have extracted fuzz_ratio, fuzz_partial_ratio, fuzz_token_set_ratio and fuzz_token_sort_ratio features with fuzzywuzzy string matching tool. Reference: https://github.com/seatgeek/fuzzywuzzy

EDA with Features

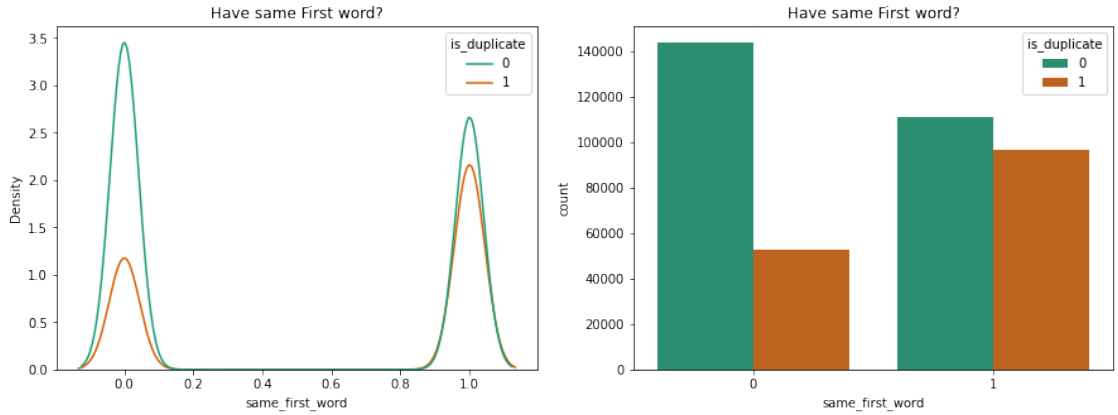
```
fig, ax =plt.subplots(1,2,figsize=(15,5))
ax[0].title.set_text('PDF of Total Number of Words')
sns.kdeplot(traindata['total_word_num'], hue=data.is_duplicate,
palette="Dark2", ax=ax[0])
ax[1].title.set_text('Boxplot of Total Number of Words')
sns.boxplot(x=data.is_duplicate, y=traindata['total_word_num'],
palette="Dark2", ax=ax[1])
plt.show()
```



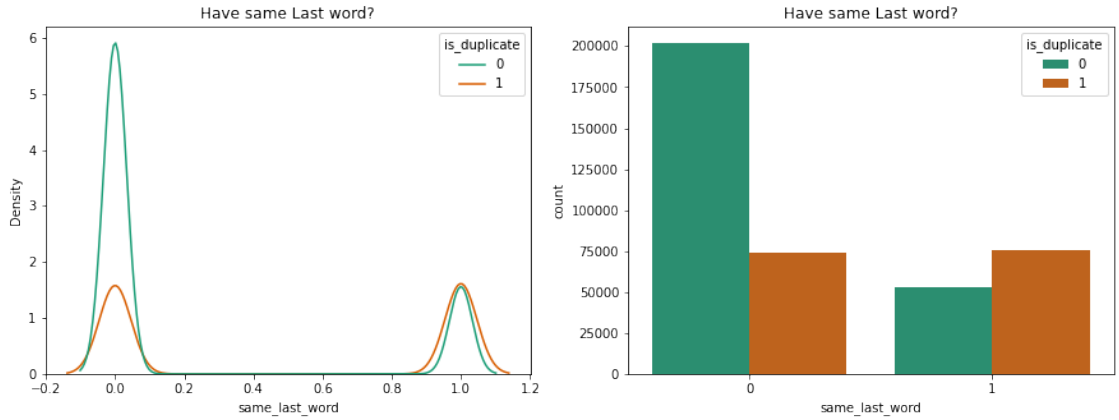

```
fig, ax =plt.subplots(1,2,figsize=(15,5))
ax[0].title.set_text('PDF of Difference in Number of Words')
sns.kdeplot(traindata['differ_word_num'], hue=data.is_duplicate,
palette="Dark2", ax=ax[0])
ax[1].title.set_text('Boxplot of Difference in Number of Words')
sns.boxplot(x=data.is_duplicate, y=traindata['differ_word_num'],
palette="Dark2", ax=ax[1])
plt.show()
```



```
fig, ax =plt.subplots(1,2,figsize=(15,5))
ax[0].title.set_text('Have same First word?')
sns.kdeplot(traindata['same_first_word'], hue=data.is_duplicate,
palette="Dark2", ax=ax[0])
ax[1].title.set_text('Have same First word?')
sns.countplot(x=traindata['same_first_word'], hue=data.is_duplicate,
palette="Dark2", ax=ax[1])
plt.show()
```

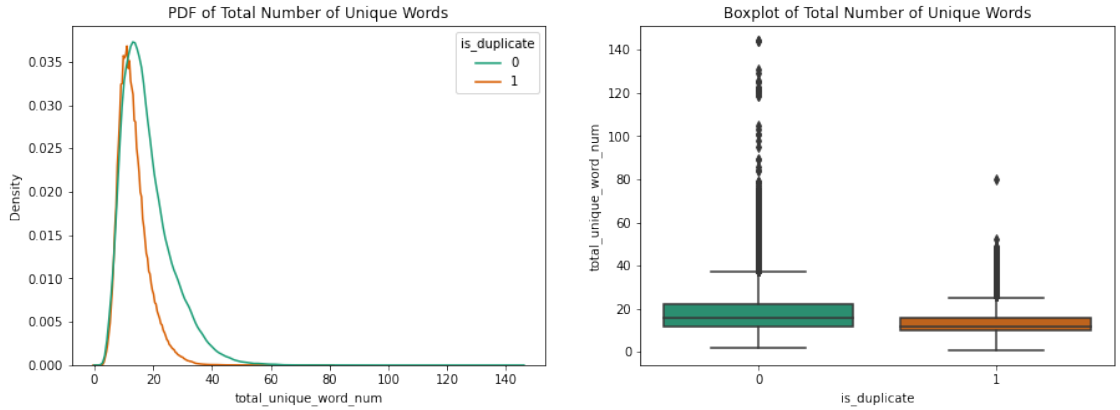



```
fig, ax =plt.subplots(1,2,figsize=(15,5))
ax[0].title.set_text('Have same Last word?')
sns.kdeplot(traindata['same_last_word'], hue=data.is_duplicate,
palette="Dark2", ax=ax[0])
ax[1].title.set_text('Have same Last word?')
sns.countplot(x=traindata['same_last_word'], hue=data.is_duplicate,
palette="Dark2", ax=ax[1])
plt.show()
```

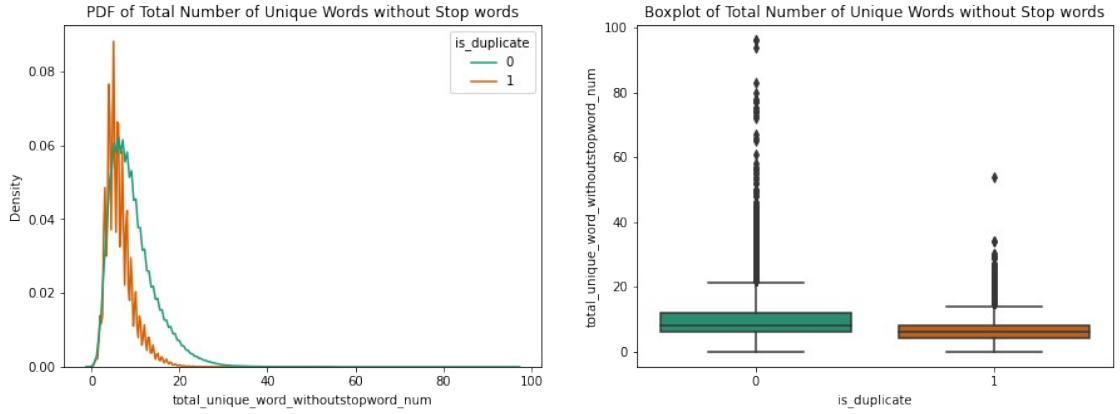



```
fig, ax =plt.subplots(1,2,figsize=(15,5))
ax[0].title.set_text('PDF of Total Number of Unique Words')
sns.kdeplot(traindata['total_unique_word_num'], hue=data.is_duplicate,
palette="Dark2", ax=ax[0])
ax[1].title.set_text('Boxplot of Total Number of Unique Words')
sns.boxplot(x=data.is_duplicate, y=traindata['total_unique_word_num'],
```

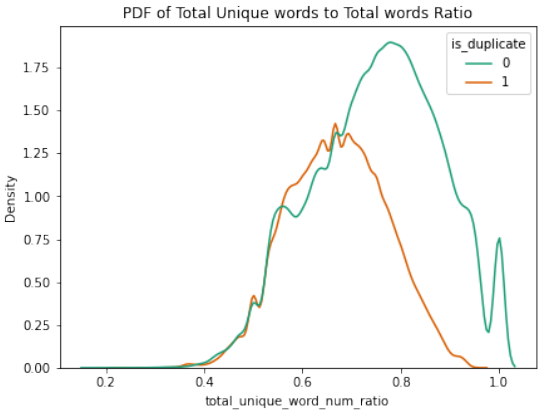
```
palette="Dark2", ax=ax[1])
plt.show()
```

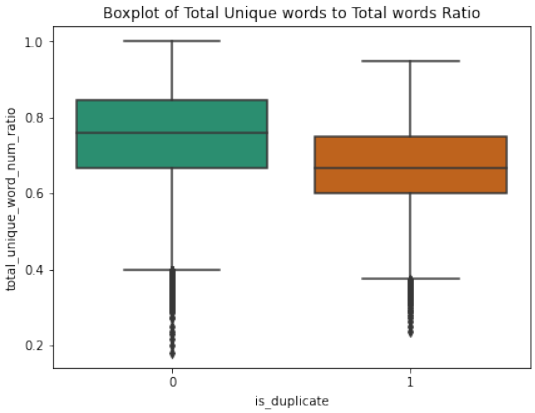



```
fig, ax =plt.subplots(1,2,figsize=(15,5))
ax[0].title.set_text('PDF of Total Number of Unique Words without Stop
words')
sns.kdeplot(traindata['total_unique_word_withoutstopword_num'],
hue=data.is_duplicate, palette="Dark2", ax=ax[0])
ax[1].title.set_text('Boxplot of Total Number of Unique Words without
Stop words')
sns.boxplot(x=data.is_duplicate,
y=traindata['total_unique_word_withoutstopword_num'], palette="Dark2",
ax=ax[1])
plt.show()
```

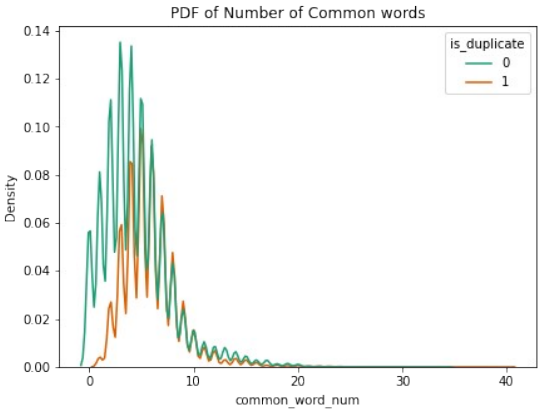


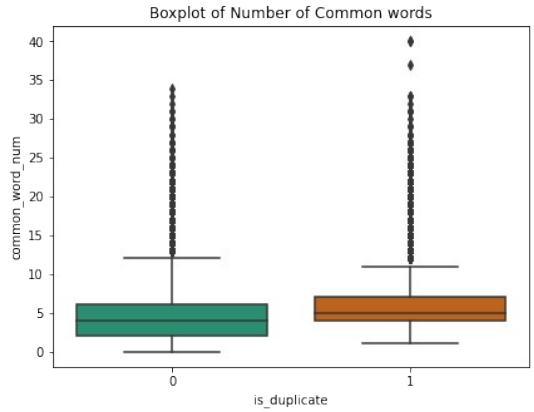

```
fig, ax =plt.subplots(1,2,figsize=(15,5))
ax[0].title.set_text('PDF of Total Unique words to Total words Ratio')
sns.kdeplot(traindata['total_unique_word_num_ratio'],
hue=data.is_duplicate, palette="Dark2", ax=ax[0])
ax[1].title.set_text('Boxplot of Total Unique words to Total words
Ratio')
sns.boxplot(x=data.is_duplicate,
y=traindata['total_unique_word_num_ratio'], palette="Dark2", ax=ax[1])
plt.show()
```



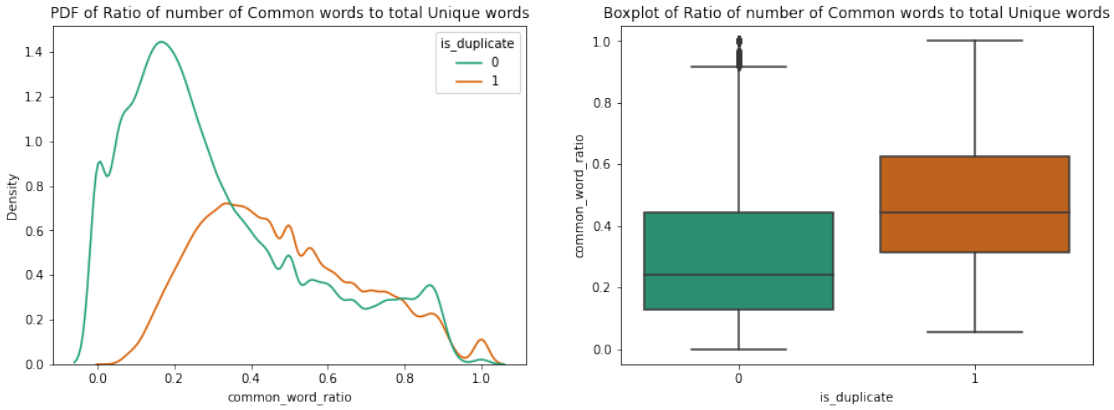



```
fig, ax =plt.subplots(1,2,figsize=(15,5))
ax[0].title.set_text('PDF of Number of Common words')
sns.kdeplot(traindata['common_word_num'], hue=data.is_duplicate,
palette="Dark2", ax=ax[0])
ax[1].title.set_text('Boxplot of Number of Common words')
sns.boxplot(x=data.is_duplicate, y=traindata['common_word_num'],
palette="Dark2", ax=ax[1])
plt.show()
```

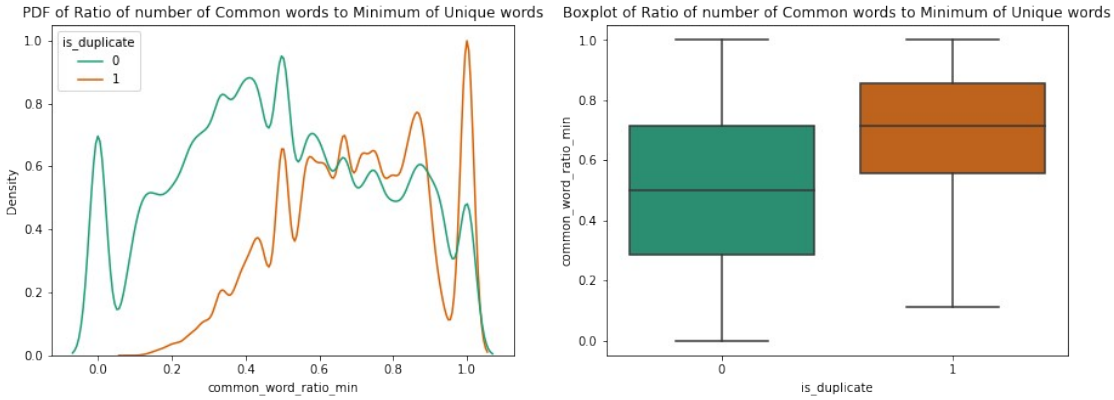




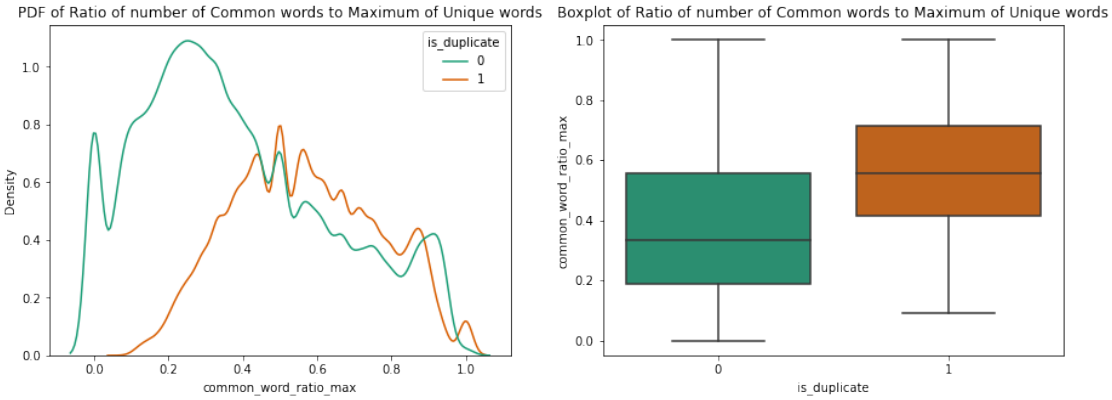

```
fig, ax =plt.subplots(1,2,figsize=(15,5))
ax[0].title.set_text('PDF of Ratio of number of Common words to total
Unique words')
sns.kdeplot(traindata['common_word_ratio'], hue=data.is_duplicate,
palette="Dark2", ax=ax[0])
ax[1].title.set_text('Boxplot of Ratio of number of Common words to
total Unique words')
sns.boxplot(x=data.is_duplicate, y=traindata['common_word_ratio'],
palette="Dark2", ax=ax[1])
plt.show()
```



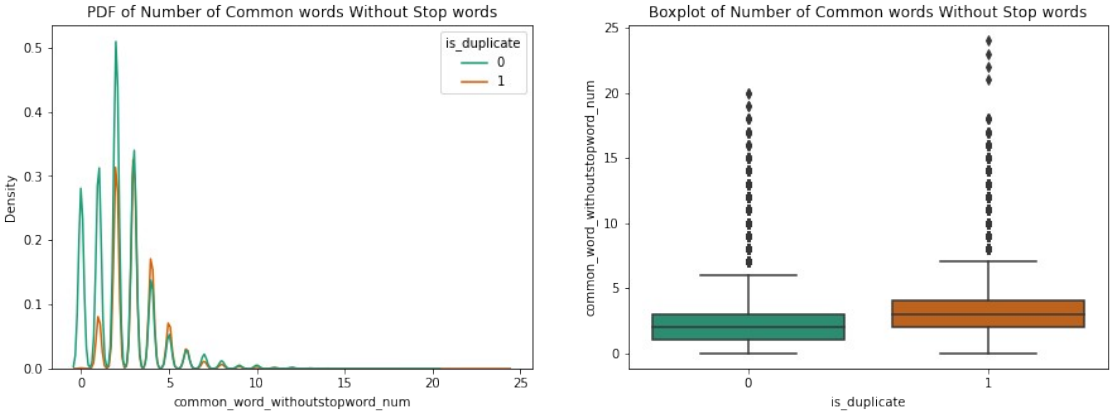

```
fig, ax =plt.subplots(1,2,figsize=(15,5))
ax[0].title.set_text('PDF of Ratio of number of Common words to
Minimum of Unique words')
sns.kdeplot(traindata['common_word_ratio_min'], hue=data.is_duplicate,
palette="Dark2", ax=ax[0])
ax[1].title.set_text('Boxplot of Ratio of number of Common words to
Minimum of Unique words')
sns.boxplot(x=data.is_duplicate, y=traindata['common_word_ratio_min'],
palette="Dark2", ax=ax[1])
plt.show()
```



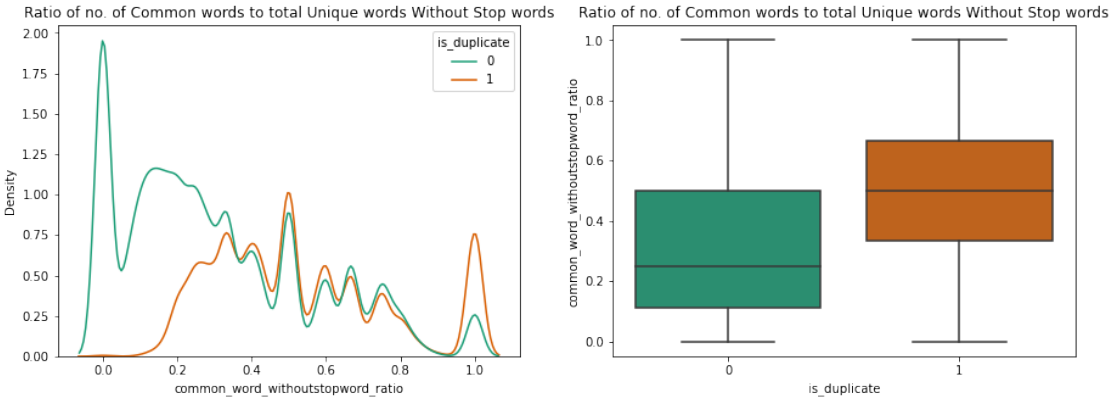

```
fig, ax =plt.subplots(1,2,figsize=(15,5))
ax[0].title.set_text('PDF of Ratio of number of Common words to
Maximum of Unique words')
sns.kdeplot(traindata['common_word_ratio_max'], hue=data.is_duplicate,
palette="Dark2", ax=ax[0])
ax[1].title.set_text('Boxplot of Ratio of number of Common words to
Maximum of Unique words')
sns.boxplot(x=data.is_duplicate, y=traindata['common_word_ratio_max'],
palette="Dark2", ax=ax[1])
plt.show()
```



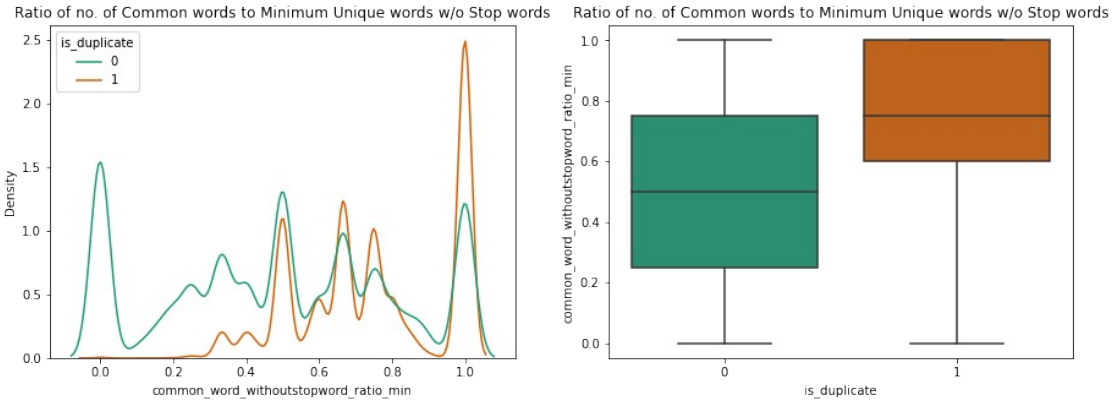

```
fig, ax =plt.subplots(1,2,figsize=(15,5))
ax[0].title.set_text('PDF of Number of Common words Without Stop
words')
sns.kdeplot(traindata['common_word_withoutstopword_num'],
hue=data.is_duplicate, palette="Dark2", ax=ax[0])
ax[1].title.set_text('Boxplot of Number of Common words Without Stop
words')
sns.boxplot(x=data.is_duplicate,
y=traindata['common_word_withoutstopword_num'], palette="Dark2",
ax=ax[1])
plt.show()
```



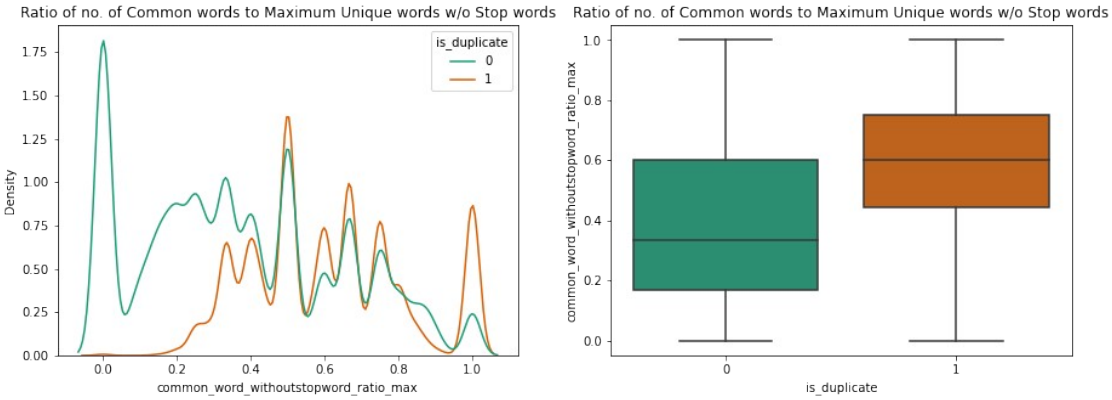

```
fig, ax =plt.subplots(1,2,figsize=(15,5))
ax[0].title.set_text('Ratio of no. of Common words to total Unique
words Without Stop words')
sns.kdeplot(traindata['common_word_withoutstopword_ratio'],
hue=data.is_duplicate, palette="Dark2", ax=ax[0])
ax[1].title.set_text('Ratio of no. of Common words to total Unique
words Without Stop words')
sns.boxplot(x=data.is_duplicate,
y=traindata['common_word_withoutstopword_ratio'], palette="Dark2",
ax=ax[1])
plt.show()
```



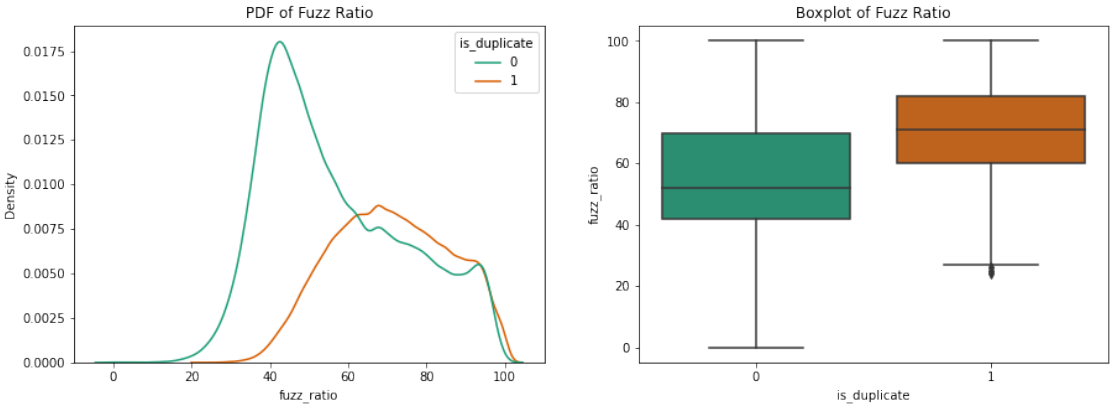

```
fig, ax =plt.subplots(1,2,figsize=(15,5))
ax[0].title.set_text('Ratio of no. of Common words to Minimum Unique
words w/o Stop words')
sns.kdeplot(traindata['common_word_withoutstopword_ratio_min'],
hue=data.is_duplicate, palette="Dark2", ax=ax[0])
ax[1].title.set_text('Ratio of no. of Common words to Minimum Unique
words w/o Stop words')
sns.boxplot(x=data.is_duplicate,
y=traindata['common_word_withoutstopword_ratio_min'], palette="Dark2",
ax=ax[1])
plt.show()
```



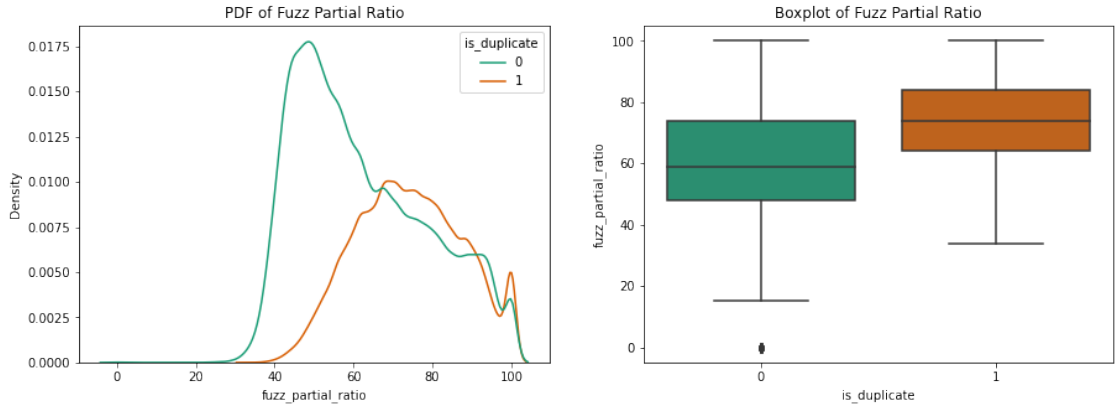

```
fig, ax =plt.subplots(1,2,figsize=(15,5))
ax[0].title.set_text('Ratio of no. of Common words to Maximum Unique
words w/o Stop words')
sns.kdeplot(traindata['common_word_withoutstopword_ratio_max'],
hue=data.is_duplicate, palette="Dark2", ax=ax[0])
ax[1].title.set_text('Ratio of no. of Common words to Maximum Unique
words w/o Stop words')
sns.boxplot(x=data.is_duplicate,
y=traindata['common_word_withoutstopword_ratio_max'], palette="Dark2",
ax=ax[1])
plt.show()
```



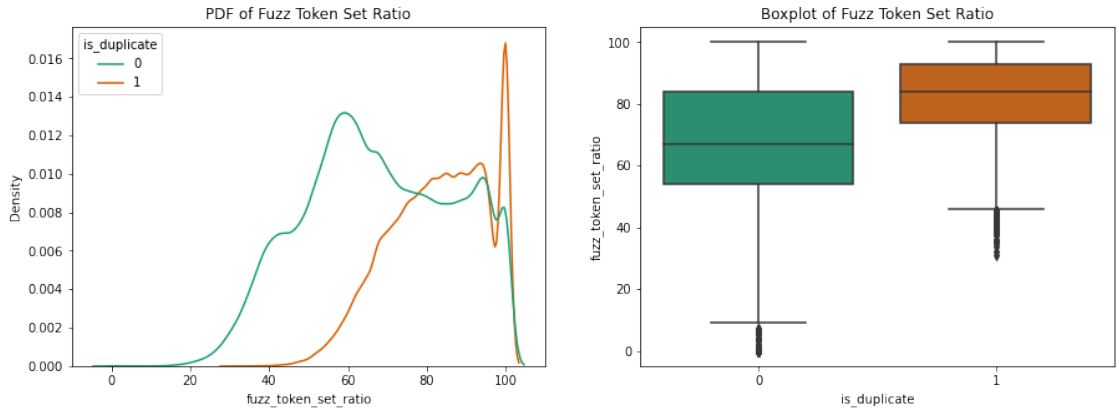

```
fig, ax =plt.subplots(1,2,figsize=(15,5))
ax[0].title.set_text('PDF of Fuzz Ratio')
sns.kdeplot(traindata['fuzz_ratio'], hue=data.is_duplicate,
palette="Dark2", ax=ax[0])
ax[1].title.set_text('Boxplot of Fuzz Ratio')
sns.boxplot(x=data.is_duplicate, y=traindata['fuzz_ratio'],
palette="Dark2", ax=ax[1])
plt.show()
```



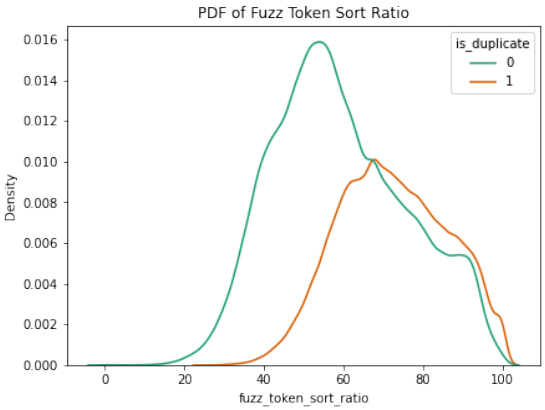

```
fig, ax =plt.subplots(1,2,figsize=(15,5))
ax[0].title.set_text('PDF of Fuzz Partial Ratio')
sns.kdeplot(traindata['fuzz_partial_ratio'], hue=data.is_duplicate,
palette="Dark2", ax=ax[0])
ax[1].title.set_text('Boxplot of Fuzz Partial Ratio')
sns.boxplot(x=data.is_duplicate, y=traindata['fuzz_partial_ratio'],
palette="Dark2", ax=ax[1])
plt.show()
```

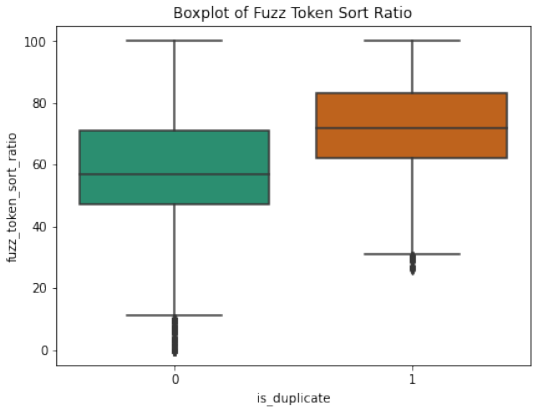



```
fig, ax =plt.subplots(1,2,figsize=(15,5))
ax[0].title.set_text('PDF of Fuzz Token Set Ratio')
sns.kdeplot(traindata['fuzz_token_set_ratio'], hue=data.is_duplicate,
palette="Dark2", ax=ax[0])
ax[1].title.set_text('Boxplot of Fuzz Token Set Ratio')
sns.boxplot(x=data.is_duplicate, y=traindata['fuzz_token_set_ratio'],
palette="Dark2", ax=ax[1])
plt.show()
```

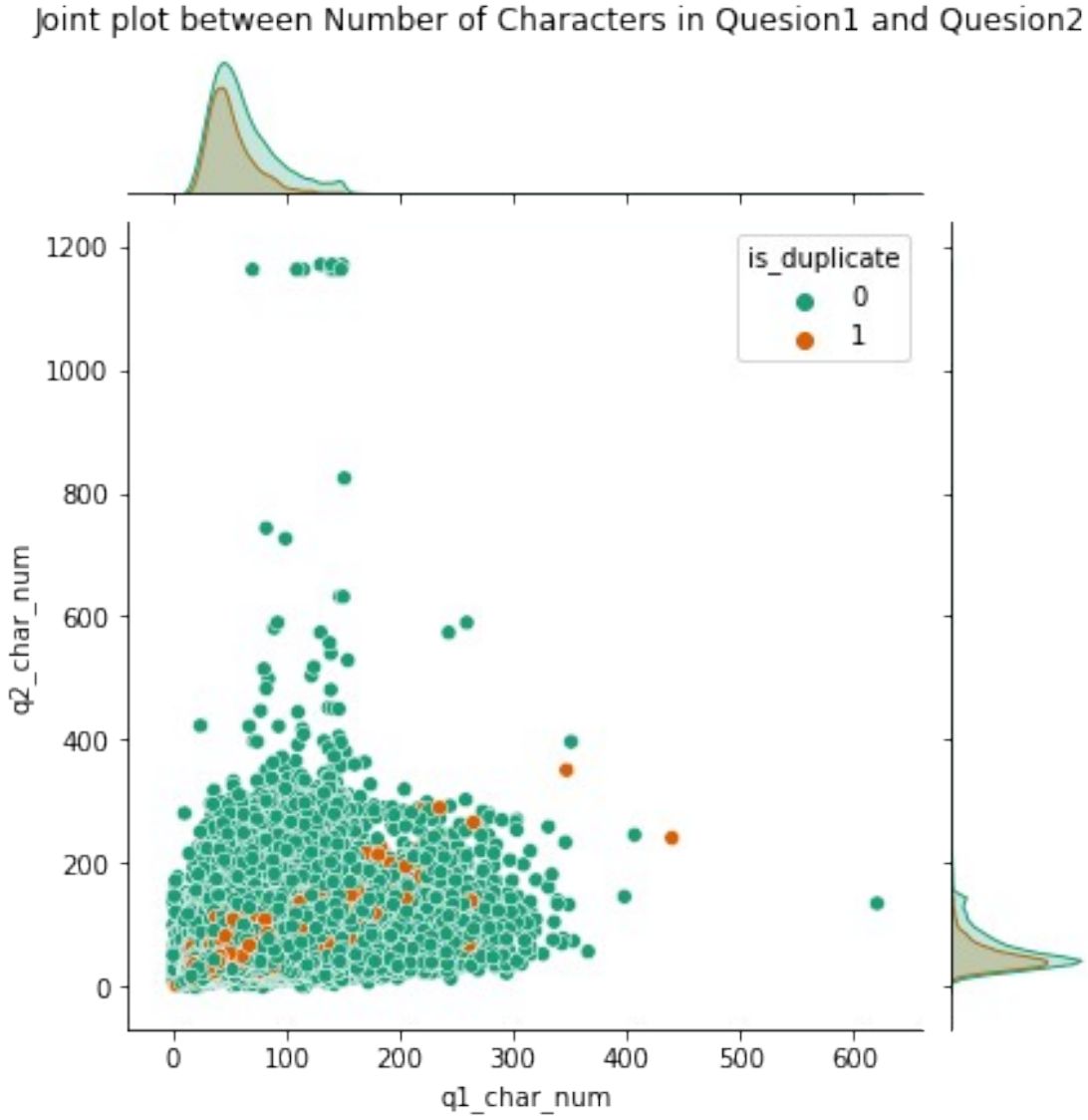



```
fig, ax =plt.subplots(1,2,figsize=(15,5))
ax[0].title.set_text('PDF of Fuzz Token Sort Ratio')
sns.kdeplot(traindata['fuzz_token_sort_ratio'], hue=data.is_duplicate,
palette="Dark2", ax=ax[0])
ax[1].title.set_text('Boxplot of Fuzz Token Sort Ratio')
sns.boxplot(x=data.is_duplicate, y=traindata['fuzz_token_sort_ratio'],
palette="Dark2", ax=ax[1])
plt.show()
```

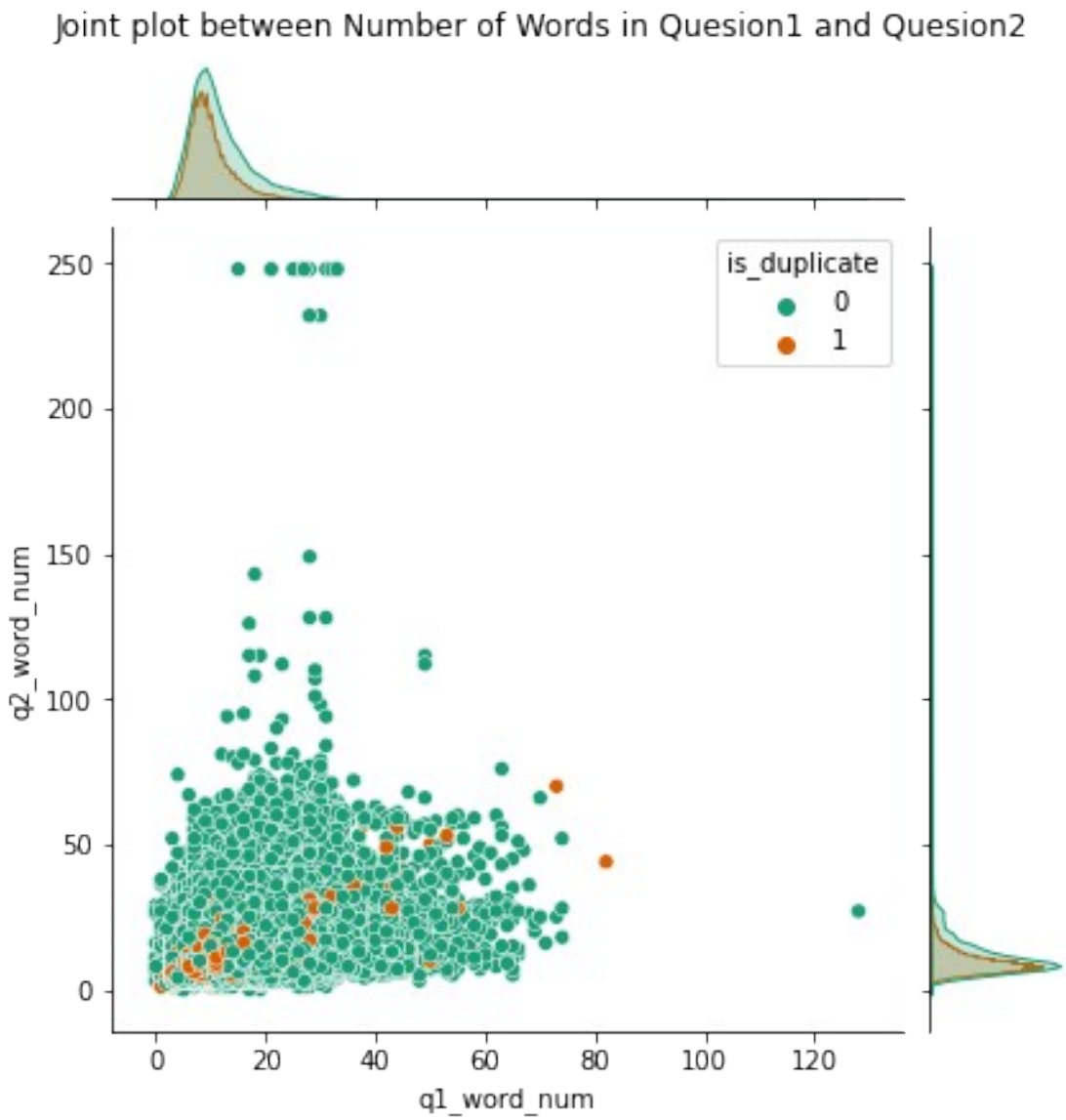





```
g = sns.jointplot(x = 'q1_char_num', y = 'q2_char_num', kind =
"scatter", hue=data.is_duplicate, data = traindata, palette="Dark2")
g.fig.suptitle("Joint plot between Number of Characters in Quesion1
and Quesion2", y=1.02)
plt.show()
```




```
g = sns.jointplot(x = 'q1_word_num', y = 'q2_word_num', kind =
"scatter", hue=data.is_duplicate, data = traindata, palette="Dark2")
g.fig.suptitle("Joint plot between Number of Words in Quesion1 and
Quesion2", y=1.02)
plt.show()
```



- If First word or Last word is the same then there is a high chance that the question pairs are duplicates.
- The number of total unique words (q1 and q2 both combined) with and without stopwords is less if question pairs are duplicate.
- For duplicate question pairs, the total unique words to total words ratio is generally smaller.
- Duplicate question pairs tend to have more common words between both the questions. Hence extracted features related to common words are also showing differences in distributions.
- The fuzz ratios tend to be generally higher for duplicate question pairs.

Featurization with SentenceBERT

SentenceBERT is a BERT based sentence embedding technique. We will use pre-trained SentenceBERT model paraphrase-mpnet-base-v2, which is recommended for best quality. The SentenceBERT produces an output of 768 dimensions. https://www.sbert.net/

```
modelST = SentenceTransformer('paraphrase-mpnet-base-v2')

# It took a lot of time, caused gpu overheat.
# So I decided to do it in batch and save them in file.
def getBertEmbeddings(data, filename):
    batch = 20000
    with open(filename, 'wb') as f:
        while(len(data)):
            tempdata = data[:batch]
            data = data[batch:]
            tempembed = modelST.encode(tempdata.values, device='cuda')
            np.save(f, tempembed, allow_pickle=True)
#             time.sleep(60) # for gpu heating issue


# Get SentenceBERT embedding of train data
getBertEmbeddings(traindata.question1_final,
'temp_train_question1_sentenceBERT.npy')
getBertEmbeddings(traindata.question2_final,
'temp_train_question2_sentenceBERT.npy')

# Get SentenceBERT embedding of test data
getBertEmbeddings(testdata.question1_final,
'temp_test_question1_sentenceBERT.npy')
getBertEmbeddings(testdata.question2_final,
'temp_test_question2_sentenceBERT.npy')

# Get cosine similarity and euclidean distance between two vectors
def cosine_euclidean(u, v):
    return np.array([np.dot(u, v) / (np.linalg.norm(u) *
np.linalg.norm(v)), np.linalg.norm(u - v)])

# open .npy files and loop through the sentence embeddings
with open('temp_train_question1_sentenceBERT.npy', 'rb') as q1_vec,
open('temp_train_question2_sentenceBERT.npy', 'rb') as q2_vec:
    distances = []
    while True:
        try:
            q1_20k = np.load(q1_vec, allow_pickle=True)
            q2_20k = np.load(q2_vec, allow_pickle=True)
            for q1,q2 in zip(q1_20k, q2_20k):
                dists = cosine_euclidean(q1, q2)
                distances.append(dists)
        except IOError as e:
```

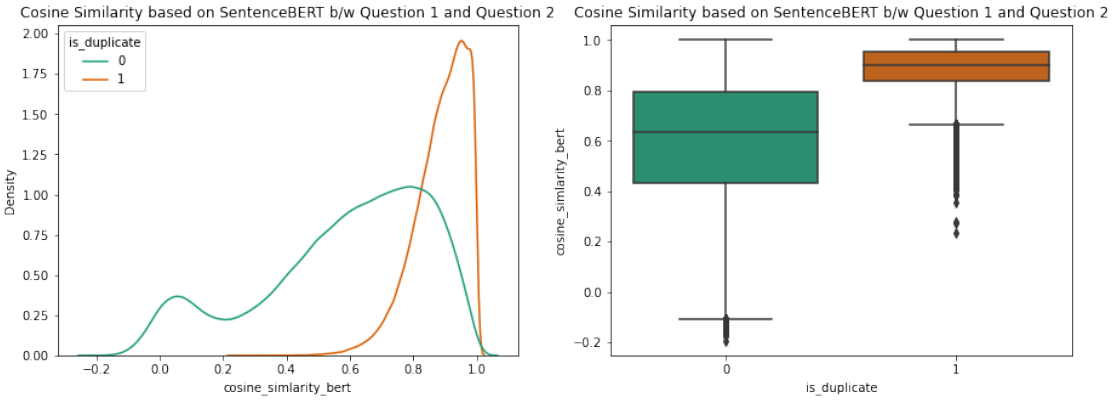
```
            distances = np.array(distances)
            break

distances = pd.DataFrame(distances, columns=['cosine_simlarity_bert',
'euclidean_distance_bert'])

traindata = pd.concat([traindata, pd.DataFrame(distances)], axis=1)

# open .npy files and loop through the sentence embeddings
with open('temp_test_question1_sentenceBERT.npy', 'rb') as q1_vec,
open('temp_test_question2_sentenceBERT.npy', 'rb') as q2_vec:
    distances = []
    while True:
        try:
            q1_20k = np.load(q1_vec, allow_pickle=True)
            q2_20k = np.load(q2_vec, allow_pickle=True)
            for q1,q2 in zip(q1_20k, q2_20k):
                dists = cosine_euclidean(q1, q2)
                distances.append(dists)
        except IOError as e:
            distances = np.array(distances)
            break
distances = pd.DataFrame(distances, columns=['cosine_simlarity_bert',
'euclidean_distance_bert'])
testdata = pd.concat([testdata, pd.DataFrame(distances)], axis=1)
```

We have created two more features **cosine_simlarity_bert** and **euclidean_distance_bert** which measures similarity and distance between both pairs of questions.

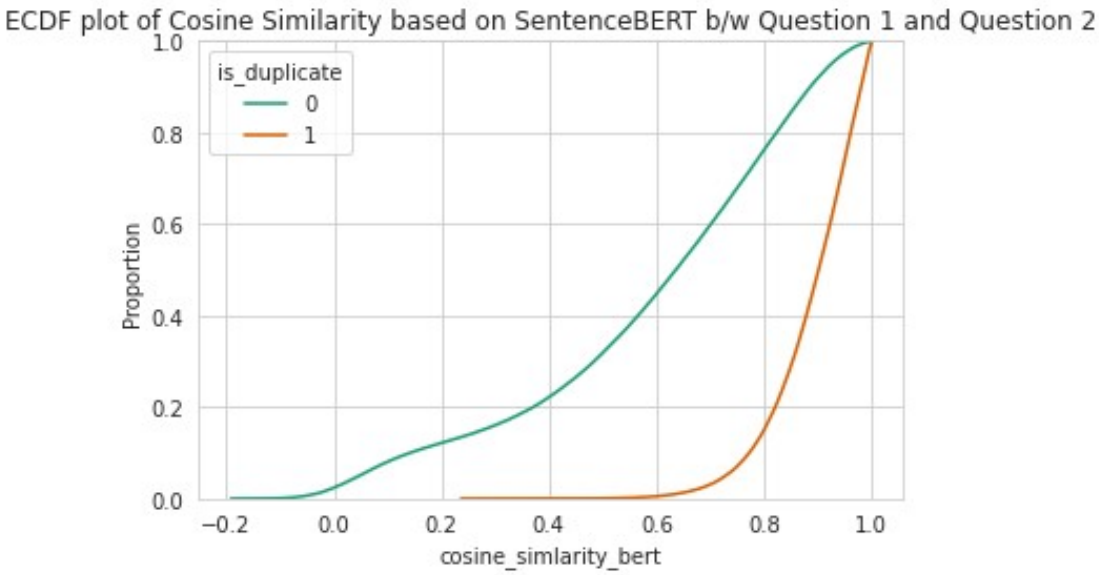
The total number of features till now is **25**.

EDA on new features related to SentenceBERT

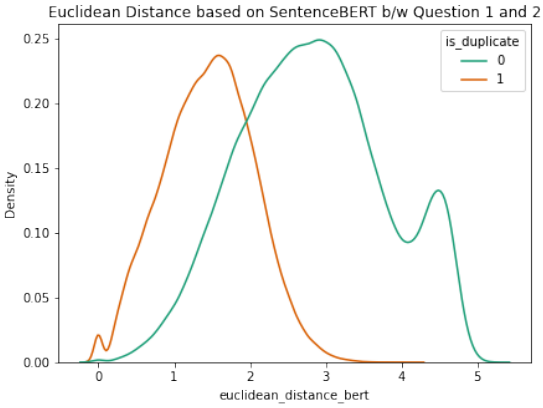
```
fig, ax =plt.subplots(1,2,figsize=(15,5))
ax[0].title.set_text('Cosine Similarity based on SentenceBERT b/w
Question 1 and Question 2')
sns.kdeplot(traindata['cosine_simlarity_bert'], hue=data.is_duplicate,
palette="Dark2", ax=ax[0])
ax[1].title.set_text('Cosine Similarity based on SentenceBERT b/w
Question 1 and Question 2')
sns.boxplot(x=data.is_duplicate, y=traindata['cosine_simlarity_bert'],
palette="Dark2", ax=ax[1])
plt.show()
```

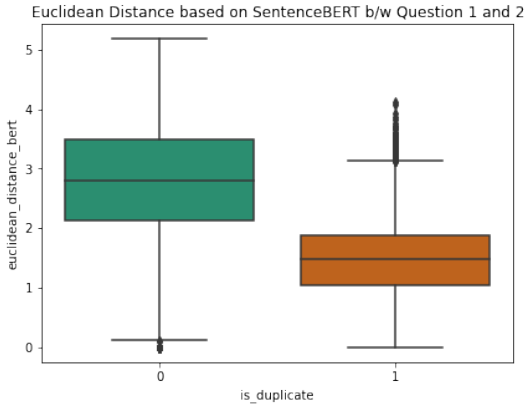



```
plt.title('ECDF plot of Cosine Similarity based on SentenceBERT b/w
Question 1 and Question 2')
sns.axes_style("whitegrid")
sns.ecdfplot(x=traindata['cosine_simlarity_bert'],
hue=data.is_duplicate, palette="Dark2")
plt.show()
```

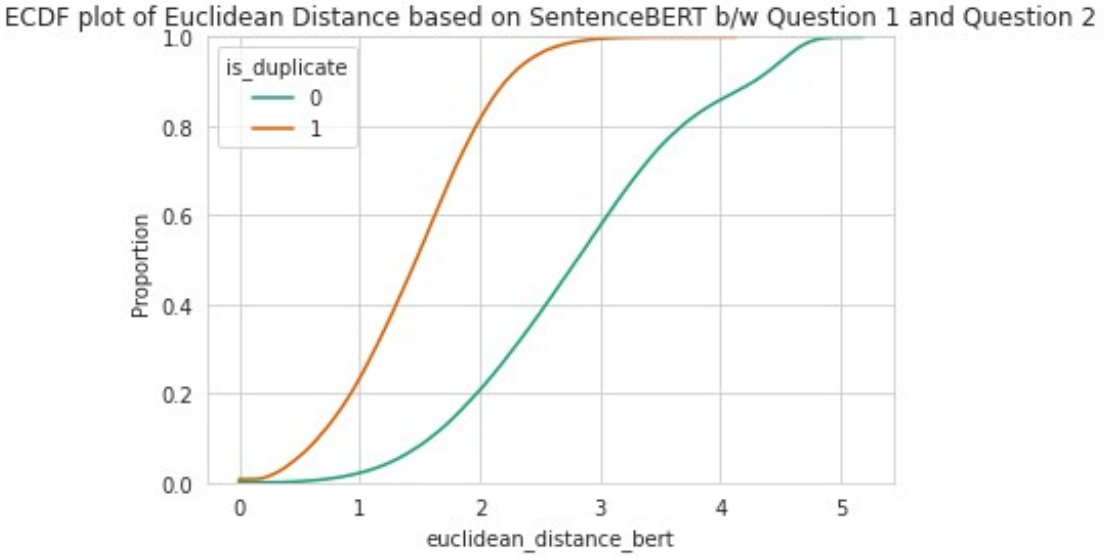



```
fig, ax =plt.subplots(1,2,figsize=(15,5))
ax[0].title.set_text('Euclidean Distance based on SentenceBERT b/w
Question 1 and 2')
sns.kdeplot(traindata['euclidean_distance_bert'],
hue=data.is_duplicate, palette="Dark2", ax=ax[0])
ax[1].title.set_text('Euclidean Distance based on SentenceBERT b/w
Question 1 and 2')
sns.boxplot(x=data.is_duplicate,
y=traindata['euclidean_distance_bert'], palette="Dark2", ax=ax[1])
plt.show()
```






```
plt.title('ECDF plot of Euclidean Distance based on SentenceBERT b/w
Question 1 and Question 2')
sns.axes_style("whitegrid")
sns.ecdfplot(x=traindata['euclidean_distance_bert'],
hue=data.is_duplicate, palette="Dark2")
plt.show()
```



These features seems to be the most successful ones. It seems we can separate most of the classes just by using one of these features.

- Cosine Similarity is larger for duplicate pairs.
- 80% of non-duplicate question pairs and only 20% of duplicate question pairs have cosine similarity of <= .815
- Euclidean Distance is smaller for duplicate pairs.
- 20% of non-duplicate question pairs and approx 80% of duplicate question pairs have euclidean distance of <= 2.

It is showing the Pareto Principle (80-20 rule).

Data Pre-processing

```
traindata.drop(columns=['question1_final', 'question2_final'],
inplace=True)

traindata = traindata.to_numpy()

scaler = MinMaxScaler()

scaler.fit(traindata)

MinMaxScaler()

traindata = scaler.transform(traindata)
```

We have normalized (min-max scaling) the extracted features of train data. We have not normalized the embeddings because it is not recommended.

```
testdata.drop(columns=['question1_final', 'question2_final'],
inplace=True)
testdata = testdata.to_numpy()
testdata = scaler.transform(testdata)

with open('temp_testdata.npy', 'wb') as f:
    batch = 20000
    while(len(testdata)):
        tempdata = testdata[:batch]
        testdata = testdata[batch:]
        np.save(f, tempdata, allow_pickle=True)
```

We have normalized the test data also. And save them in batch of 20k, just like we did with the embeddings.

```
def loadVectors(filename):
    with open(filename, 'rb') as f:
        q_vectors = []
        while True:
            try:
                q_vec = np.load(f, allow_pickle=True)
                q_vectors.extend(list(q_vec))
            except IOError as e:
                q_vectors = np.array(q_vectors)
                break
    return q_vectors

train_question1_vec =
loadVectors('temp_train_question1_sentenceBERT.npy')

train_question2_vec =
loadVectors('temp_train_question2_sentenceBERT.npy')

traindata = np.hstack((traindata, train_question1_vec,
train_question2_vec))
```

```
traindata.shape
```

```
(404287, 1561)
```

We have **1561** features (25 + 768 + 768).

- **25** are extracted features.
- **768+768** for sentence embedding of question 1 and question 2.

```
oversample = RandomOverSampler(sampling_strategy='minority')
X_train, y_train = oversample.fit_resample(traindata,
data.is_duplicate.to_numpy())

print(np.count_nonzero(y_train == 0))
print(np.count_nonzero(y_train == 1))
```

```
255024
255024
```

Since the dataset was imbalanced. We did **oversample** by sampling from the minority class. Now we have **510048** data points. **255024** from each class.

Training Models

Support Vector Classifier

Training

```
splits = ShuffleSplit(n_splits=1, test_size=.3, random_state=42)

svc_param_grid = {'C':[1e-2, 1e-1, 1e0, 1e1, 1e2]}

svc_clf = LinearSVC(penalty='l2', loss='squared_hinge', dual=False,
max_iter=3000)

svc_clf_search = HalvingGridSearchCV(svc_clf, svc_param_grid,
cv=splits, factor=2, scoring='accuracy', verbose=3)

svc_clf_search.fit(X_train, y_train)
```

```
n_iterations: 3
n_required_iterations: 3
n_possible_iterations: 3
min_resources_: 127512
max_resources_: 510048
aggressive_elimination: False
factor: 2
----------
iter: 0
n_candidates: 5
n_resources: 127512
Fitting 1 folds for each of 5 candidates, totalling 5 fits
```

```
[CV 1/1] END ........C=0.01;, score=(train=0.859, test=0.855) total
time=  37.2s
[CV 1/1] END .........C=0.1;, score=(train=0.862, test=0.854) total
time= 1.4min
[CV 1/1] END .........C=1.0;, score=(train=0.863, test=0.855) total
time= 2.3min
[CV 1/1] END ........C=10.0;, score=(train=0.863, test=0.855) total
time= 3.5min
[CV 1/1] END .......C=100.0;, score=(train=0.863, test=0.855) total
time= 4.0min
----------
iter: 1
n_candidates: 3
n_resources: 255024
Fitting 1 folds for each of 3 candidates, totalling 3 fits
[CV 1/1] END .........C=1.0;, score=(train=0.861, test=0.857) total
time= 5.1min
[CV 1/1] END .......C=100.0;, score=(train=0.861, test=0.857) total
time= 6.1min
[CV 1/1] END ........C=10.0;, score=(train=0.861, test=0.857) total
time= 6.0min
----------
iter: 2
n_candidates: 2
n_resources: 510048
Fitting 1 folds for each of 2 candidates, totalling 2 fits
[CV 1/1] END .........C=1.0;, score=(train=0.860, test=0.858) total
time=18.2min
[CV 1/1] END .......C=100.0;, score=(train=0.860, test=0.858) total
time=12.1min
```

```
HalvingGridSearchCV(cv=ShuffleSplit(n_splits=1, random_state=42,
test_size=0.3, train_size=None),
                    estimator=LinearSVC(dual=False, max_iter=3000),
factor=2,
                    param_grid={'C': [0.01, 0.1, 1.0, 10.0, 100.0]},
                    refit=<function _refit_callable at
0x7fc44740e1f0>,
                    scoring='accuracy', verbose=3)
```

```
svc_clf_search.best_params_
```

```
{'C': 100.0}
```

```
svc_clf_search.best_score_
```

```
0.8578962846779727
```

The Halving Grid Search CV found C=100 to be the best param. And the best accuracy is 85.79%.

```
svc_clf_model = svc_clf_search.best_estimator_
```

```
svc_clf_model
```

```
LinearSVC(C=100.0, dual=False, max_iter=3000)
```

Now since we need to minimize log loss for the competition. We would want a good predicted probability. Calibrated Classifier can be used to get a good predicted probability.

```
svc_calibrated = CalibratedClassifierCV(base_estimator=svc_clf_model,
method="sigmoid", cv=splits)
```

```
svc_calibrated.fit(X_train, y_train)
```

```
CalibratedClassifierCV(base_estimator=LinearSVC(C=100.0, dual=False,
                                                max_iter=3000),
                       cv=ShuffleSplit(n_splits=1, random_state=42,
test_size=0.3, train_size=None))
```

Testing

```
 with open('testdata.npy', 'rb') as X_test_1, \
    open('test_question1_sentenceBERT.npy', 'rb') as X_test_q1, \
    open('test_question2_sentenceBERT.npy', 'rb') as X_test_q2:
    y_pred_proba_svc = []
    while True:
        try:
            test_20k = np.load(X_test_1, allow_pickle=True)
            q1_20k = np.load(X_test_q1, allow_pickle=True)
            q2_20k = np.load(X_test_q2, allow_pickle=True)
            X_test = np.hstack((test_20k, q1_20k, q2_20k))

y_pred_proba_svc.extend(list(svc_calibrated.predict_proba(X_test)
[:,1]))
        except IOError as e:
            break

testids = pd.read_csv('test_id.csv', na_filter=False)

submission_svc = pd.DataFrame({'test_id':testids.test_id.values,
'is_duplicate':y_pred_proba_svc})

submission_svc.to_csv('submission_svc.csv', index=False)
```

Support Vector Classifier resulted in log loss of **0.36980**

Random Forest

Training

```
splits = ShuffleSplit(n_splits=1, test_size=.3, random_state=42)

rf_param_grid = {
                    'n_estimators':[200, 500, 800],
                    'min_samples_split':[5, 15],
```

```
                    'max_depth': [70, 150, None]
                }

rf_clf = RandomForestClassifier()

rf_clf_search = HalvingGridSearchCV(rf_clf, rf_param_grid, cv=splits,
factor=2, scoring='accuracy', verbose=3)

rf_clf_search.fit(X_train, y_train)
```

```
n_iterations: 5
n_required_iterations: 5
n_possible_iterations: 5
min_resources_: 31878
max_resources_: 510048
aggressive_elimination: False
factor: 2
----------
iter: 0
n_candidates: 18
n_resources: 31878
Fitting 1 folds for each of 18 candidates, totalling 18 fits
[CV 1/1] END max_depth=70, min_samples_split=5, n_estimators=200;,
score=(train=1.000, test=0.839) total time= 3.4min
[CV 1/1] END max_depth=70, min_samples_split=5, n_estimators=500;,
score=(train=1.000, test=0.840) total time= 8.1min
[CV 1/1] END max_depth=70, min_samples_split=5, n_estimators=800;,
score=(train=1.000, test=0.841) total time=12.8min
[CV 1/1] END max_depth=70, min_samples_split=15, n_estimators=200;,
score=(train=0.999, test=0.839) total time= 3.0min
[CV 1/1] END max_depth=70, min_samples_split=15, n_estimators=500;,
score=(train=1.000, test=0.840) total time= 7.5min
[CV 1/1] END max_depth=70, min_samples_split=15, n_estimators=800;,
score=(train=1.000, test=0.840) total time=12.1min
[CV 1/1] END max_depth=150, min_samples_split=5, n_estimators=200;,
score=(train=1.000, test=0.841) total time= 3.0min
[CV 1/1] END max_depth=150, min_samples_split=5, n_estimators=500;,
score=(train=1.000, test=0.840) total time= 7.7min
[CV 1/1] END max_depth=150, min_samples_split=5, n_estimators=800;,
score=(train=1.000, test=0.841) total time=12.1min
[CV 1/1] END max_depth=150, min_samples_split=15, n_estimators=200;,
score=(train=0.999, test=0.838) total time= 3.0min
[CV 1/1] END max_depth=150, min_samples_split=15, n_estimators=500;,
score=(train=1.000, test=0.840) total time= 7.6min
[CV 1/1] END max_depth=150, min_samples_split=15, n_estimators=800;,
score=(train=1.000, test=0.841) total time=12.2min
[CV 1/1] END max_depth=None, min_samples_split=5, n_estimators=200;,
score=(train=1.000, test=0.842) total time= 3.2min
[CV 1/1] END max_depth=None, min_samples_split=5, n_estimators=500;,
score=(train=1.000, test=0.842) total time= 7.7min
[CV 1/1] END max_depth=None, min_samples_split=5, n_estimators=800;,
```

```
score=(train=1.000, test=0.841) total time=12.2min
[CV 1/1] END max_depth=None, min_samples_split=15, n_estimators=200;,
score=(train=0.999, test=0.840) total time= 3.1min
[CV 1/1] END max_depth=None, min_samples_split=15, n_estimators=500;,
score=(train=0.999, test=0.842) total time= 8.6min
[CV 1/1] END max_depth=None, min_samples_split=15, n_estimators=800;,
score=(train=1.000, test=0.840) total time=13.6min
----------
iter: 1
n_candidates: 9
n_resources: 63756
Fitting 1 folds for each of 9 candidates, totalling 9 fits
[CV 1/1] END max_depth=70, min_samples_split=15, n_estimators=500;,
score=(train=1.000, test=0.848) total time=17.7min
[CV 1/1] END max_depth=150, min_samples_split=15, n_estimators=800;,
score=(train=1.000, test=0.848) total time=28.0min
[CV 1/1] END max_depth=70, min_samples_split=5, n_estimators=800;,
score=(train=1.000, test=0.848) total time=28.8min
[CV 1/1] END max_depth=150, min_samples_split=5, n_estimators=200;,
score=(train=1.000, test=0.848) total time= 7.3min
[CV 1/1] END max_depth=None, min_samples_split=5, n_estimators=800;,
score=(train=1.000, test=0.848) total time=29.1min
[CV 1/1] END max_depth=150, min_samples_split=5, n_estimators=800;,
score=(train=1.000, test=0.850) total time=27.5min
[CV 1/1] END max_depth=None, min_samples_split=15, n_estimators=500;,
score=(train=1.000, test=0.849) total time=17.5min
[CV 1/1] END max_depth=None, min_samples_split=5, n_estimators=200;,
score=(train=1.000, test=0.849) total time= 7.0min
[CV 1/1] END max_depth=None, min_samples_split=5, n_estimators=500;,
score=(train=1.000, test=0.848) total time=18.2min
----------
iter: 2
n_candidates: 5
n_resources: 127512
Fitting 1 folds for each of 5 candidates, totalling 5 fits
[CV 1/1] END max_depth=None, min_samples_split=5, n_estimators=800;,
score=(train=1.000, test=0.863) total time=67.0min
[CV 1/1] END max_depth=150, min_samples_split=5, n_estimators=200;,
score=(train=1.000, test=0.864) total time=15.9min
[CV 1/1] END max_depth=None, min_samples_split=15, n_estimators=500;,
score=(train=0.999, test=0.862) total time=39.9min
[CV 1/1] END max_depth=None, min_samples_split=5, n_estimators=200;,
score=(train=1.000, test=0.863) total time=16.1min
[CV 1/1] END max_depth=150, min_samples_split=5, n_estimators=800;,
score=(train=1.000, test=0.864) total time=61.9min
----------
iter: 3
n_candidates: 3
n_resources: 255024
Fitting 1 folds for each of 3 candidates, totalling 3 fits
```

```
[CV 1/1] END max_depth=None, min_samples_split=5, n_estimators=800;,
score=(train=1.000, test=0.881) total time=142.1min
[CV 1/1] END max_depth=150, min_samples_split=5, n_estimators=800;,
score=(train=1.000, test=0.880) total time=139.6min
[CV 1/1] END max_depth=150, min_samples_split=5, n_estimators=200;,
score=(train=1.000, test=0.880) total time=33.6min
----------
iter: 4
n_candidates: 2
n_resources: 510048
Fitting 1 folds for each of 2 candidates, totalling 2 fits
[CV 1/1] END max_depth=150, min_samples_split=5, n_estimators=800;,
score=(train=1.000, test=0.905) total time=304.0min
[CV 1/1] END max_depth=None, min_samples_split=5, n_estimators=800;,
score=(train=1.000, test=0.905) total time=317.9min

HalvingGridSearchCV(cv=ShuffleSplit(n_splits=1, random_state=42,
test_size=0.3, train_size=None),
                    estimator=RandomForestClassifier(), factor=2,
                    param_grid={'max_depth': [70, 150, None],
                                'min_samples_split': [5, 15],
                                'n_estimators': [200, 500, 800]},
                    refit=<function _refit_callable at
0x7f1597f4c310>,
                    scoring='accuracy', verbose=3)

rf_clf_search.best_params_

{'max_depth': 150, 'min_samples_split': 5, 'n_estimators': 800}

rf_clf_search.best_score_

0.9052576544783191

rf_clf_model = rf_clf_search.best_estimator_

rf_clf_model

RandomForestClassifier(max_depth=150, min_samples_split=5,
n_estimators=800)
```

Testing

```
with open('testdata.npy', 'rb') as X_test_1, \
    open('test_question1_sentenceBERT.npy', 'rb') as X_test_q1, \
    open('test_question2_sentenceBERT.npy', 'rb') as X_test_q2:
    y_pred_proba_rf = []
    while True:
        try:
            test_20k = np.load(X_test_1, allow_pickle=True)
            q1_20k = np.load(X_test_q1, allow_pickle=True)
            q2_20k = np.load(X_test_q2, allow_pickle=True)
            X_test = np.hstack((test_20k, q1_20k, q2_20k))
```

```
y_pred_proba_rf.extend(list(rf_clf_model.predict_proba(X_test)[:,1]))
        except IOError as e:
            break

testids = pd.read_csv('test_id.csv', na_filter=False)

submission_rf = pd.DataFrame({'test_id':testids.test_id.values,
'is_duplicate':y_pred_proba_rf})

submission_rf.to_csv('submission_rf.csv', index=False)
```

Random Forest Classifier resulted in log loss of **0.32372**

XGBoost

Training

```
X_train_orig, idices = np.unique(X_train, axis=0, return_index=True)

y_train_orig = y_train[idices]

X_train_orig.shape
```

```
(403940, 1561)
```

We got rid of oversampled data by removing the duplicate rows.

```
params = dict(
            objective = "binary:logistic",
            eval_metric = "logloss",
            booster = "gbtree",
            tree_method = "hist",
            grow_policy = "lossguide",
            max_depth = 4,
            eta = 0.15,
            subsample = .8,
            colsample_bytree = .8,
            reg_lambda = 1,
            reg_alpha = 1
        )

X_train, X_cv, y_train, y_cv = train_test_split(X_train_orig,
y_train_orig, test_size=0.25)

dtrain = xgb.DMatrix(X_train, label=y_train)
dvalid = xgb.DMatrix(X_cv, label=y_cv)

watchlist = [(dtrain, 'train'), (dvalid, 'valid')]

xgb_model2 = xgb.train(params, dtrain, 500, watchlist,
early_stopping_rounds=20, verbose_eval=10)
```

```
[0]  train-logloss:0.62420 valid-logloss:0.62430
[10] train-logloss:0.39826 valid-logloss:0.39854
[20] train-logloss:0.35911 valid-logloss:0.35996
[30] train-logloss:0.34384 valid-logloss:0.34563
[40] train-logloss:0.33342 valid-logloss:0.33610
[50] train-logloss:0.32587 valid-logloss:0.32959
[60] train-logloss:0.31950 valid-logloss:0.32411
[70] train-logloss:0.31465 valid-logloss:0.32005
[80] train-logloss:0.31063 valid-logloss:0.31706
[90] train-logloss:0.30688 valid-logloss:0.31417
[100]train-logloss:0.30387 valid-logloss:0.31206
[110]train-logloss:0.30093 valid-logloss:0.30996
[120]train-logloss:0.29834 valid-logloss:0.30837
[130]train-logloss:0.29572 valid-logloss:0.30658
[140]train-logloss:0.29337 valid-logloss:0.30513
[150]train-logloss:0.29116 valid-logloss:0.30366
[160]train-logloss:0.28899 valid-logloss:0.30231
[170]train-logloss:0.28686 valid-logloss:0.30088
[180]train-logloss:0.28486 valid-logloss:0.29982
[190]train-logloss:0.28304 valid-logloss:0.29883
[200]train-logloss:0.28109 valid-logloss:0.29775
[210]train-logloss:0.27915 valid-logloss:0.29659
[220]train-logloss:0.27727 valid-logloss:0.29559
[230]train-logloss:0.27551 valid-logloss:0.29470
[240]train-logloss:0.27379 valid-logloss:0.29377
[250]train-logloss:0.27217 valid-logloss:0.29293
[260]train-logloss:0.27060 valid-logloss:0.29213
[270]train-logloss:0.26911 valid-logloss:0.29146
[280]train-logloss:0.26758 valid-logloss:0.29076
[290]train-logloss:0.26617 valid-logloss:0.29014
[300]train-logloss:0.26470 valid-logloss:0.28947
[310]train-logloss:0.26316 valid-logloss:0.28869
[320]train-logloss:0.26173 valid-logloss:0.28805
[330]train-logloss:0.26034 valid-logloss:0.28730
[340]train-logloss:0.25888 valid-logloss:0.28662
[350]train-logloss:0.25756 valid-logloss:0.28608
[360]train-logloss:0.25618 valid-logloss:0.28541
[370]train-logloss:0.25482 valid-logloss:0.28483
[380]train-logloss:0.25364 valid-logloss:0.28441
[390]train-logloss:0.25243 valid-logloss:0.28392
[400]train-logloss:0.25123 valid-logloss:0.28354
[410]train-logloss:0.24996 valid-logloss:0.28312
[420]train-logloss:0.24880 valid-logloss:0.28274
[430]train-logloss:0.24760 valid-logloss:0.28233
[440]train-logloss:0.24646 valid-logloss:0.28194
[450]train-logloss:0.24519 valid-logloss:0.28138
[460]train-logloss:0.24404 valid-logloss:0.28105
[470]train-logloss:0.24290 valid-logloss:0.28060
[480]train-logloss:0.24175 valid-logloss:0.28011
```

```
[490] train-logloss:0.24067 valid-logloss:0.27982
[499] train-logloss:0.23959 valid-logloss:0.27938
```

Testing

```
with open('testdata.npy', 'rb') as X_test_1, \
    open('test_question1_sentenceBERT.npy', 'rb') as X_test_q1, \
    open('test_question2_sentenceBERT.npy', 'rb') as X_test_q2:
    y_pred_proba_xgb = []
    while True:
        try:
            test_20k = np.load(X_test_1, allow_pickle=True)
            q1_20k = np.load(X_test_q1, allow_pickle=True)
            q2_20k = np.load(X_test_q2, allow_pickle=True)
            X_test = xgb.DMatrix(np.hstack((test_20k, q1_20k,
q2_20k)))
            y_pred_proba_xgb.extend(list(xgb_model2.predict(X_test)))
        except IOError as e:
            break
testids = pd.read_csv('test_id.csv', na_filter=False)
submission_xgb2 = pd.DataFrame({'test_id':testids.test_id.values,
'is_duplicate':y_pred_proba_xgb})
submission_xgb2.to_csv('submission_xgb2.csv', index=False)
```

XgBoost resulted in log loss of 0.28170.