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Quora Question Pairs

Description

Quora is a place to gain and share knowledge—about anything. It's a platform to ask questions and connect with people who contribute unique insights and quality answers. This empowers people to learn from each other and to better understand the world.

Over 100 million people visit Quora every month, so it's no surprise that many people ask similarly worded questions. Multiple questions with the same intent can cause seekers to spend more time finding the best answer to their question, and make writers feel they need to answer multiple versions of the same question. Quora values canonical questions because they provide a better experience to active seekers and writers, and offer more value to both of these groups in the long term.

Problem Statement

- Identify which questions asked on Quora are duplicates of questions that have already been asked.
- This could be useful to instantly provide answers to questions that have already been answered.
- We are tasked with predicting whether a pair of questions are duplicates or not.

Real world/Business Objectives and Constraints

1. The cost of a mis-classification can be very high.
2. You would want a probability of a pair of questions to be duplicates so that you can choose any threshold of choice.
3. No strict latency concerns.
4. Interpretability is partially important.

Machine Learning Probelm

Data Overview

- Data will be in a file Train.csv
- Train.csv contains 5 columns : qid1, qid2, question1, question2, is_duplicate
- Size of Train.csv - 60MB
- Number of rows in Train.csv = 404,290

Mapping the real world problem to an ML problem

Type of Machine Leaning Problem

- It is a binary classification problem, for a given pair of questions we need to predict if they are duplicate or not.

Performance Metric

- log-loss
- Binary Confusion Matrix

```
In [1]: import warnings
        warnings.filterwarnings("ignore")
        import numpy as np
        import pandas as pd
        import seaborn as sns
        import matplotlib.pyplot as plt
        from subprocess import check_output
        %matplotlib inline
        import plotly.offline as py
        py.init_notebook_mode(connected=True)a
        import plotly.graph_objs as go
        import plotly.tools as tls
        import os
        import gc

        import re
        from nltk.corpus import stopwords
        import distance
        from nltk.stem import PorterStemmer
        from bs4 import BeautifulSoup
        # This package is used for finding longest common subsequence between two strings
        # you can write your own dp code for this
        import distance
        from nltk.stem import PorterStemmer
        from bs4 import BeautifulSoup
        from fuzzywuzzy import fuzz
        from sklearn.manifold import TSNE
        # Import the Required lib packages for WORD-Cloud generation
        # https://stackoverflow.com/questions/45625434/how-to-install-wordcloud-in-python3-6
        from wordcloud import WordCloud, STOPWORDS
        from os import path
        from PIL import Image

        import sqlite3
        from sqlalchemy import create_engine # database connection
        import csv
        from sklearn.decomposition import TruncatedSVD
        from sklearn.preprocessing import normalize
        from sklearn.feature_extraction.text import CountVectorizer
        from sklearn.manifold import TSNE
        import seaborn as sns
        from sklearn.metrics import confusion_matrix
        from sklearn.metrics.classification import accuracy_score, log_loss
        from sklearn.feature_extraction.text import TfidfVectorizer
        from collections import Counter
        from scipy.sparse import hstack
        from sklearn.svm import SVC
        from sklearn.cross_validation import StratifiedKFold
        from collections import Counter, defaultdict
        from sklearn.calibration import CalibratedClassifierCV
        from sklearn.model_selection import train_test_split
        from sklearn.model_selection import GridSearchCV
        import math
        from sklearn.metrics import normalized_mutual_info_score
        from sklearn.model_selection import cross_val_score
        from sklearn.linear_model import SGDClassifier
        from mlxtend.classifier import StackingClassifier

        from sklearn import model_selection
        from sklearn.linear_model import LogisticRegression
        from sklearn.metrics import precision_recall_curve, auc, roc_curve
```

```
In [4]: import scipy
```

```
In [3]: df = pd.read_csv("train.csv")

        print("Number of data points:", df.shape[0])
```

```
Number of data points: 404290
```

```
In [4]: df.head()
```

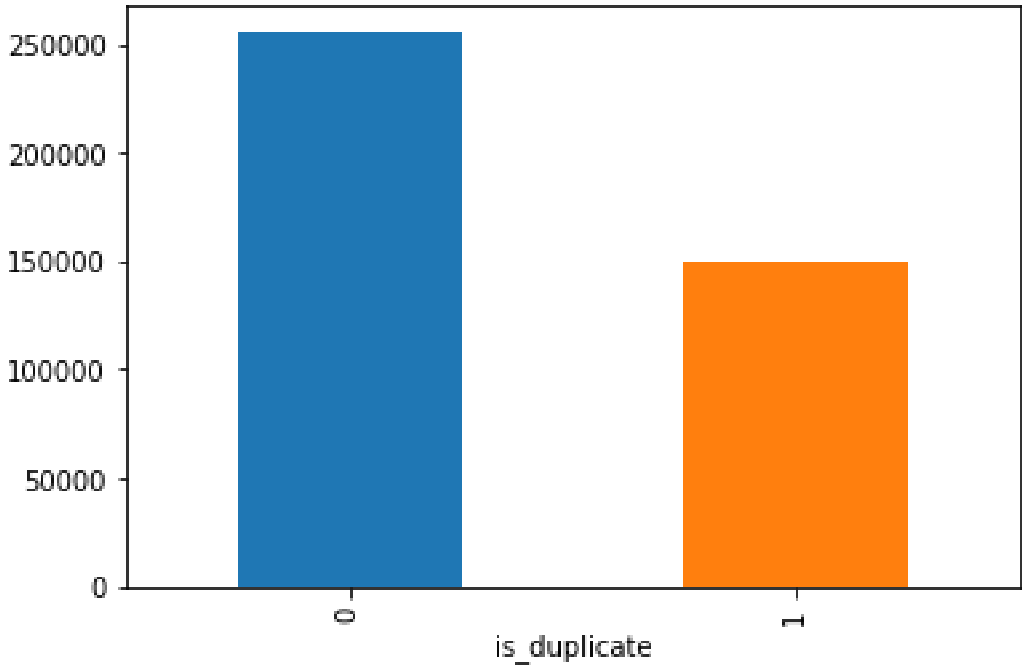
```
Out[4]:    id  qid1  qid2                                          question1  \
        0   0     1     2  What is the step by step guide to invest in sh...
        1   1     3     4  What is the story of Kohinoor (Koh-i-Noor) Dia...
        2   2     5     6  How can I increase the speed of my internet 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
```

```
In [5]: df.info()
```

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

```
In [6]: df.groupby("is_duplicate")['id'].count().plot.bar()
```

```
Out[6]: <matplotlib.axes._subplots.AxesSubplot at 0x7f86091f5e10>
```



```
In [7]: print('~> Total number of question pairs for training:\n   {}'.format(len(df)))
```

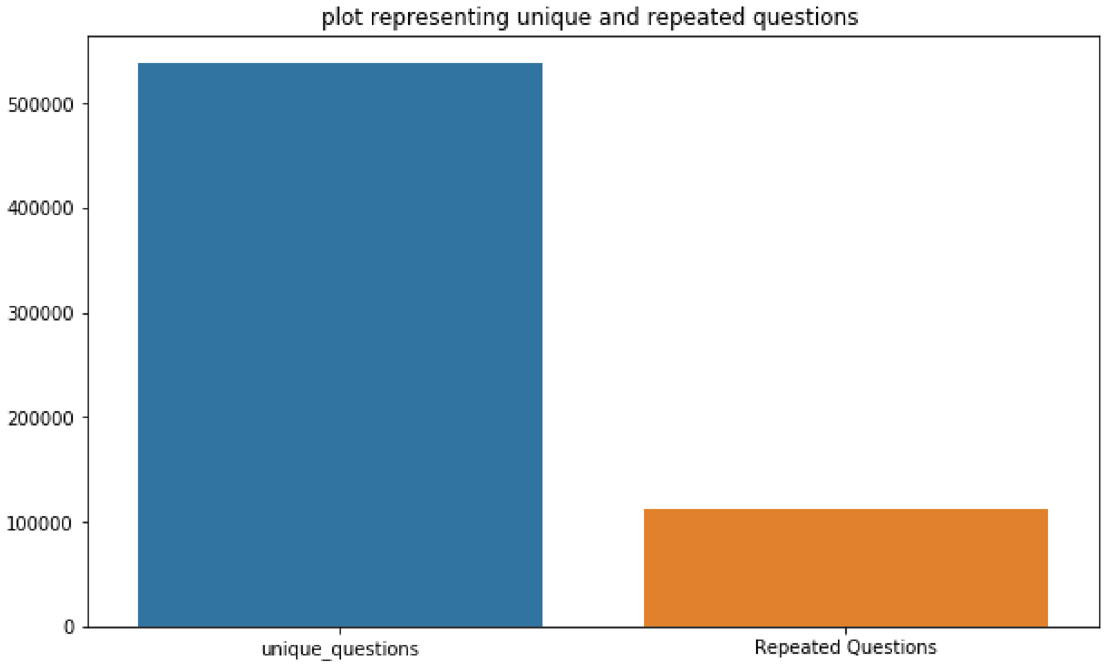
```
~> Total number of question pairs for training:
   404290
```

```
In [8]: print('~> Question pairs are not Similar (is_duplicate = 0):\n   {}%'.format(100 - rou
        print('\n~> Question pairs are Similar (is_duplicate = 1):\n   {}%'.format(round(df['i
~> Question pairs are not Similar (is_duplicate = 0):
   63.08%

~> Question pairs are Similar (is_duplicate = 1):
   36.92%
```

```
In [9]: #number of unique questions
        qids = pd.Series(df['qid1'].tolist() + df['qid2'].tolist())
        unique_qs = len(np.unique(qids))
        qs_morethan_onetime = np.sum(qids.value_counts() > 1)
        print('Total number of Unique Questions are: {}\n'.format(unique_qs))

        print('Number of unique questions that appear more than one time : {} ({}%)\n'.format(

        print('Max number of times a single question is repeated : {}\n'.format(max(qids.value_

        q_vals=qids.value_counts()

        q_vals=q_vals.values
```

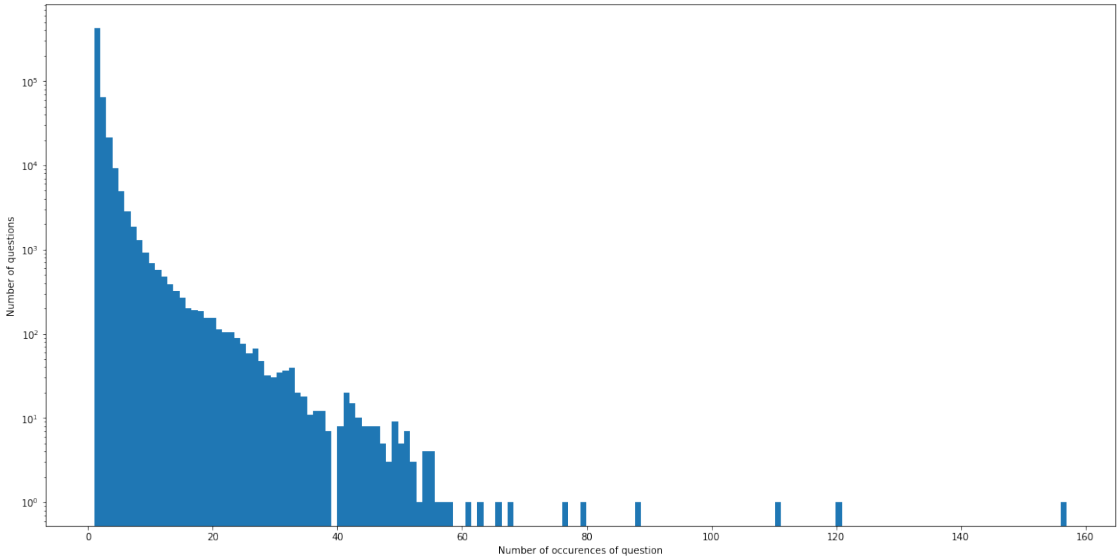
```
Total number of Unique Questions are: 537933

Number of unique questions that appear more than one time : 111780 (20.77953945937505%)

Max number of times a single question is repeated : 157
```

```
In [10]: x = ["unique_questions" , "Repeated Questions"]
         y = [unique_qs , qs_morethan_onetime]

         plt.figure(figsize=(10,6))
         plt.title("plot representing unique and repeated questions ")
         sns.barplot(x,y)
         plt.show()
```



```
In [11]: # checking whether there are any repeated pair of questions

         pair_duplicates = df[['qid1', 'qid2', 'is_duplicate']].groupby(['qid1' , 'qid2']).cou

         print("Number of duplicate questions", (pair_duplicates).shape[0] - df.shape[0])

Number of duplicate questions 0
```

```
In [12]: # Number of occurrences of each question
         plt.figure(figsize=(20,10))

         plt.hist(qids.value_counts(), bins=160)

         plt.yscale('log', nonposy='clip')

         plt.xlabel('Number of occurences of question')

         plt.ylabel('Number of questions')

         print('Maximum number of times a single question is repeated: {}\n'.format(max(qids.va

Maximum number of times a single question is repeated: 157
```



```
In [13]: #Checking whether there are any rows with null values
         nan_rows = df[df.isnull().any(1)]
         print(nan_rows)

            id    qid1    qid2                         question1  \
105780  105780  174363  174364    How can I develop android app?
201841  201841  303951  174364  How can I create an Android app?
363362  363362  493340  493341                               NaN

                                               question2  is_duplicate
105780                                               NaN             0
201841                                               NaN             0
363362  My Chinese name is Haichao Yu. What English na...             0
```

- There are two rows with null values in question2

```
In [14]: #Filling the null values with ' '
         df = df.fillna('')
         nan_rows = df[df.isnull().any(1)]
         print(nan_rows)

Empty DataFrame
Columns: [id, qid1, qid2, question1, question2, is_duplicate]
Index: []
```

### 0.0.1 Basic Feature Extraction (before cleaning)

Let us now construct a few features like: - ____freq_qid1____ = Frequency of qid1's - ____freq_qid2____ = Frequency of qid2's - ____q1len____ = Length of q1 - ____q2len____ = Length of q2 - ____q1_n_words____ = Number of words in Question 1 - ____q2_n_words____ = Number of words in Question 2 - ____word_Common____ = (Number of common unique words in Question 1 and Question 2) - ____word_Total____ =(Total num of words in Question 1 + Total num of words in Question 2) - ____word_share____ = (word_common)/(word_Total) - ____freq_q1+freq_q2____ = sum total of frequency of qid1 and qid2 - ____freq_q1-freq_q2____ = absolute difference of frequency of qid1 and qid2

```
In [15]: if os.path.isfile('df_fe_without_preprocessing_train.csv'):
             df = pd.read_csv("df_fe_without_preprocessing_train.csv", encoding='latin-1')
         else:
             df['freq_qid1'] = df.groupby('qid1')['qid1'].transform('count')
             df['freq_qid2'] = df.groupby('qid2')['qid2'].transform('count')
             df['q1len'] = df['question1'].str.len()
             df['q2len'] = df['question2'].str.len()
             df['q1_n_words'] = df['question1'].apply(lambda row: len(row.split(" ")))
             df['q2_n_words'] = df['question2'].apply(lambda row: len(row.split(" ")))

             def normalized_word_Common(row):
                 w1 = set(map(lambda word: word.lower().strip(), row['question1'].split(" ")))
                 w2 = set(map(lambda word: word.lower().strip(), row['question2'].split(" ")))
                 return 1.0* len(w1 & w2)

             df['word_Common'] = df.apply(normalized_word_Common , axis=1)

             def normalized_word_Total(row):
                 w1 = set(map(lambda word: word.lower().strip() , row['question1'].split(" "))
                 w2 = set(map(lambda word: word.lower().strip(), row['question2'].split(" ")))
                 return 1.0 * (len(w1) + len(w2))
             df['word_Total'] = df.apply(normalized_word_Total, axis=1)

             def normalized_word_share(row):
                 w1 = set(map(lambda word: word.lower().strip(), row['question1'].split(" ")))
                 w2 = set(map(lambda word: word.lower().strip(), row['question2'].split(" ")))
                 return 1.0 * len(w1 & w2)/(len(w1) + len(w2))
             df['word_share'] = df.apply(normalized_word_share, axis=1)

             df['freq_q1+q2'] = df['freq_qid1']+df['freq_qid2']
             df['freq_q1-q2'] = abs(df['freq_qid1']-df['freq_qid2'])

             df.to_csv("df_fe_without_preprocessing_train.csv", index=False)

         df.head()
```

```
Out[15]:    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  freq_qid1  \
0  What is the step by step guide to invest in sh...             0          1
1  What would happen if the Indian government sto...             0          4
2  How can Internet speed be increased by hacking...             0          1
3  Find the remainder when [math]23^{24}[/math] i...             0          1
4            Which fish would survive in salt water?             0          3

   freq_qid2  q1len  q2len  q1_n_words  q2_n_words  word_Common  word_Total  \
0          1     66     57          14          12         10.0        23.0
1          1     51     88           8          13          4.0        20.0
2          1     73     59          14          10          4.0        24.0
3          1     50     65          11           9          0.0        19.0
4          1     76     39          13           7          2.0        20.0

   word_share  freq_q1+q2  freq_q1-q2
0    0.434783           2           0
1    0.200000           5           3
2    0.166667           2           0
3    0.000000           2           0
4    0.100000           4           2
```

### 0.0.2 Analysis of some of the extracted features

- Here are some questions have only one single words.

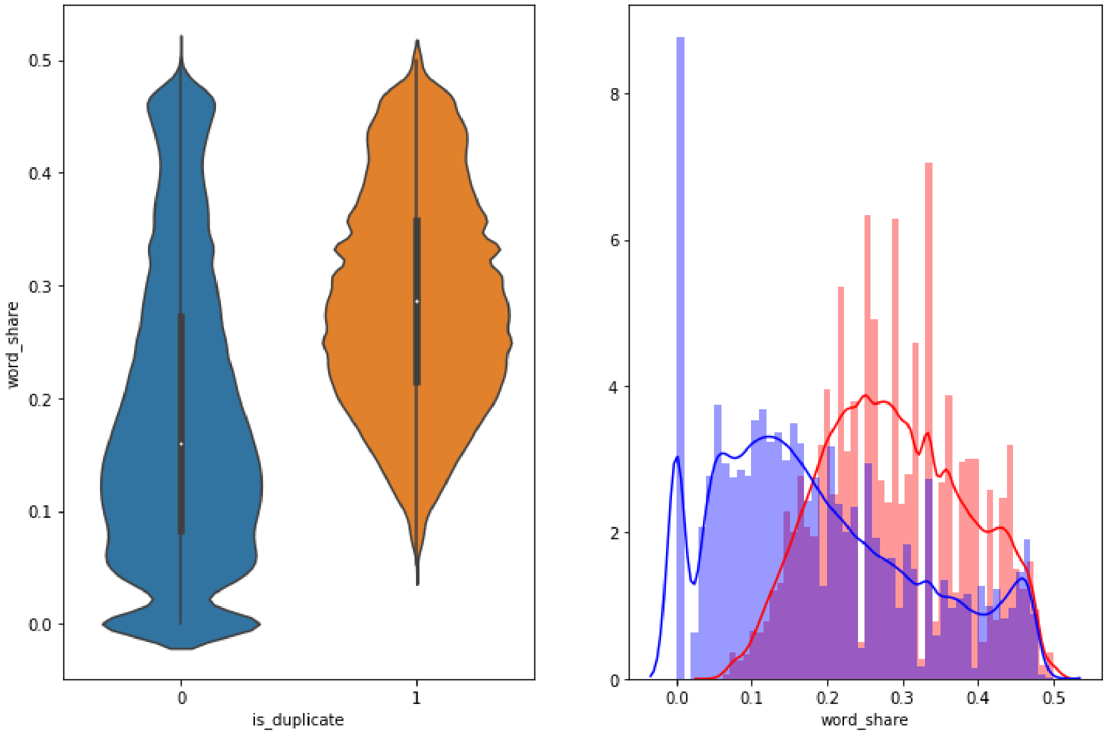
```
In [16]: print("Minimum length of the questions in question1 : ", min(df['q1_n_words']))
         print("Minimum length of the questions in question2 : ", min(df['q2_n_words']))

         print ("Number of Questions with minimum length [question1] :", df[df['q1_n_words']==
         print ("Number of Questions with minimum length [question2] :", df[df['q2_n_words']==
```

```
Minimum length of the questions in question1 :  1
Minimum length of the questions in question2 :  1
Number of Questions with minimum length [question1] : 67
Number of Questions with minimum length [question2] : 24
```

**Feature: word_shapre**

```
In [17]: plt.figure(figsize=(12,8))

         plt.subplot(1,2,1)
         sns.violinplot(x = 'is_duplicate', y = 'word_share', data = df[0:])
         plt.subplot(1,2,2)
         sns.distplot(df[df['is_duplicate'] == 1.0]['word_share'][0:], label = "1", color= 'red
         sns.distplot(df[df['is_duplicate'] == 0.0]['word_share'][0:], label = "0", color='blue
```

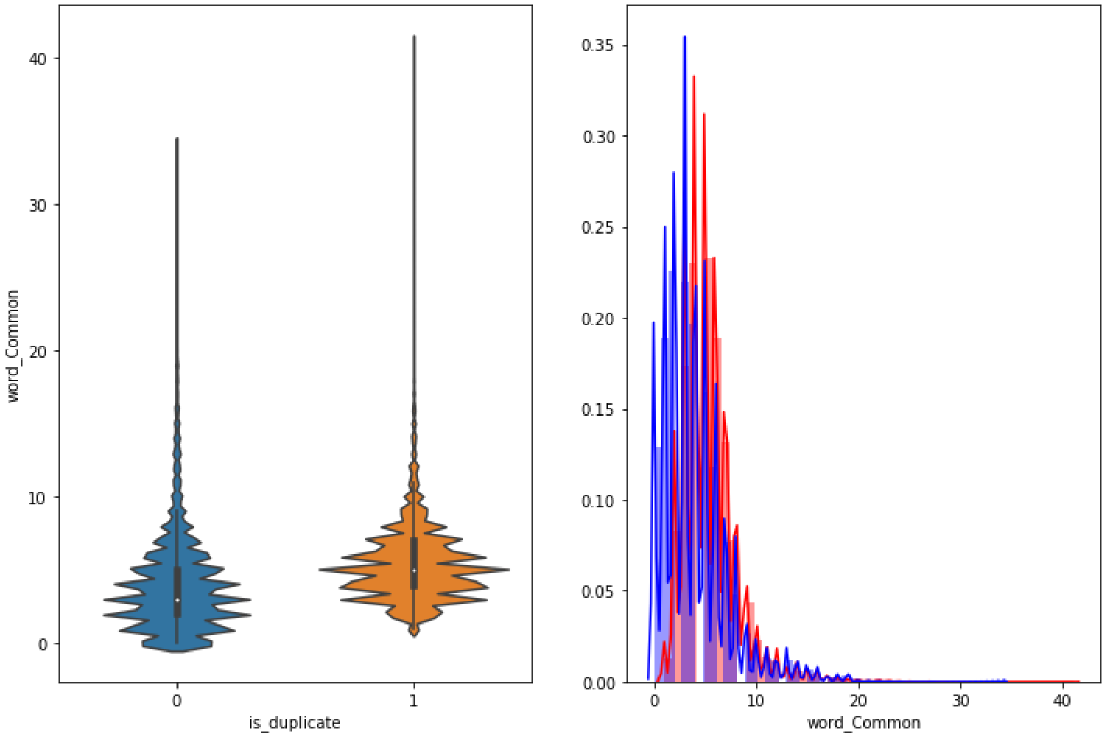
```
Out[17]: <matplotlib.axes._subplots.AxesSubplot at 0x7f85f8a9c160>
```



- The distributions for normalized word_share have some overlap on the far right-hand side, i.e., there are quite a lot of questions with high word similarity
- The average word share and Common no. of words of qid1 and qid2 is more when they are duplicate(Similar)

**Feature: word_Common**

```
In [18]: plt.figure(figsize=(12, 8))

         plt.subplot(1,2,1)
         sns.violinplot(x = 'is_duplicate', y = 'word_Common', data = df[0:])

         plt.subplot(1,2,2)
         sns.distplot(df[df['is_duplicate'] == 1.0]['word_Common'][0:] , label = "1", color =
         sns.distplot(df[df['is_duplicate'] == 0.0]['word_Common'][0:] , label = "0" , color =
         plt.show()
```



The distributions of the word_Common feature in similar and non-similar questions are highly overlapping

## 0.1 EDA : Advanced Feature Extraction

```
In [19]: df.head(2)
```

```
Out[19]:    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...

                                                    question2  is_duplicate  freq_qid1  \
         0  What is the step by step guide to invest in sh...             0          1
         1  What would happen if the Indian government sto...             0          4

            freq_qid2  q1len  q2len  q1_n_words  q2_n_words  word_Common  word_Total  \
         0          1     66     57          14          12         10.0        23.0
         1          1     51     88           8          13          4.0        20.0

            word_share  freq_q1+q2  freq_q1-q2
         0    0.434783           2           0
         1    0.200000           5           3
```

### 0.1.1 Preprocessing of Text

- Preprocessing:
  - Removing html tags
  - Removing Punctuations
  - Performing stemming
  - Removing Stopwords
  - Expanding contractions etc

```
In [20]: # To get the results in 4 decemal points
         SAFE_DIV = 0.0001

         STOP_WORDS = stopwords.words("english")


         def preprocess(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("n't", " not").replace("what's", "what is").repla
                                     .replace("'ve", " have").replace("i'm", "i am").replace("'
                                     .replace("he's", "he is").replace("she's", "she is").repla
                                     .replace("%", " percent ").replace("", " rupee ").replace("
                                     .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)


             porter = PorterStemmer()
             pattern = re.compile('\W')

             if type(x) == type(''):
                 x = re.sub(pattern, ' ', x)


             if type(x) == type(''):
                 x = porter.stem(x)
                 example1 = BeautifulSoup(x)
                 x = example1.get_text()


             return x
```

- Function to Compute and get the features : With 2 parameters of Question 1 and Question 2

### 0.1.2 Advanced Feature Extraction (NLP and Fuzzy Features)

Definition: - **Token**: You get a token by splitting sentence a space - **Stop_Word** : stop words as per NLTK. - **Word** : A token that is not a stop_word

Features: - **cwc_min** : Ratio of common_word_count to min lenghth of word count of Q1 and Q2 cwc_min = common_word_count / (min(len(q1_words), len(q2_words)) - **cwc_max** : Ratio of common_word_count to max lenghth of word count of Q1 and Q2 cwc_max = common_word_count / (max(len(q1_words), len(q2_words)) - **csc_min** : Ratio of common_stop_count to min lenghth of stop count of Q1 and Q2 csc_min = common_stop_count / (min(len(q1_stops), len(q2_stops)) - **csc_max** : Ratio of common_stop_count to max lenghth of stop count of Q1 and Q2csc_max = common_stop_count / (max(len(q1_stops), len(q2_stops)) - **ctc_min** : Ratio of common_token_count to min lenghth of token count of Q1 and Q2ctc_min = common_token_count / (min(len(q1_tokens), len(q2_tokens))

- **ctc_max** : Ratio of common_token_count to max lenghth of token count of Q1 and Q2ctc_max = common_token_count / (max(len(q1_tokens), len(q2_tokens))
- **last_word_eq** : Check if First word of both questions is equal or notlast_word_eq = int(q1_tokens[-1] == q2_tokens[-1])
- **first_word_eq** : Check if First word of both questions is equal or notfirst_word_eq = int(q1_tokens[0] == q2_tokens[0])
- **abs_len_diff** : Abs. length differenceabs_len_diff = abs(len(q1_tokens) - len(q2_tokens))
- **mean_len** : Average Token Length of both Questionsmean_len = (len(q1_tokens) + len(q2_tokens))/2
- **fuzz_ratio** : https://github.com/seatgeek/fuzzywuzzy#usage http://chairnerd.seatgeek.com/fuzzywuzzy-fuzzy-string-matching-in-python/
- **fuzz_partial_ratio** : https://github.com/seatgeek/fuzzywuzzy#usage http://chairnerd.seatgeek.com/fuzzywuzzy-fuzzy-string-matching-in-python/
- **token_sort_ratio** : https://github.com/seatgeek/fuzzywuzzy#usage http://chairnerd.seatgeek.com/fuzzywuzzy-fuzzy-string-matching-in-python/
- **token_set_ratio** : https://github.com/seatgeek/fuzzywuzzy#usage http://chairnerd.seatgeek.com/fuzzywuzzy-fuzzy-string-matching-in-python/
- **longest_substr_ratio** : Ratio of length longest common substring to min lenghth of token count of Q1 and Q2longest_substr_ratio = len(longest common substring) / (min(len(q1_tokens), len(q2_tokens))

```
In [31]: def get_token_features(q1, q2):
             token_features = [0.0]*10

             # Converting the Sentence into Tokens:
             q1_tokens = q1.split()
             q2_tokens = q2.split()

             if len(q1_tokens) == 0 or len(q2_tokens) == 0:
                 return token_features
             # Get the non-stopwords in Questions
             q1_words = set([word for word in q1_tokens if word not in STOP_WORDS])
```

```
    q2_words = set([word for word in q2_tokens if word not in STOP_WORDS])

    #Get the stopwords in Questions
    q1_stops = set([word for word in q1_tokens if word in STOP_WORDS])
    q2_stops = set([word for word in q2_tokens if word in STOP_WORDS])

    # Get the common non-stopwords from Question pair
    common_word_count = len(q1_words.intersection(q2_words))

    # Get the common stopwords from Question pair
    common_stop_count = len(q1_stops.intersection(q2_stops))

    # Get the common Tokens from Question pair
    common_token_count = len(set(q1_tokens).intersection(set(q2_tokens)))


    token_features[0] = common_word_count / (min(len(q1_words), len(q2_words)) + SAFE_
    token_features[1] = common_word_count / (max(len(q1_words), len(q2_words)) + SAFE_
    token_features[2] = common_stop_count / (min(len(q1_stops), len(q2_stops)) + SAFE_
    token_features[3] = common_stop_count / (max(len(q1_stops), len(q2_stops)) + SAFE_
    token_features[4] = common_token_count / (min(len(q1_tokens), len(q2_tokens)) + SA
    token_features[5] = common_token_count / (max(len(q1_tokens), len(q2_tokens)) + SA

    # Last word of both question is same or not
    token_features[6] = int(q1_tokens[-1] == q2_tokens[-1])

    # First word of both question is same or not
    token_features[7] = int(q1_tokens[0] == q2_tokens[0])

    token_features[8] = abs(len(q1_tokens) - len(q2_tokens))

    #Average Token Length of both Questions
    token_features[9] = (len(q1_tokens) + len(q2_tokens))/2
    return token_features

# get the Longest Common sub string

def get_longest_substr_ratio(a, b):
    strs = list(distance.lcsubstrings(a, b))
    if len(strs) == 0:
        return 0
    else:
        return len(strs[0]) / (min(len(a), len(b)) + 1)

def extract_features(df):
    # preprocessing each question
    df["question1"] = df["question1"].fillna("").apply(preprocess)
    df["question2"] = df["question2"].fillna("").apply(preprocess)
    print("token features...")

    # Merging Features with dataset

    token_features = df.apply(lambda x: get_token_features(x["question1"], x["questio

    df["cwc_min"]       = list(map(lambda x: x[0], token_features))
    df["cwc_max"]       = list(map(lambda x: x[1], token_features))
    df["csc_min"]       = list(map(lambda x: x[2], token_features))
    df["csc_max"]       = list(map(lambda x: x[3], token_features))
    df["ctc_min"]       = list(map(lambda x: x[4], token_features))
    df["ctc_max"]       = list(map(lambda x: x[5], token_features))
    df["last_word_eq"]  = list(map(lambda x: x[6], token_features))
    df["first_word_eq"] = list(map(lambda x: x[7], token_features))
    df["abs_len_diff"]  = list(map(lambda x: x[8], token_features))
    df["mean_len"]      = list(map(lambda x: x[9], token_features))

    #Computing Fuzzy Features and Merging with Dataset

    # do read this blog: http://chairnerd.seatgeek.com/fuzzywuzzy-fuzzy-string-matchi
    # https://stackoverflow.com/questions/31806695/when-to-use-which-fuzz-function-to
    # https://github.com/seatgeek/fuzzywuzzy
    print("fuzzy features..")

    df["token_set_ratio"]       = df.apply(lambda x: fuzz.token_set_ratio(x["question
    # The token sort approach involves tokenizing the string in question, sorting the
    # then joining them back into a string We then compare the transformed strings wi
    df["token_sort_ratio"]      = df.apply(lambda x: fuzz.token_sort_ratio(x["questio
    df["fuzz_ratio"]            = df.apply(lambda x: fuzz.QRatio(x["question1"], x["q
    df["fuzz_partial_ratio"]    = df.apply(lambda x: fuzz.partial_ratio(x["question1"]
    df["longest_substr_ratio"]  = df.apply(lambda x: get_longest_substr_ratio(x["ques
    return df
```

In [32]:

```
if os.path.isfile('nlp_features_train.csv'):
    df = pd.read_csv("nlp_features_train.csv",encoding='latin-1')
    df.fillna('')
else:
    print("Extracting features for train:")
    df = pd.read_csv("train.csv")
    df = extract_features(df)
    df.to_csv("nlp_features_train.csv", index=False)
df.head(2)
```

```
Extracting features for train:
token features...
fuzzy features..
```

```
Out[32]:    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...

                                                    question2  is_duplicate   cwc_min  \
         0  what is the step by step guide to invest in sh...             0  0.999980
         1  what would happen if the indian government sto...             0  0.799984

             cwc_max   csc_min   csc_max          ...          ctc_max  last_word_eq  \
         0  0.833319  0.999983  0.999983          ...         0.785709           0.0
         1  0.399996  0.749981  0.599988          ...         0.466664           0.0

            first_word_eq  abs_len_diff  mean_len  token_set_ratio  token_sort_ratio  \
         0            1.0           2.0      13.0              100                93
         1            1.0           5.0      12.5               86                63

            fuzz_ratio  fuzz_partial_ratio  longest_substr_ratio
         0          93                 100              0.982759
         1          66                  75              0.596154

         [2 rows x 21 columns]
```

Analysis of extracted features
Plotting Word clouds

- Creating Word Cloud of Duplicates and Non-Duplicates Question pairs
- We can observe the most frequent occuring words

```
In [33]: df_duplicate = df[df['is_duplicate'] == 1]
         dfp_nonduplicate = df[df['is_duplicate'] == 0]

         # Converting 2d array of q1 and q2 and filatten the array : like {{1,2}, {3,4} }  to

         p = np.dstack([df_duplicate["question1"] , df_duplicate["question2"]]).flatten()
         n = np.dstack([dfp_nonduplicate["question1"], dfp_nonduplicate["question2"]]).flatten

         print ("Number of data points in class 1 (duplicate pairs) :",len(p))
         print ("Number of data points in class 0 (non duplicate pairs) :",len(n))

         #Saving the np array into a text file
         np.savetxt('train_p.txt', p, delimiter=' ', fmt='%s')
         np.savetxt('train_n.txt', n, delimiter=' ', fmt='%s')
```

```
Number of data points in class 1 (duplicate pairs) : 298526
Number of data points in class 0 (non duplicate pairs) : 510054
```

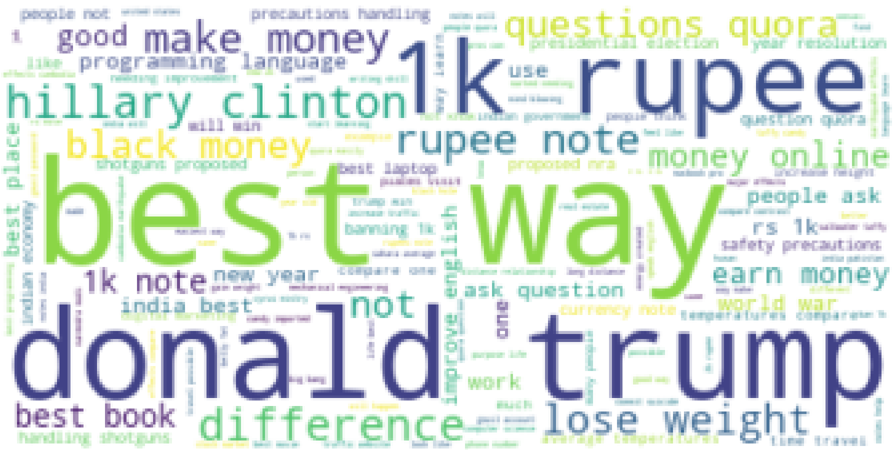
```
In [34]: # reading the text files and removing the Stop Words:
         d = path.dirname('.')
         textp_w = open(path.join(d, 'train_p.txt')).read()
         textn_w = open(path.join(d, 'train_n.txt')).read()
         stopwords = set(STOPWORDS)
         stopwords.add("said")
         stopwords.add("br")
         stopwords.add(" ")
         stopwords.remove("not")

         stopwords.remove("no")
         #stopwords.remove("good")
         #stopwords.remove("love")
         stopwords.remove("like")
         #stopwords.remove("best")
         #stopwords.remove("!")
         print ("Total number of words in duplicate pair questions :",len(textp_w))
         print ("Total number of words in non duplicate pair questions :",len(textn_w))
```

```
Total number of words in duplicate pair questions : 16109886
Total number of words in non duplicate pair questions : 33193067
```

__ Word Clouds generated from duplicate pair question's text __

```
In [35]: wc = WordCloud(background_color="white", max_words=len(textp_w), stopwords=stopwords)
         wc.generate(textp_w)
         print ("Word Cloud for Duplicate Question pairs")
         plt.imshow(wc, interpolation='bilinear')
         plt.axis("off")
         plt.show()
```

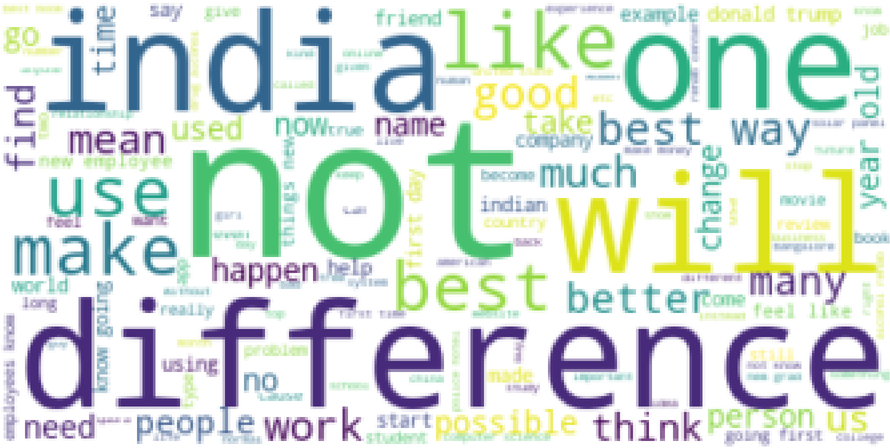
```
Word Cloud for Duplicate Question pairs
```



__ Word Clouds generated from non duplicate pair question's text __

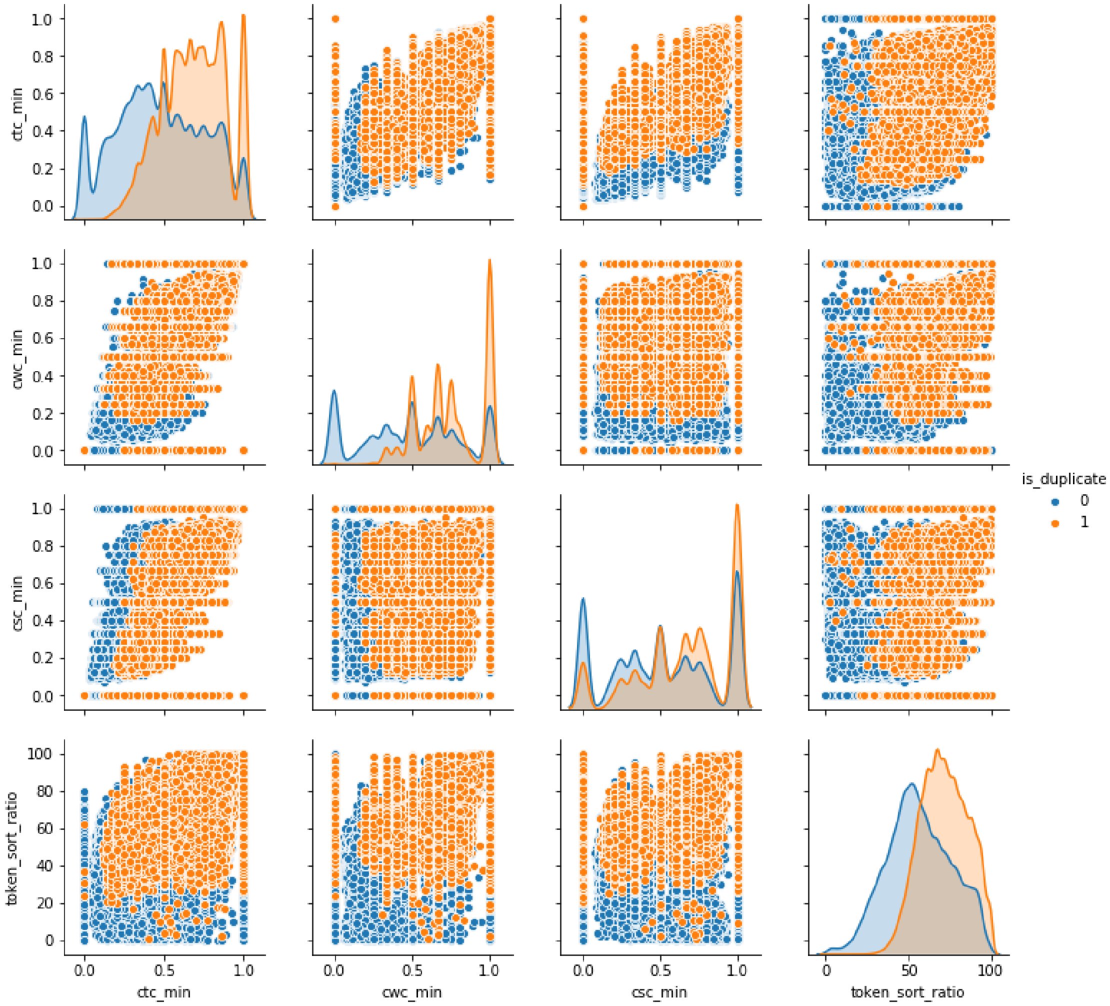
```
In [36]: wc = WordCloud(background_color="white", max_words=len(textn_w),stopwords=stopwords)
         # generate word cloud
         wc.generate(textn_w)
         print ("Word Cloud for non-Duplicate Question pairs:")
         plt.imshow(wc, interpolation='bilinear')
         plt.axis("off")
         plt.show()
```

```
Word Cloud for non-Duplicate Question pairs:
```

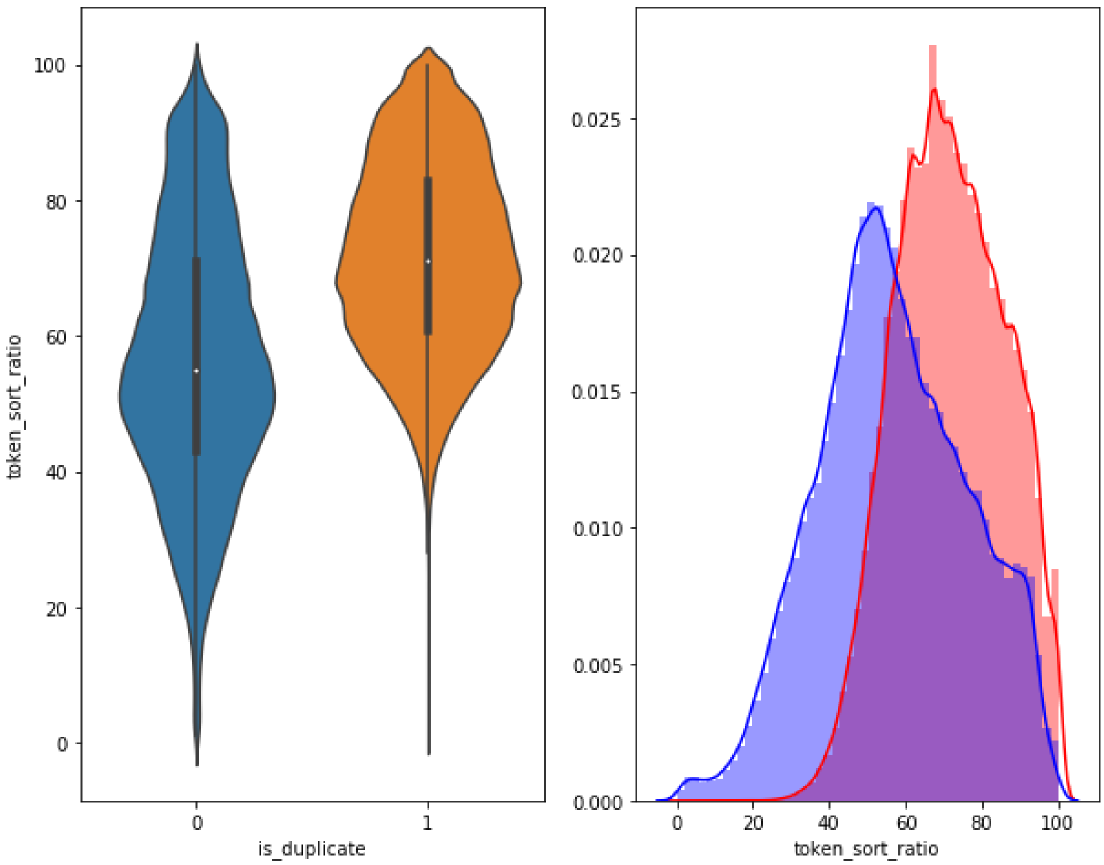


**Pair plot of features ['ctc_min', 'cwc_min', 'csc_min', 'token_sort_ratio']**

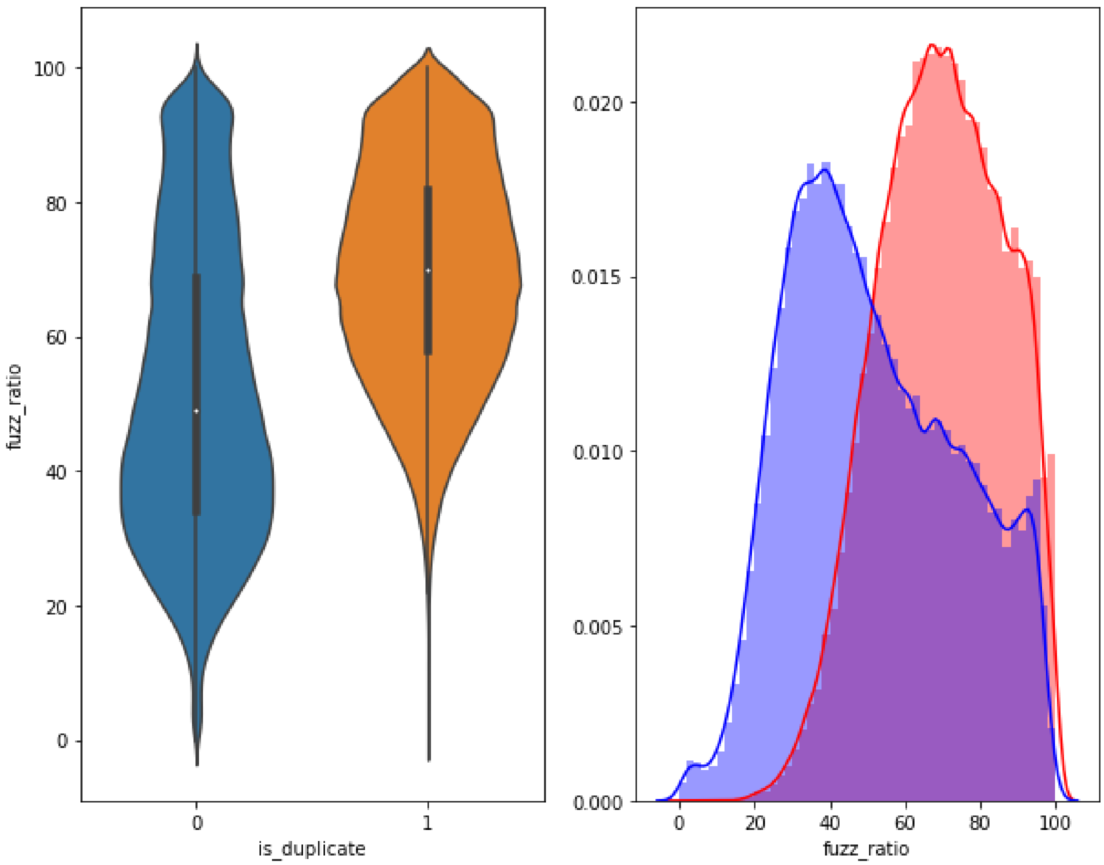
```
In [37]: n = df.shape[0]
         sns.pairplot(df[['ctc_min', 'cwc_min', 'csc_min', 'token_sort_ratio', 'is_duplicate']]
         plt.show()
```



```
In [38]: # Distribution of the token_sort_ratio
         plt.figure(figsize=(10, 8))

         plt.subplot(1,2,1)
         sns.violinplot(x = 'is_duplicate', y = 'token_sort_ratio', data = df[0:] , )

         plt.subplot(1,2,2)
         sns.distplot(df[df['is_duplicate'] == 1.0]['token_sort_ratio'][0:] , label = "1", colo
         sns.distplot(df[df['is_duplicate'] == 0.0]['token_sort_ratio'][0:] , label = "0" , co
         plt.show()
```



```
In [39]: plt.figure(figsize=(10, 8))

         plt.subplot(1,2,1)
         sns.violinplot(x = 'is_duplicate', y = 'fuzz_ratio', data = df[0:] , )

         plt.subplot(1,2,2)
         sns.distplot(df[df['is_duplicate'] == 1.0]['fuzz_ratio'][0:] , label = "1", color = '
         sns.distplot(df[df['is_duplicate'] == 0.0]['fuzz_ratio'][0:] , label = "0" , color =
         plt.show()
```

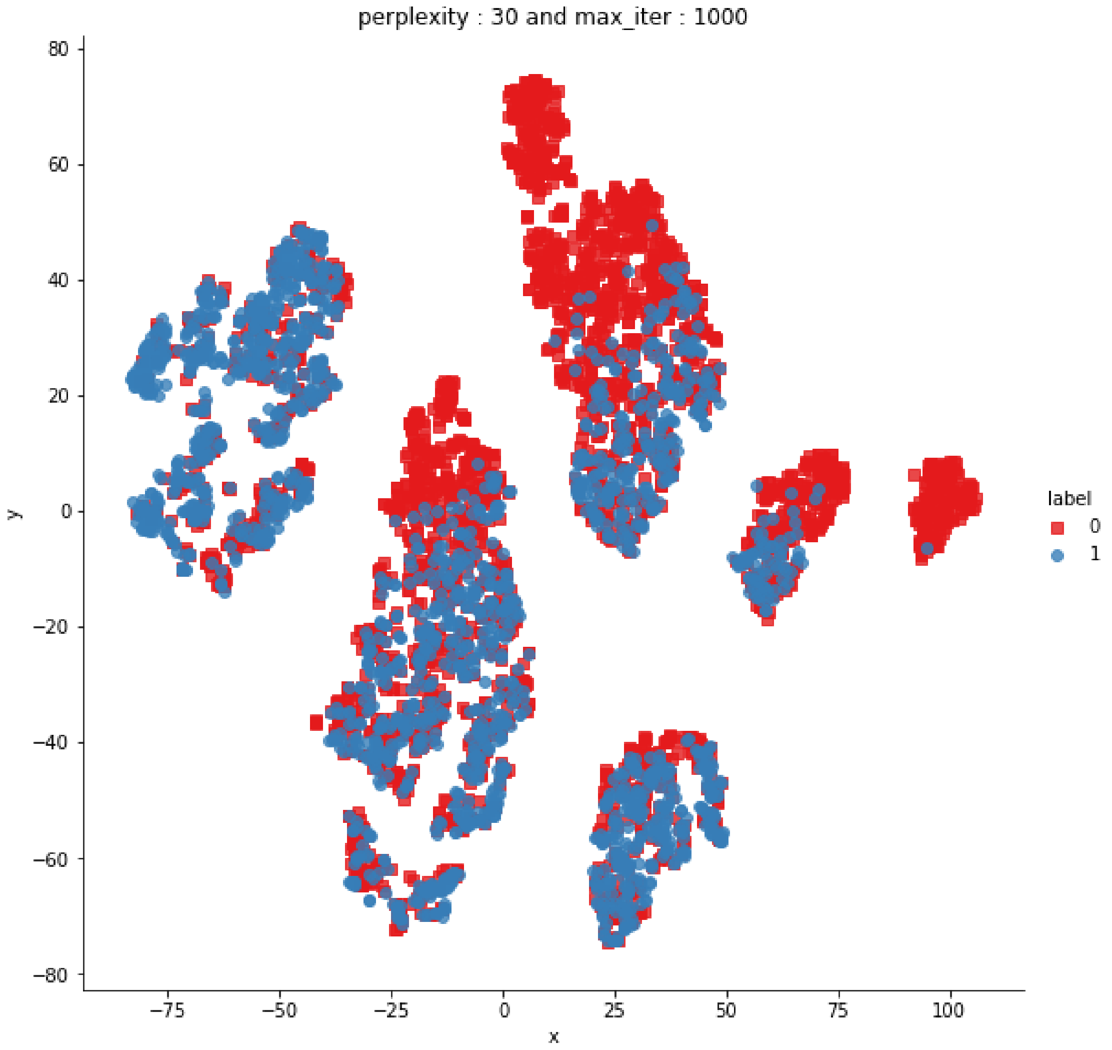


## 0.2 Visualization

```
In [40]: # Using TSNE for Dimentionality reduction for 15 Features(Generated after cleaning th

         from sklearn.preprocessing import MinMaxScaler

         dfp_subsampled = df[0:5000]
         X = MinMaxScaler().fit_transform(dfp_subsampled[['cwc_min', 'cwc_max', 'csc_min', 'cs
         y = dfp_subsampled['is_duplicate'].values

In [41]: tsne2d = TSNE(
             n_components=2,
             init='random', # pca
             random_state=101,
             method='barnes_hut',
             n_iter=1000,
             verbose=2,
             angle=0.5
         ).fit_transform(X)
```

```
[t-SNE] Computing 91 nearest neighbors...
[t-SNE] Indexed 5000 samples in 0.092s...
[t-SNE] Computed neighbors for 5000 samples in 0.671s...
[t-SNE] Computed conditional probabilities for sample 1000 / 5000
[t-SNE] Computed conditional probabilities for sample 2000 / 5000
[t-SNE] Computed conditional probabilities for sample 3000 / 5000
[t-SNE] Computed conditional probabilities for sample 4000 / 5000
[t-SNE] Computed conditional probabilities for sample 5000 / 5000
[t-SNE] Mean sigma: 0.130446
[t-SNE] Computed conditional probabilities in 0.614s
[t-SNE] Iteration 50: error = 81.2911148, gradient norm = 0.0457501 (50 iterations in 4.529s)
[t-SNE] Iteration 100: error = 70.6044159, gradient norm = 0.0086692 (50 iterations in 3.014s)
[t-SNE] Iteration 150: error = 68.9124908, gradient norm = 0.0056016 (50 iterations in 2.859s)
[t-SNE] Iteration 200: error = 68.1010742, gradient norm = 0.0047585 (50 iterations in 2.972s)
[t-SNE] Iteration 250: error = 67.5907974, gradient norm = 0.0033576 (50 iterations in 3.095s)
[t-SNE] KL divergence after 250 iterations with early exaggeration: 67.590797
[t-SNE] Iteration 300: error = 1.7929677, gradient norm = 0.0011899 (50 iterations in 3.134s)
[t-SNE] Iteration 350: error = 1.3937442, gradient norm = 0.0004817 (50 iterations in 3.037s)
[t-SNE] Iteration 400: error = 1.2280033, gradient norm = 0.0002773 (50 iterations in 3.042s)
[t-SNE] Iteration 450: error = 1.1383208, gradient norm = 0.0001865 (50 iterations in 3.086s)
[t-SNE] Iteration 500: error = 1.0834006, gradient norm = 0.0001423 (50 iterations in 3.069s)
[t-SNE] Iteration 550: error = 1.0474092, gradient norm = 0.0001144 (50 iterations in 3.152s)
[t-SNE] Iteration 600: error = 1.0231259, gradient norm = 0.0000995 (50 iterations in 3.171s)
[t-SNE] Iteration 650: error = 1.0066353, gradient norm = 0.0000895 (50 iterations in 3.141s)
[t-SNE] Iteration 700: error = 0.9954656, gradient norm = 0.0000805 (50 iterations in 3.219s)
[t-SNE] Iteration 750: error = 0.9871529, gradient norm = 0.0000719 (50 iterations in 3.223s)
[t-SNE] Iteration 800: error = 0.9801921, gradient norm = 0.0000657 (50 iterations in 3.217s)
[t-SNE] Iteration 850: error = 0.9743395, gradient norm = 0.0000631 (50 iterations in 3.234s)
[t-SNE] Iteration 900: error = 0.9693972, gradient norm = 0.0000606 (50 iterations in 3.408s)
[t-SNE] Iteration 950: error = 0.9654404, gradient norm = 0.0000594 (50 iterations in 3.495s)
[t-SNE] Iteration 1000: error = 0.9622302, gradient norm = 0.0000565 (50 iterations in 3.410s)
[t-SNE] KL divergence after 1000 iterations: 0.962230
```

```
In [42]: df = pd.DataFrame({'x':tsne2d[:,0], 'y':tsne2d[:,1] ,'label':y})

         # draw the plot in appropriate place in the grid
         sns.lmplot(data=df, x='x', y='y', hue='label', fit_reg=False, size=8,palette="Set1",ma
         plt.title("perplexity : {} and max_iter : {}".format(30, 1000))
         plt.show()
```



```
In [43]: from sklearn.manifold import TSNE
         tsne3d = TSNE(
             n_components=3,
             init='random', # pca
             random_state=101,
             method='barnes_hut',
             n_iter=1000,
             verbose=2,
             angle=0.5
         ).fit_transform(X)
```

```
[t-SNE] Computing 91 nearest neighbors...
[t-SNE] Indexed 5000 samples in 0.016s...
[t-SNE] Computed neighbors for 5000 samples in 0.679s...
[t-SNE] Computed conditional probabilities for sample 1000 / 5000
```

```
[t-SNE] Computed conditional probabilities for sample 2000 / 5000
[t-SNE] Computed conditional probabilities for sample 3000 / 5000
[t-SNE] Computed conditional probabilities for sample 4000 / 5000
[t-SNE] Computed conditional probabilities for sample 5000 / 5000
[t-SNE] Mean sigma: 0.130446
[t-SNE] Computed conditional probabilities in 0.504s
[t-SNE] Iteration 50: error = 80.5316772, gradient norm = 0.0296611 (50 iterations in 22.021s)
[t-SNE] Iteration 100: error = 69.3823166, gradient norm = 0.0032796 (50 iterations in 10.199s
[t-SNE] Iteration 150: error = 67.9726028, gradient norm = 0.0016793 (50 iterations in 9.181s)
[t-SNE] Iteration 200: error = 67.4176178, gradient norm = 0.0010922 (50 iterations in 9.438s)
[t-SNE] Iteration 250: error = 67.1033630, gradient norm = 0.0008839 (50 iterations in 9.155s)
[t-SNE] KL divergence after 250 iterations with early exaggeration: 67.103363
[t-SNE] Iteration 300: error = 1.5262967, gradient norm = 0.0007234 (50 iterations in 11.931s)
[t-SNE] Iteration 350: error = 1.1826925, gradient norm = 0.0002056 (50 iterations in 15.686s)
[t-SNE] Iteration 400: error = 1.0364963, gradient norm = 0.0000999 (50 iterations in 14.883s)
[t-SNE] Iteration 450: error = 0.9654390, gradient norm = 0.0000914 (50 iterations in 14.851s)
[t-SNE] Iteration 500: error = 0.9289201, gradient norm = 0.0000634 (50 iterations in 14.666s)
[t-SNE] Iteration 550: error = 0.9090494, gradient norm = 0.0000504 (50 iterations in 14.297s)
[t-SNE] Iteration 600: error = 0.8954713, gradient norm = 0.0000525 (50 iterations in 13.905s)
[t-SNE] Iteration 650: error = 0.8866501, gradient norm = 0.0000497 (50 iterations in 13.969s)
[t-SNE] Iteration 700: error = 0.8820391, gradient norm = 0.0000369 (50 iterations in 14.313s)
[t-SNE] Iteration 750: error = 0.8775222, gradient norm = 0.0000342 (50 iterations in 14.287s)
[t-SNE] Iteration 800: error = 0.8723416, gradient norm = 0.0000288 (50 iterations in 14.493s)
[t-SNE] Iteration 850: error = 0.8663230, gradient norm = 0.0000297 (50 iterations in 14.432s)
[t-SNE] Iteration 900: error = 0.8605922, gradient norm = 0.0000286 (50 iterations in 14.494s)
[t-SNE] Iteration 950: error = 0.8555549, gradient norm = 0.0000312 (50 iterations in 14.543s)
[t-SNE] Iteration 1000: error = 0.8521745, gradient norm = 0.0000278 (50 iterations in 14.383s
[t-SNE] KL divergence after 1000 iterations: 0.852175
```

```
In [44]: trace1 = go.Scatter3d(
             x=tsne3d[:,0],
             y=tsne3d[:,1],
             z=tsne3d[:,2],
             mode='markers',
             marker=dict(
                 sizemode='diameter',
                 color = y,
                 colorscale = 'Portland',
                 colorbar = dict(title = 'duplicate'),
                 line=dict(color='rgb(255, 255, 255)'),
                 opacity=0.75
             )
         )

         data=[trace1]
         layout=dict(height=800, width=800, title='3d embedding with engineered features')
         fig=dict(data=data, layout=layout)
```

```
        py.iplot(fig, filename='3DBubble')
```

```
In [46]: # avoid decoding problems
         df = pd.read_csv("train.csv")

         # encode questions to unicode
         # https://stackoverflow.com/a/6812069
         # ----------------- python 2 ---------------------
         # df['question1'] = df['question1'].apply(lambda x: unicode(str(x),"utf-8"))
         # df['question2'] = df['question2'].apply(lambda x: unicode(str(x),"utf-8"))
         # ----------------- python 3 ---------------------
         df['question1'] = df['question1'].apply(lambda x: str(x))
         df['question2'] = df['question2'].apply(lambda x: str(x))
```

```
In [47]: df.head()
```

```
Out[47]:    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
```

```
In [58]: #prepro_features_train.csv (Simple Preprocessing Feartures)
         #nlp_features_train.csv (NLP Features)
         if os.path.isfile('nlp_features_train.csv'):
             dfnlp = pd.read_csv("nlp_features_train.csv",encoding='latin-1')
         else:
             print("download nlp_features_train.csv from drive or run previous notebook")

         if os.path.isfile('df_fe_without_preprocessing_train.csv'):
             dfppro = pd.read_csv("df_fe_without_preprocessing_train.csv",encoding='latin-1')
         else:
             print("download df_fe_without_preprocessing_train.csv from drive or run previous 
```

```
In [76]: df1 = dfnlp.drop(['qid1','qid2','question1','question2', 'id', 'is_duplicate'],axis=1
         df2 = dfppro.drop(['qid1','qid2','question1','question2','is_duplicate','id'],axis=1)
         df3 = df.drop(['qid1','qid2','id'],axis=1)
```

```
In [77]: df1.head()
```

```
Out[77]:     cwc_min   cwc_max   csc_min   csc_max   ctc_min   ctc_max  last_word_eq  \
         0  0.999980  0.833319  0.999983  0.999983  0.916659  0.785709           0.0
         1  0.799984  0.399996  0.749981  0.599988  0.699993  0.466664           0.0
         2  0.399992  0.333328  0.399992  0.249997  0.399996  0.285712           0.0
         3  0.000000  0.000000  0.000000  0.000000  0.000000  0.000000           0.0
         4  0.399992  0.199998  0.999950  0.666644  0.571420  0.307690           0.0

            first_word_eq  abs_len_diff  mean_len  token_set_ratio  token_sort_ratio  \
         0            1.0           2.0      13.0              100                93
         1            1.0           5.0      12.5               86                63
         2            1.0           4.0      12.0               63                63
         3            0.0           2.0      12.0               28                24
         4            1.0           6.0      10.0               67                47

            fuzz_ratio  fuzz_partial_ratio  longest_substr_ratio
         0          93                 100              0.982759
         1          66                  75              0.596154
         2          43                  47              0.166667
         3           9                  14              0.039216
         4          35                  56              0.175000
```

```
In [78]: df2.head()
```

```
Out[78]:    freq_qid1  freq_qid2  q1len  q2len  q1_n_words  q2_n_words  word_Common  \
         0          1          1     66     57          14          12         10.0
         1          4          1     51     88           8          13          4.0
         2          1          1     73     59          14          10          4.0
         3          1          1     50     65          11           9          0.0
         4          3          1     76     39          13           7          2.0

            word_Total  word_share  freq_q1+q2  freq_q1-q2
         0        23.0    0.434783           2           0
         1        20.0    0.200000           5           3
         2        24.0    0.166667           2           0
         3        19.0    0.000000           2           0
         4        20.0    0.100000           4           2
```

```
In [79]: df3.head()
```

```
Out[79]:                                            question1  \
         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...
         4  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
```

```
In [80]: df3["question1"] = df3["question1"].fillna("").apply(preprocess)
         df3["question2"] = df3["question2"].fillna("").apply(preprocess)
```

```
In [81]: df3.head()
```

```
Out[81]:                                           question1  \
         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...
         4  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
```

```
In [82]: print(df1.shape)
         print(df2.shape)
         print(df3.shape)
```

```
(404290, 15)
(404290, 11)
(404290, 3)
```

```
In [84]: df1['id'] = [i for i in range(404290)]
         df2['id'] = [i for i in range(404290)]
         df3['id'] = [i for i in range(404290)]
```

```
In [ ]:
```

```
In [86]: # storing the final features to csv file
         if not os.path.isfile('final_features.csv'):
             df3  = df3.merge(df2,on='id',how='left')
             df3  = df3.merge(df1,on='id',how='left')
             df3.to_csv('final_features.csv')
```

```
In [88]: Y = df3['is_duplicate']
         X = df3.drop('is_duplicate', axis=1)
```

```
In [90]: from sklearn.model_selection import train_test_split
```

```
In [91]: X_train,X_test, y_train, y_test = train_test_split(X, Y, test_size=0.3)
In [154]: from sklearn.feature_extraction.text import TfidfVectorizer
          from sklearn.feature_extraction.text import CountVectorizer
          # merge texts
          questions = list(X_train['question1']) + list(X_train['question2'])

          tfidf = TfidfVectorizer(min_df=5)
          tfidf.fit(questions)

Out[154]: TfidfVectorizer(analyzer='word', binary=False, decode_error='strict',
                  dtype=<class 'numpy.float64'>, encoding='utf-8', input='content',
                  lowercase=True, max_df=1.0, max_features=None, min_df=5,
                  ngram_range=(1, 1), norm='l2', preprocessor=None, smooth_idf=True,
                  stop_words=None, strip_accents=None, sublinear_tf=False,
                  token_pattern='(?u)\\b\\w\\w+\\b', tokenizer=None, use_idf=True,
                  vocabulary=None)

In [155]: len(tfidf.get_feature_names())

Out[155]: 25282

In [5]: from scipy.sparse import coo_matrix
        import scipy

In [160]: X_train_q1 = coo_matrix(tfidf.transform(X_train['question1']))
          X_train_q2 = coo_matrix(tfidf.transform(X_train['question2']))

In [161]: X_train_q1.shape

Out[161]: (283003, 25282)

In [162]: X_train_q2.shape

Out[162]: (283003, 25282)

In [163]: X_train_q1_q2 = scipy.sparse.hstack((X_train_q1, X_train_q2))
          scipy.sparse.save_npz("X_train_q1_q2.npz", X_train_q1_q2)

In [164]: X_train_q1_q2

Out[164]: <283003x50564 sparse matrix of type '<class 'numpy.float64'>'
                  with 5647482 stored elements in COOrdinate format>

In [165]: X_test_q1 = coo_matrix(tfidf.transform(X_test['question1']))
          X_test_q2 = coo_matrix(tfidf.transform(X_test['question2']))

          X_test_q1_q2 = scipy.sparse.hstack((X_test_q1, X_test_q2))
          scipy.sparse.save_npz("X_test_q1_q2.npz", X_test_q1_q2)

In [166]: X_test_q1.shape
```

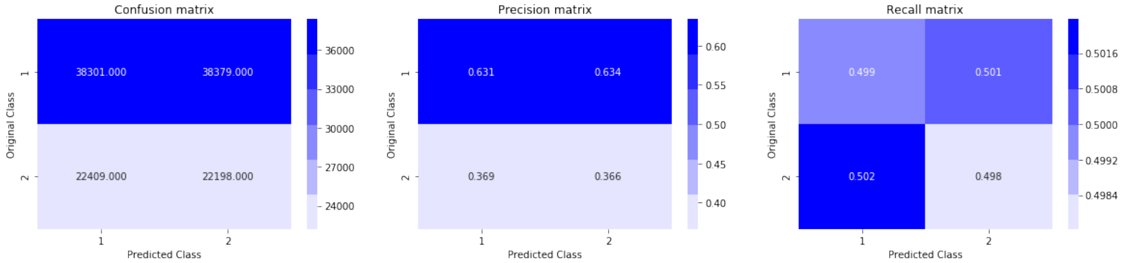
```
Out[166]: (121287, 25282)

In [167]: X_test_q2.shape

Out[167]: (121287, 25282)

In [168]: X_test_q1_q2.shape

Out[168]: (121287, 50564)

In [118]: X_train_no_tfidf = X_train.drop(['question1', 'question2','id'], axis=1)
          X_test_no_tfidf = X_test.drop(['question1', 'question2','id'], axis=1)

          X_train_no_tfidf = np.array(X_train_no_tfidf)
          X_test_no_tfidf = np.array(X_test_no_tfidf)

In [169]: X_train_final = scipy.sparse.hstack((X_train_no_tfidf, X_train_q1_q2))
          X_test_final = scipy.sparse.hstack((X_test_no_tfidf, X_test_q1_q2))

In [170]: X_test_final.shape

Out[170]: (121287, 50590)

In [172]: X_train_final.shape

Out[172]: (283003, 50590)

In [173]: scipy.sparse.save_npz("X_train_final.npz", X_train_final)
          scipy.sparse.save_npz("X_test_final.npz", X_test_final)

In [5]: X_train_final = scipy.sparse.load_npz("X_train_final.npz")
        X_test_final = scipy.sparse.load_npz("X_test_final.npz")

In [174]: np.save("y_train.npy", y_train)
          np.save("y_test.npy",y_test)

In [6]: y_train = np.load("y_train.npy")
        y_test = np.load("y_test.npy")

In [7]: print("-"*10, "Distribution of output variable in train data", "-"*10)
        train_distr = Counter(y_train)
        train_len = len(y_train)
        print("Class 0: ",int(train_distr[0])/train_len,"Class 1: ", int(train_distr[1])/train_
        print("-"*10, "Distribution of output variable in test data", "-"*10)
        test_distr = Counter(y_test)
        test_len = len(y_test)
        print("Class 0: ",int(test_distr[1])/test_len, "Class 1: ",int(test_distr[1])/test_len

---------- Distribution of output variable in train data ----------
Class 0:  0.6301947329180256 Class 1:  0.3698052670819744
---------- Distribution of output variable in test data ----------
Class 0:  0.36778055356303646 Class 1:  0.36778055356303646
```

```
In [8]: # This function plots the confusion matrices given y_i, y_i_hat.
        def plot_confusion_matrix(test_y, predict_y):
            C = confusion_matrix(test_y, predict_y)
            # C = 9,9 matrix, each cell (i,j) represents number of points of class i are predi

            A =(((C.T)/(C.sum(axis=1))).T)
            #divid each element of the confusion matrix with the sum of elements in that colum

            # C = [[1, 2],
            #     [3, 4]]
            # C.T = [[1, 3],
            #        [2, 4]]
            # C.sum(axis = 1)  axis=0 corresonds to columns and axis=1 corresponds to rows in
            # C.sum(axix =1) = [[3, 7]]
            # ((C.T)/(C.sum(axis=1))) = [[1/3, 3/7]
            #                            [2/3, 4/7]]

            # ((C.T)/(C.sum(axis=1))).T = [[1/3, 2/3]
            #                            [3/7, 4/7]]
            # sum of row elements = 1

            B =(C/C.sum(axis=0))
            #divid each element of the confusion matrix with the sum of elements in that row
            # C = [[1, 2],
            #     [3, 4]]
            # C.sum(axis = 0)  axis=0 corresonds to columns and axis=1 corresponds to rows in
            # C.sum(axix =0) = [[4, 6]]
            # (C/C.sum(axis=0)) = [[1/4, 2/6],
            #                       [3/4, 4/6]]
            plt.figure(figsize=(20,4))

            labels = [1,2]
            # representing A in heatmap format
            cmap=sns.light_palette("blue")
            plt.subplot(1, 3, 1)
            sns.heatmap(C, annot=True, cmap=cmap, fmt=".3f", xticklabels=labels, yticklabels=la
            plt.xlabel('Predicted Class')
            plt.ylabel('Original Class')
            plt.title("Confusion matrix")

            plt.subplot(1, 3, 2)
            sns.heatmap(B, annot=True, cmap=cmap, fmt=".3f", xticklabels=labels, yticklabels=la
            plt.xlabel('Predicted Class')
            plt.ylabel('Original Class')
            plt.title("Precision matrix")

            plt.subplot(1, 3, 3)
            # representing B in heatmap format
            sns.heatmap(A, annot=True, cmap=cmap, fmt=".3f", xticklabels=labels, yticklabels=la
            plt.xlabel('Predicted Class')
            plt.ylabel('Original Class')
            plt.title("Recall matrix")

            plt.show()
```

### 0.2.1 Building a random model (Finding worst-case log-loss)

```
In [9]: # we need to generate 9 numbers and the sum of numbers should be 1
        # one solution is to genarate 9 numbers and divide each of the numbers by their sum
        # ref: https://stackoverflow.com/a/18662466/4084039
        # we create a output array that has exactly same size as the CV data
        predicted_y = np.zeros((test_len,2))
        for i in range(test_len):
            rand_probs = np.random.rand(1,2)
            predicted_y[i] = ((rand_probs/sum(sum(rand_probs)))[0])
        print("Log loss on Test Data using Random Model",log_loss(y_test, predicted_y, eps=1e-

        predicted_y =np.argmax(predicted_y, axis=1)
        plot_confusion_matrix(y_test, predicted_y)
```

```
Log loss on Test Data using Random Model 0.887986141587283
```



### 0.2.2 Assignments

### Logistic regression

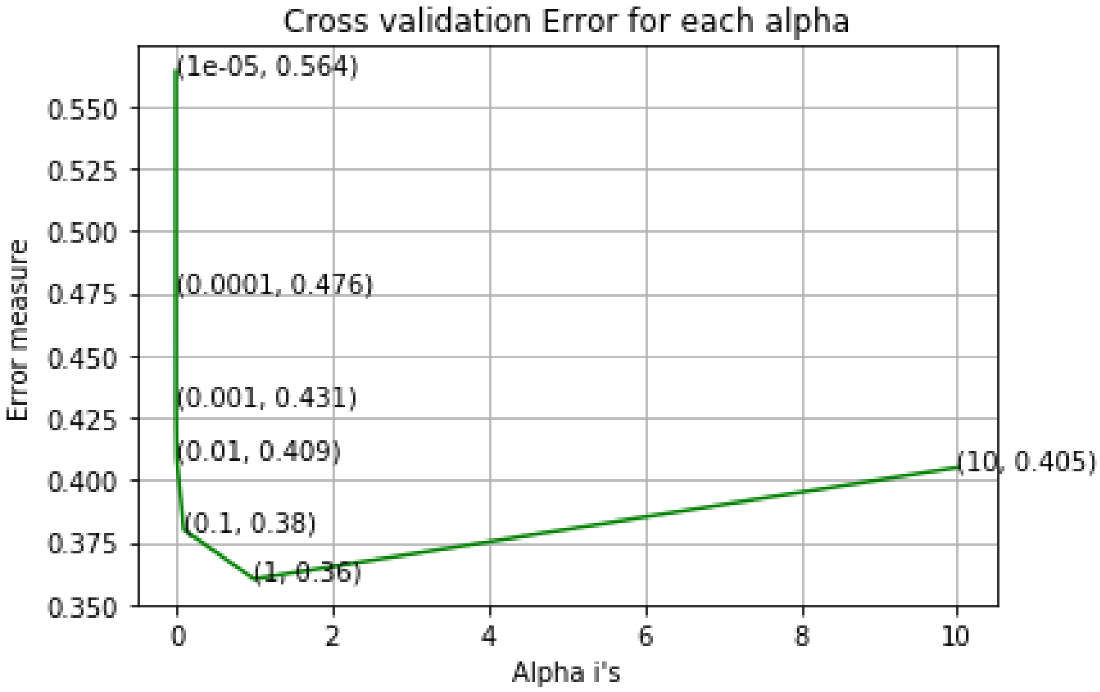
```
In [10]: from sklearn.linear_model import LogisticRegression
```

```
In [11]: C = [10 ** x for x in range(-5, 2)] #Hyperparameters

         log_error_array = []

         for i in C:
             clf = LogisticRegression(C=i, penalty='l1')
             clf.fit(X_train_final , y_train)
```

```
    predict_y = clf.predict_proba(X_test_final)
    log_error_array.append(log_loss(y_test, predict_y))
    print('For values of alpha = ', i, "The log loss is : ",log_loss(y_test, predict_
```

```
For values of alpha =  1e-05 The log loss is :  0.5639018216726743
For values of alpha =  0.0001 The log loss is :  0.4758010198922024
For values of alpha =  0.001 The log loss is :  0.43085331599330706
For values of alpha =  0.01 The log loss is :  0.4086512961198796
For values of alpha =  0.1 The log loss is :  0.38013118168319154
For values of alpha =  1 The log loss is :  0.36028017700335574
For values of alpha =  10 The log loss is :  0.4050001803564682
```

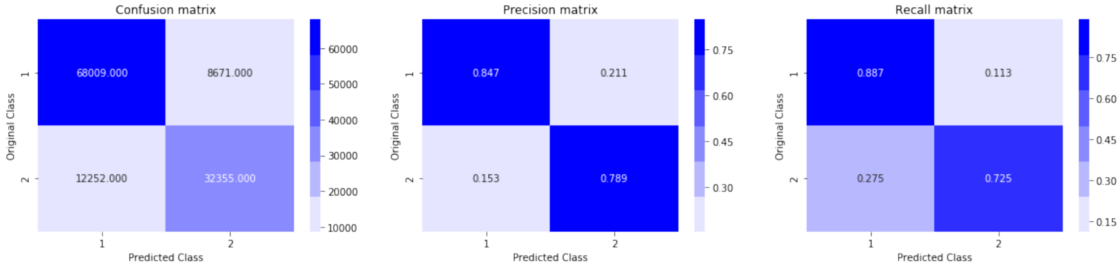
In [12]:
```
fig, ax = plt.subplots()
ax.plot(C, log_error_array , c = 'g')
for i , txt in enumerate(np.round(log_error_array, 3)):
    ax.annotate((C[i], np.round(txt,3)), (C[i], log_error_array[i]))
plt.grid()
plt.title("Cross validation Error for each alpha")
plt.xlabel("Alpha i's")
plt.ylabel("Error measure")
plt.show()
```



In [13]:
```
best_C = np.argmin(log_error_array)
clf = LogisticRegression(C=C[best_C], penalty='l1')
```

```
        clf.fit(X_train_final, y_train)

        predict_y = clf.predict_proba(X_train_final)
        print('For values of best C = ', C[best_C], "The train log loss is:",log_loss(y_train
        predict_y = clf.predict_proba(X_test_final)
        print('For values of best C = ', C[best_C], "The test log loss is:",log_loss(y_test, 
        predicted_y =np.argmax(predict_y,axis=1)
        print("Total number of data points :", len(predicted_y))
        plot_confusion_matrix(y_test, predicted_y)
```

```
For values of best C =  1 The train log loss is: 0.331123802842563
For values of best C =  1 The test log loss is: 0.3602795275278825
Total number of data points : 121287
```

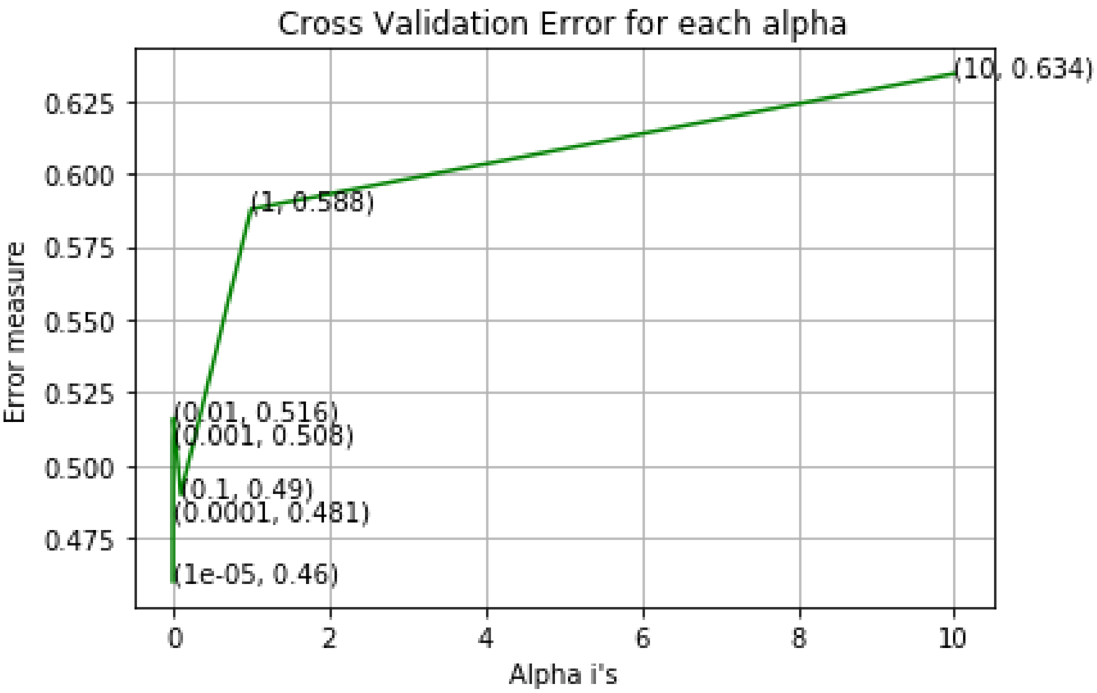


### 0.2.3 Linear-SVM

```
In [185]: alpha = [10 ** x for x in range(-5, 2)]

          log_error_array=[]
          for i in alpha:
              clf = SGDClassifier(alpha=i, penalty='l1', loss='hinge', random_state=42)
              clf.fit(X_train_final, y_train)
              sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
              sig_clf.fit(X_train_final, y_train)
              predict_y = sig_clf.predict_proba(X_test_final)
              log_error_array.append(log_loss(y_test, predict_y, labels=clf.classes_, eps=1e-1
              print('For values of alpha = ', i, "The log loss is:",log_loss(y_test, predict_y
```

```
For values of alpha =  1e-05 The log loss is: 0.46027481491319144
For values of alpha =  0.0001 The log loss is: 0.48135681645364076
For values of alpha =  0.001 The log loss is: 0.5078195121421616
For values of alpha =  0.01 The log loss is: 0.5161922829916686
For values of alpha =  0.1 The log loss is: 0.4898780030371454
For values of alpha =  1 The log loss is: 0.5878611630991508
For values of alpha =  10 The log loss is: 0.6342679561431821
```

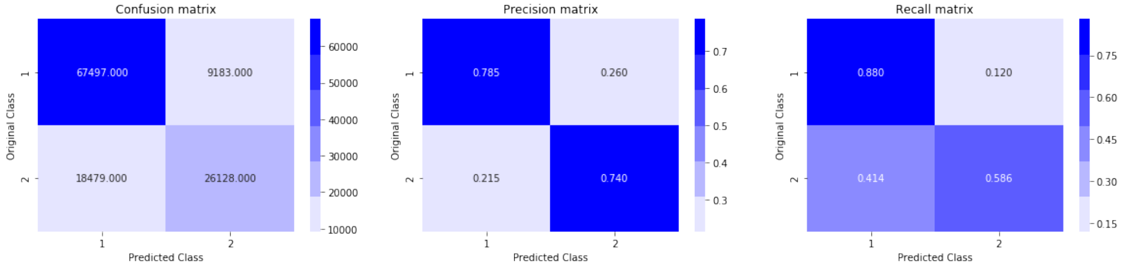
```
In [186]: fig, ax = plt.subplots()
          ax.plot(alpha, log_error_array,c='g')
          for i, txt in enumerate(np.round(log_error_array,3)):
              ax.annotate((alpha[i],np.round(txt,3)), (alpha[i],log_error_array[i]))
          plt.grid()
          plt.title("Cross Validation Error for each alpha")
          plt.xlabel("Alpha i's")
          plt.ylabel("Error measure")
          plt.show()
```



```
In [188]: best_alpha = np.argmin(log_error_array)
          clf = SGDClassifier(alpha=alpha[best_alpha], penalty='l1', loss='hinge', random_stat
          clf.fit(X_train_final, y_train)
          sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
          sig_clf.fit(X_train_final, y_train)

          predict_y = sig_clf.predict_proba(X_train_final)
          print('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_
          predict_y = sig_clf.predict_proba(X_test_final)
          print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_
          predicted_y =np.argmax(predict_y,axis=1)
          print("Total number of data points :", len(predicted_y))
          plot_confusion_matrix(y_test, predicted_y)
```

```
For values of best alpha =  1e-05 The train log loss is: 0.4609891589352754
For values of best alpha =  1e-05 The test log loss is: 0.46027481491319144
```

```
Total number of data points : 121287
```



### 0.2.4 XgBoost

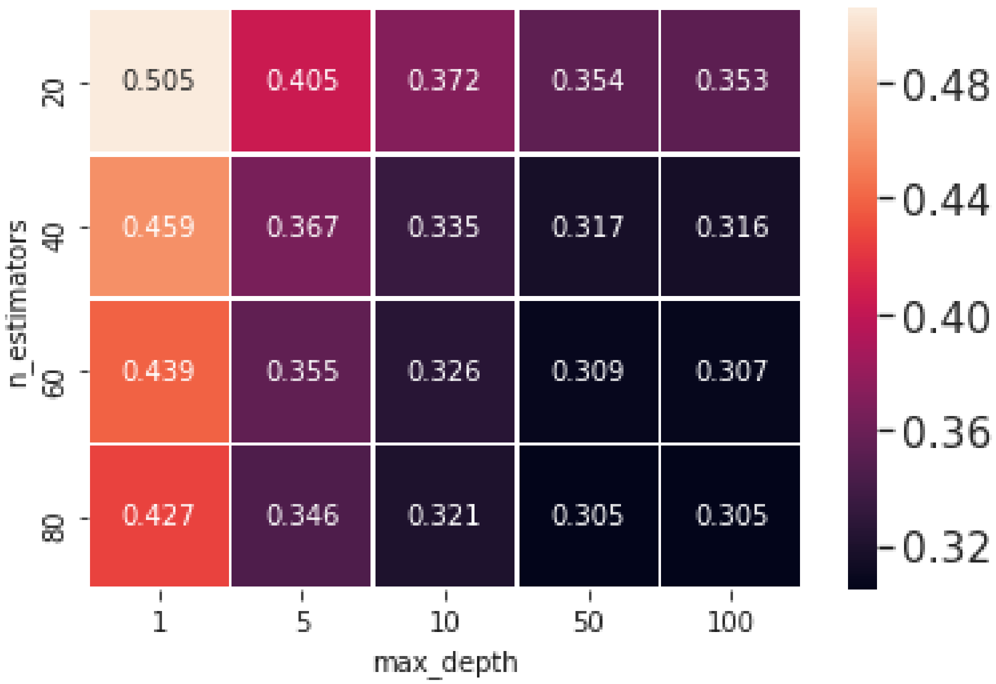
```
In [12]: from xgboost import XGBClassifier
         from sklearn.model_selection import RandomizedSearchCV
         from random import uniform , randint
         import time
         from time import time
         from scipy.stats import randint as sp_randint
```

```
In [18]: n_estimators = [20,40,60,80]
         max_depth = [1,5,10,50,100]
         train_logloss = []
         test_logloss = []
         for i in n_estimators:
             for j in max_depth:
                 XGBC = XGBClassifier(n_estimators=i, max_depth=j, learning_rate=0.1 , subsampl
                 XGBC.fit(X_train_final, y_train)
                 predict_y = XGBC.predict_proba(X_train_final)
                 train_logloss.append(log_loss(y_train, predict_y))
                 predict_y = XGBC.predict_proba(X_test_final)
                 test_logloss.append(log_loss(y_test, predict_y))
                 print('For n_estimators = ', i, "For max_depth = ", j , "The log loss is : ",
```

```
For n_estimators =  20 For max_depth =  1 The log loss is :  0.505317008570422
For n_estimators =  20 For max_depth =  5 The log loss is :  0.40512208062513017
For n_estimators =  20 For max_depth =  10 The log loss is :  0.37166848886404164
For n_estimators =  20 For max_depth =  50 The log loss is :  0.35380716501560255
For n_estimators =  20 For max_depth =  100 The log loss is :  0.35320647914112396
For n_estimators =  40 For max_depth =  1 The log loss is :  0.4594901655361766
For n_estimators =  40 For max_depth =  5 The log loss is :  0.36655743800223484
For n_estimators =  40 For max_depth =  10 The log loss is :  0.33510101852921775
For n_estimators =  40 For max_depth =  50 The log loss is :  0.3172568716427387
For n_estimators =  40 For max_depth =  100 The log loss is :  0.3160795764098314
For n_estimators =  60 For max_depth =  1 The log loss is :  0.43886784540460644
For n_estimators =  60 For max_depth =  5 The log loss is :  0.3548624613874577
For n_estimators =  60 For max_depth =  10 The log loss is :  0.3262185720426577
For n_estimators =  60 For max_depth =  50 The log loss is :  0.30896396985777047
For n_estimators =  60 For max_depth =  100 The log loss is :  0.307464759693885
For n_estimators =  80 For max_depth =  1 The log loss is :  0.42669610015479303
For n_estimators =  80 For max_depth =  5 The log loss is :  0.3458184261023534
For n_estimators =  80 For max_depth =  10 The log loss is :  0.3209356713896733
For n_estimators =  80 For max_depth =  50 The log loss is :  0.3052338348039778
For n_estimators =  80 For max_depth =  100 The log loss is :  0.3050986576600217
```

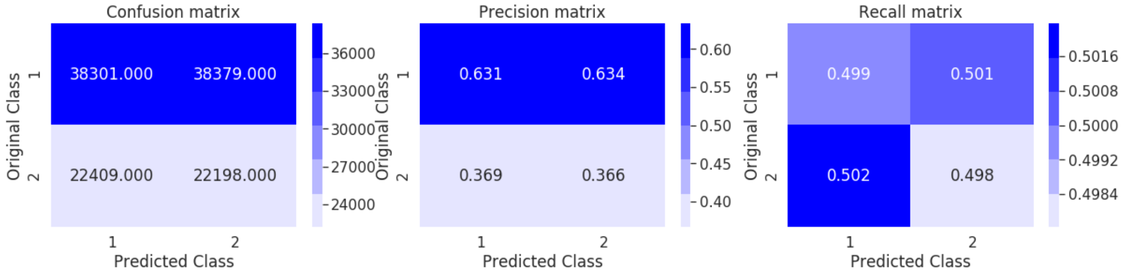
```
In [19]: fig, ax = plt.subplots()
         # auc on test
         print("===================Test Data===================")
         test_scores = np.array(test_logloss).reshape(len(n_estimators),len(max_depth))
         df_cm_cv = pd.DataFrame(test_scores, n_estimators, max_depth)
         sns.set(font_scale=1.4)
         ax = sns.heatmap(df_cm_cv, annot=True, annot_kws={"size": 10}, fmt='.3g',linewidths=.
         ax.set_xlabel("max_depth")
         ax.set_ylabel("n_estimators")
         plt.show()
```

```
===================Test Data===================
```



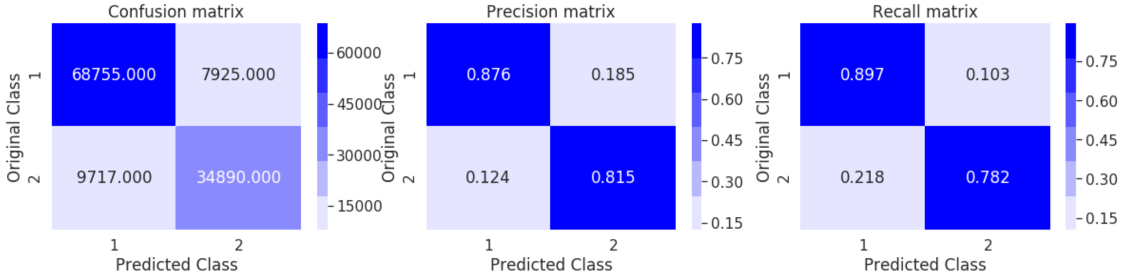
```
In [20]: i = 80 # n_estimators
         j = 100 # max_depth
         XGBC = XGBClassifier(n_estimators=i, max_depth=j, learning_rate=0.1 , subsample=0.5 ,
         XGBC.fit(X_train_final, y_train)
         predict_y = XGBC.predict_proba(X_test_final)
         print('For n_estimators = ', i, "For max_depth = ", j , "The log loss is : ",log_loss
         plot_confusion_matrix(y_test, predicted_y)
```

```
For n_estimators =  80 For max_depth =  100 The log loss is :  0.3050986576600217
```



```
In [45]: print('For n_estimators = ', i, "For max_depth = ", j , "The log loss is : ",log_loss
         predicted_y =np.argmax(predict_y,axis=1)
         print("Total number of data points :", len(predicted_y))
         plot_confusion_matrix(y_test, predicted_y)
```

```
For n_estimators =  80 For max_depth =  100 The log loss is :  0.3050986576600217
Total number of data points : 121287
```



## 0.3 Conclusions

```
In [47]: # Please compare all your models using Prettytable library
         from prettytable import PrettyTable
```

```
x = PrettyTable(["Algorithm" , "log loss"])

x.add_row(["Logistic regression", "0.3602795275278825"])
x.add_row(["Linear-SVM", "0.46027481491319144"])
x.add_row(["XgBoost", "0.3050986576600217"])
print(x.get_string(title=""))
```

```
+---------------------+---------------------+
|      Algorithm      |       log loss      |
+---------------------+---------------------+
| Logistic regression |  0.3602795275278825 |
|      Linear-SVM     | 0.46027481491319144 |
|       XgBoost       |  0.3050986576600217 |
+---------------------+---------------------+
```

```
In [ ]:
```

Step by step procedure followed to solve this case studey

- first we load the train.csv data set into data frame
- we find number of data points : 404290
- we find there are 6 columns in data
- those are [id , qid1, qid2, question1, question2. is_duplicate ]
- clearly observe that is_dupicate is labeled column
- Question pairs are not Similar (is_duplicate = 0): 63.08%
- Question pairs are Similar (is_duplicate = 1): 36.92%
- we done some EDA to understand data much more rigorous
- we find Total number of Unique Questions are: 537933
- Number of unique questions that appear more than one time : 111780 (20.77953945937505%)
- Max number of times a single question is repeated : 157
- Number of duplicate questions 0
- Maximum number of times a single question is repeated: 157
- Checking whether there are any rows with null values
- There are two rows with null values in question2

Basic Feature Extraction (before cleaning)

- hear we done some basic feature extraction
- ____freq_qid1____ = Frequency of qid1's
- ____freq_qid2____ = Frequency of qid2's
- ____q1len____ = Length of q1
- ____q2len____ = Length of q2
- ____q1_n_words____ = Number of words in Question 1
- ____q2_n_words____ = Number of words in Question 2
- ____word_Common____ = (Number of common unique words in Question 1 and Question 2)
- ____word_Total____ =(Total num of words in Question 1 + Total num of words in Question 2)

- ____word_share____ = (word_common)/(word_Total)
- ____freq_q1+freq_q2____ = sum total of frequency of qid1 and qid2
- ____freq_q1-freq_q2____ = absolute difference of frequency of qid1 and qid2

Analysis of some of the extracted features

- we find some questions have only one single words.
- Minimum length of the questions in question1 : 1
- Minimum length of the questions in question2 : 1
- Number of Questions with minimum length [question1] : 67
- Number of Questions with minimum length [question2] : 24
- when we perform univariat analysis on Feature : word_shapre
- The distributions for normalized word_share have some overlap on the far right-hand side, i.e., there are quite a lot of questions with high word similarity
- The average word share and Common no. of words of qid1 and qid2 is more when they are duplicate(Similar)
- Feature: word_Common
- The distributions of the word_Common feature in similar and non-similar questions are highly overlapping

EDA : Advanced Feature Extraction

- we done some advanced feature extraction on data

Preprocessing of Text

- Removing html tags
- Removing Punctuations
- Performing stemming
- Removing Stopwords
- Expanding contractions etc

Preprocessing of Text

Definition: - **Token**: You get a token by splitting sentence a space - **Stop_Word** : stop words as per NLTK. - **Word** : A token that is not a stop_word

Features: - **cwc_min** : Ratio of common_word_count to min lenghth of word count of Q1 and Q2 cwc_min = common_word_count / (min(len(q1_words), len(q2_words)) - **cwc_max** : Ratio of common_word_count to max lenghth of word count of Q1 and Q2 cwc_max = common_word_count / (max(len(q1_words), len(q2_words)) - **csc_min** : Ratio of common_stop_count to min lenghth of stop count of Q1 and Q2 csc_min = common_stop_count / (min(len(q1_stops), len(q2_stops)) - **csc_max** : Ratio of common_stop_count to max lenghth of stop count of Q1 and Q2csc_max = common_stop_count / (max(len(q1_stops), len(q2_stops)) - **ctc_min** : Ratio of common_token_count to min lenghth of token count of Q1 and Q2ctc_min = common_token_count / (min(len(q1_tokens), len(q2_tokens))

- **ctc_max** : Ratio of common_token_count to max lenghth of token count of Q1 and Q2ctc_max = common_token_count / (max(len(q1_tokens), len(q2_tokens))
- **last_word_eq** : Check if First word of both questions is equal or notlast_word_eq = int(q1_tokens[-1] == q2_tokens[-1])
- **first_word_eq** : Check if First word of both questions is equal or notfirst_word_eq = int(q1_tokens[0] == q2_tokens[0])
- **abs_len_diff** : Abs. length differenceabs_len_diff = abs(len(q1_tokens) - len(q2_tokens))
- **mean_len** : Average Token Length of both Questionsmean_len = (len(q1_tokens) + len(q2_tokens))/2
- **fuzz_ratio** : https://github.com/seatgeek/fuzzywuzzy#usage http://chairnerd.seatgeek.com/fuzzywuzzy-fuzzy-string-matching-in-python/
- **fuzz_partial_ratio** : https://github.com/seatgeek/fuzzywuzzy#usage http://chairnerd.seatgeek.com/fuzzywuzzy-fuzzy-string-matching-in-python/
- **token_sort_ratio** : https://github.com/seatgeek/fuzzywuzzy#usage http://chairnerd.seatgeek.com/fuzzywuzzy-fuzzy-string-matching-in-python/
- **token_set_ratio** : https://github.com/seatgeek/fuzzywuzzy#usage http://chairnerd.seatgeek.com/fuzzywuzzy-fuzzy-string-matching-in-python/
- **longest_substr_ratio** : Ratio of length longest common substring to min lenghth of token count of Q1 and Q2longest_substr_ratio = len(longest common substring) / (min(len(q1_tokens), len(q2_tokens))
- append the new features as a columns to data set

Plotting Word clouds: - Creating Word Cloud of Duplicates and Non-Duplicates Question pairs - We can observe the most frequent occuring words

Visualization :

- we visualize the data using TSNE
- we find some labels are well separated and some labels are overlaped

Vectorizer & train and test data

- we drop some columns [qid1, qid2]
- we merge three data frames by using id column
- take X = total data
- take Y = labels
- split the data into train and test data
- applying tfidf vectorizer on train data
- trainsform the vectorizer to X_train_q1 and X_train_q2

- we find most of columns/values are zeros
- so we convert train and test vectorized data into sparse matrix
- then merge X_train_q1 and X_train_q2 using hstack function
- done both train and test data
- save those train and test data as .npz files

Machine Learning Models

- our loss function is logloss
- in order to find best logloss first we build a random model to find log-loss
- we observe log_loss on test data using random mode : 0.887
- in order to reduce log loss we apply some machine learnign algorithams

Logistic Regression

- when we apply logistic regression we done hyperparameter tuning
- we find best hyperparameter C / (1/lambda) is : 1
- log-loss its reduced is : 0.3602
- we are using l1 reglarization because the features are very high
- then we plot confusion matrix and Rresision and recall matrixs

Linear SVM

- when we apply linear SVM we done hyperparameter tuning
- we find best hyperparameter alpha is : 0.00001
- log-loss its reduced is : 0.4602
- we are using l1 reglarization because the features are very high
- then we plot confusion matrix and Rresision and recall matrixs

XgBoost

- when we apply XgBoost we done hyperparameter tuning
- we find best hyperparameter n_estimators : 80 and max_depth : 100
- log-loss its reduced is : 0.3050
- then we plot confusion matrix and Rresision and recall matrixs