Quora Question Pairs

1. Business Problem

1.1 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.

> Credits: Kaggle

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.

1.2 Sources/Useful Links

- Source : https://www.kaggle.com/c/quora-question-pairs (https://www.kaggle.com/c/quora-question-pairs)

Useful Links

- Discussions : https://www.kaggle.com/anokas/data-analysis-xgboost-starter-0-35460-lb/comments (https://www.kaggle.com/anokas/data-analysis-xgboost-starter-0-35460-lb/comments)
- Kaggle Winning Solution and other approaches: https://www.dropbox.com/sh/93968nfnrzh8bp5/AACZdtsApc1QSTQc7X0H3QZ5a?dl=0 (https://www.dropbox.com/sh/93968nfnrzh8bp5/AACZdtsApc1QSTQc7X0H3QZ5a?dl=0)
- Blog 1 : https://engineering.quora.com/Semantic-Question-Matching-with-Deep-Learning (https://engineering.quora.com/Semantic-Question-Matching-with-Deep-Learning)
- Blog 2 : https://towardsdatascience.com/identifying-duplicate-questions-on-quora-top-12-on-kaggle-4c1cf93f1c30 (https://towardsdatascience.com/identifying-duplicate-questions-on-quora-top-12-on-kaggle-4c1cf93f1c30)

1.3 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.

2.0 Data Information

2.1 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

2.2 Example Data point

```
"id","qid1","qid2","question1","question2","is_duplicate"
"0","1","2","What is the step by step guide to invest in share market in india?","W
hat is the step by step guide to invest in share market?","0"
"1","3","4","What is the story of Kohinoor (Koh-i-Noor) Diamond?","What would happe
n if the Indian government stole the Kohinoor (Koh-i-Noor) diamond back?","0"
"7","15","16","How can I be a good geologist?","What should I do to be a great geol
ogist?","1"
"11","23","24","How do I read and find my YouTube comments?","How can I see all my
Youtube comments?","1"
```

3.0 Mapping the real world problem to an ML problem

3.1 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.

3.2 Performance Metric

Source: https://www.kaggle.com/c/quora-question-pairs#evaluation (https://www.kaggle.com/c/quora-question-pairs#evaluation)

Metric(s):

- log-loss : https://www.kaggle.com/wiki/LogarithmicLoss (https://www.kaggle.com/wiki/LogarithmicLoss)
- Binary Confusion Matrix

3.3 Train and Test Construction

We build train and test by randomly splitting in the ratio of 70:30 or 80:20 whatever we choose as we have sufficient points to work with.

4.0 Exploratory Data Analysis

In [18]:

```
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)
import plotly.graph_objs as go
import plotly.tools as tls
import os
import gc

import re
from nltk.corpus import stopwords
from nltk.stem import PorterStemmer
from bs4 import BeautifulSoup


from nltk.corpus import stopwords
# This package is used for finding longest common subsequence between two stri
ngs
# you can write your own dp code for this
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-pyt
hon3-6
from wordcloud import WordCloud, STOPWORDS
from os import path
from PIL import Image
```

In [17]:

```
!pip install fuzzywuzzy
```

```
Requirement already satisfied: fuzzywuzzy in /usr/local/lib/python3.6/dist-pa
ckages (0.17.0)
```

4.1 Reading data and basic stats

In [19]:

```
from google.colab import drive
drive.mount('/content/drive')
```

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

In [0]:

```
df = pd.read_csv("/content/drive/My Drive/Quora/train.csv")

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

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

In [0]:

```
df.head()
```

Out[0]:

	id	qid1	qid2	question1	question2	is_duplicate
0	0	1	2	What is the step by step guide to invest in sh...	What is the step by step guide to invest in sh...	0
1	1	3	4	What is the story of Kohinoor (Koh-i-Noor) Dia...	What would happen if the Indian government sto...	0
2	2	5	6	How can I increase the speed of my internet co...	How can Internet speed be increased by hacking...	0
3	3	7	8	Why am I mentally very lonely? How can I solve...	Find the remainder when [math]23^{24}[/math] i...	0
4	4	9	10	Which one dissolve in water quikly sugar, salt...	Which fish would survive in salt water?	0

In [0]:

```
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
```

We are given a minimal number of data fields here, consisting of:

- id: Looks like a simple rowID
- qid{1, 2}: The unique ID of each question in the pair
- question{1, 2}: The actual textual contents of the questions.
- is_duplicate: The label that we are trying to predict - whether the two questions are duplicates of each other.

4.2.1 Distribution of data points among output classes

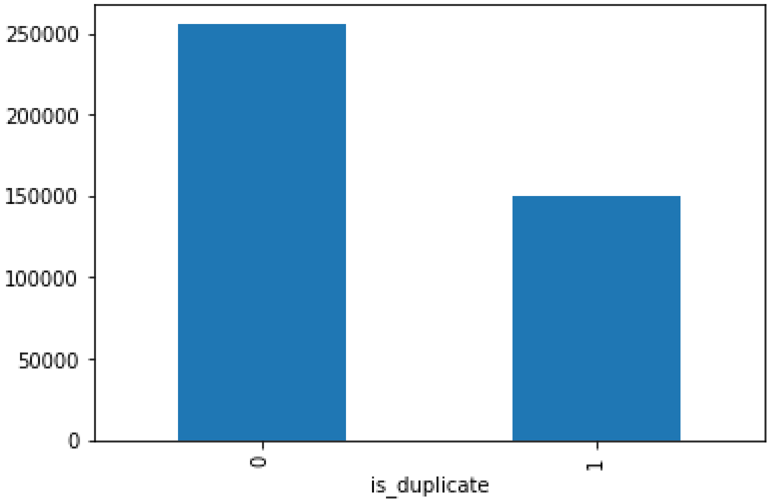
- Number of duplicate(smilar) and non-duplicate(non similar) questions

In [0]:

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

Out[0]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x7f8c8ed43438>
```



In [0]:

```
print('~> Total number of question pairs for training:\n   {}'.format(len(df)))
print('\n~> Question pairs are not Similar (is_duplicate = 0):\n   {}%'.format(100 - round(df['is_duplicate'].mean()*100, 2)))
print('\n~> Question pairs are Similar (is_duplicate = 1):\n   {}%'.format(round(df['is_duplicate'].mean()*100, 2)))
```

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

~> Question pairs are not Similar (is_duplicate = 0):
   63.08%

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

4.2.2 Number of unique questions

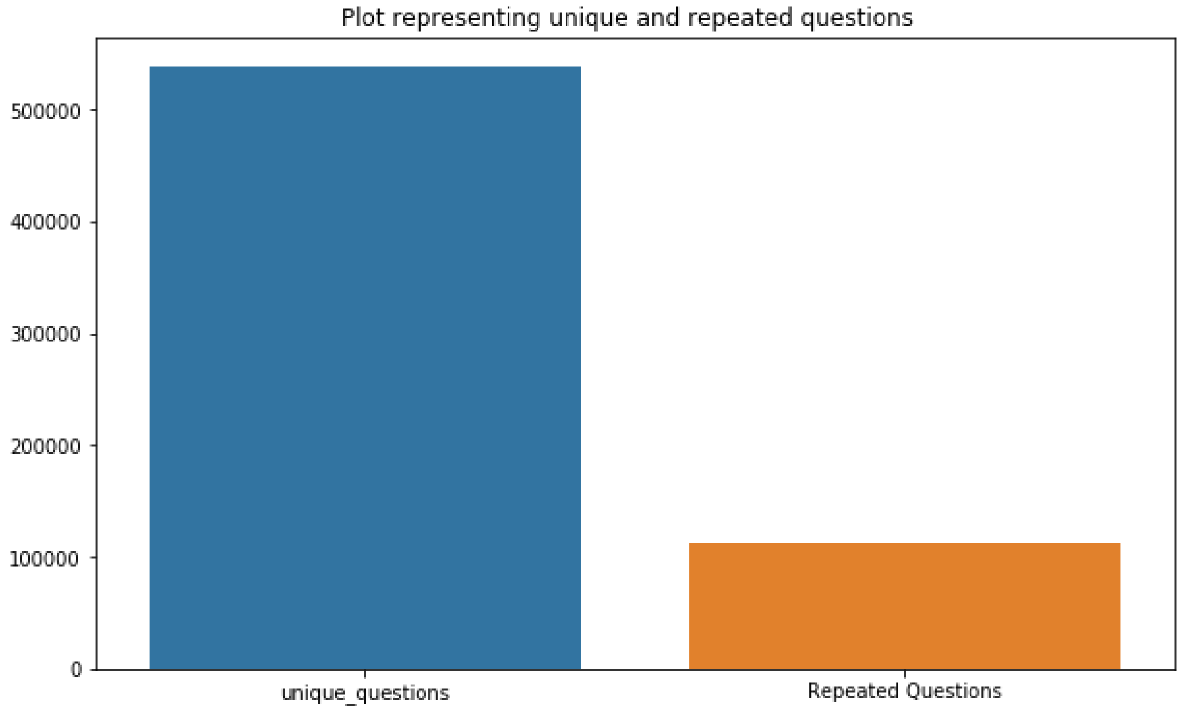
In [0]:

```
qids = pd.Series(df['qid1'].tolist() + df['qid2'].tolist()) # Adding in one co
lumn
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 len(np.unique(qids))

print ('Number of unique questions that appear more than one time: {} ({}%)\n'
.format(qs_morethan_onetime,qs_morethan_onetime/unique_qs*100))

print ('Max number of times a single question is repeated: {}\n'.format(max(qi
ds.value_counts())))

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 (20.7795394
5937505%)

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

In [0]:

```
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()
```



4.2.3 Checking for Duplicates

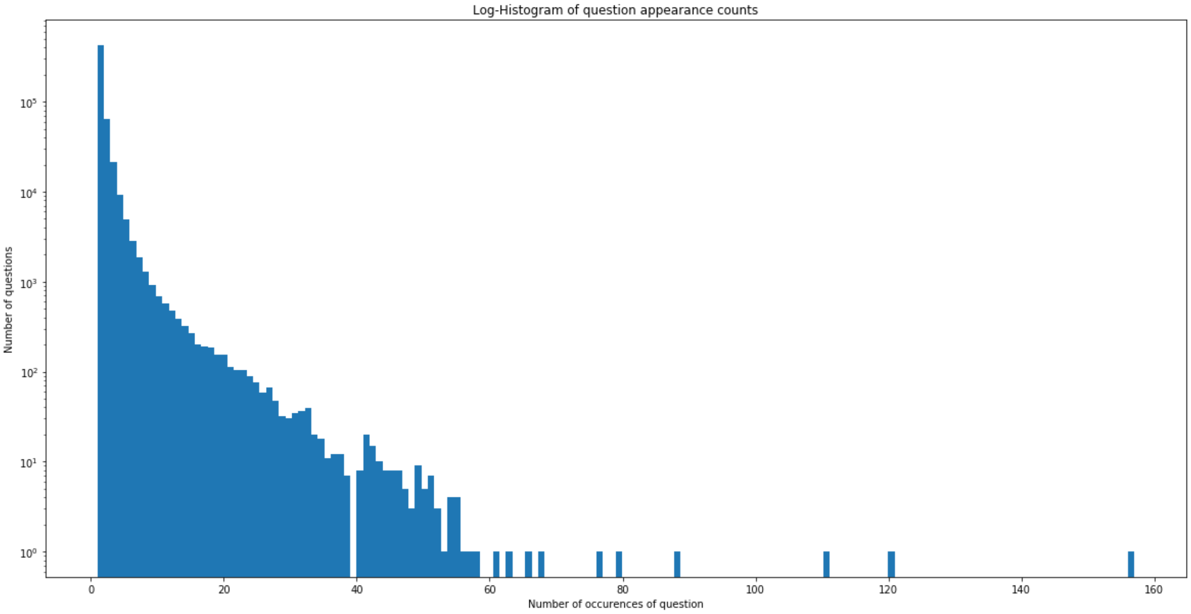
```
In [0]: #checking whether there are any repeated pair of questions

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

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

```
Number of duplicate questions 0
```

4.2.4 Number of occurrences of each question

```
In [0]: plt.figure(figsize=(20, 10))

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

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

        plt.title('Log-Histogram of question appearance counts')

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

        plt.ylabel('Number of questions')

        print ('Maximum number of times a single question is repeated: {}\n'.format(ma
        x(qids.value_counts())))
```

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



4.2.5 Checking for NULL values

In [0]:

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

Out[0]:

	id	qid1	qid2	question1	question2	is_duplicate
105780	105780	174363	174364	How can I develop android app?	NaN	0
201841	201841	303951	174364	How can I create an Android app?	NaN	0
363362	363362	493340	493341	NaN	My Chinese name is Haichao Yu. What English na...	0

There are two rows with null values in question2

In [0]:

```
# 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: []
```

4.3 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 [0]:

```
if os.path.isfile("/content/drive/My Drive/ML_Assignment/df_fe_without_preproc
essing_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("/content/drive/My Drive/ML_Assignment/df_fe_without_preprocessi
ng_train.csv", index=False)

df.head()
```

Out[0]:

	id	qid1	qid2	question1	question2	is_duplicate	freq_qid1	freq_qid2	q1len	q2len	q1_
0	0	1	2	What is the step by step guide to invest in sh...	What is the step by step guide to invest in sh...	0	1	1	66	57	
1	1	3	4	What is the story of Kohinoor (Koh-i-Noor) Dia...	What would happen if the Indian government sto...	0	4	1	51	88	
2	2	5	6	How can I increase the speed of my internet co...	How can Internet speed be increased by hacking...	0	1	1	73	59	
3	3	7	8	Why am I mentally very lonely? How can I solve...	Find the remainder when [math]23^{24}[/math] i...	0	1	1	50	65	
4	4	9	10	Which one dissolve in water quikly sugar, salt...	Which fish would survive in salt water?	0	3	1	76	39	

4.3.1 Analysis of some of the extracted features

- Here are some questions have only one single words.

In [0]:

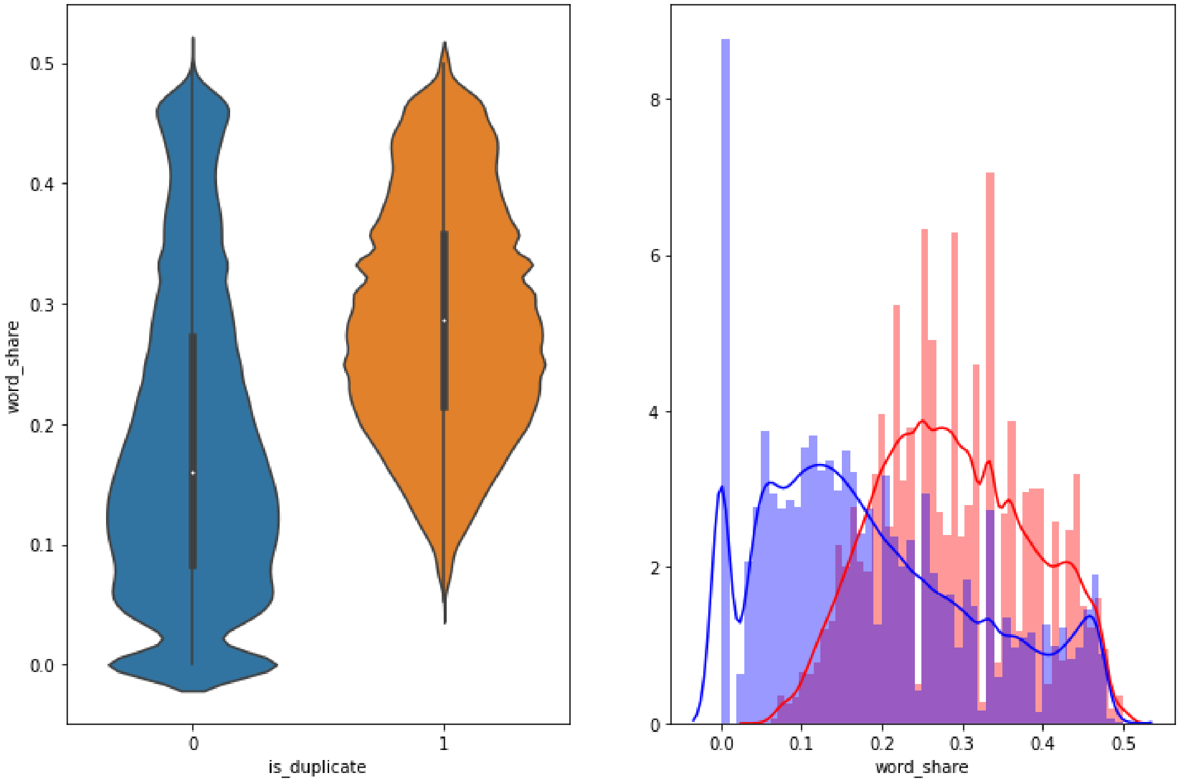
```
print ("Minimum length of the questions in question1 : " , min(df['q1_n_words'
]))

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_wo
rds']== 1].shape[0])
print ("Number of Questions with minimum length [question2] :", df[df['q2_n_wo
rds']== 1].shape[0])
```

```
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
```

4.3.2 Feature: word_share

In [0]:

```
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", co
lor = 'red')
sns.distplot(df[df['is_duplicate'] == 0.0]['word_share'][0:] , label = "0" , c
olor = 'blue' )
plt.show()
```



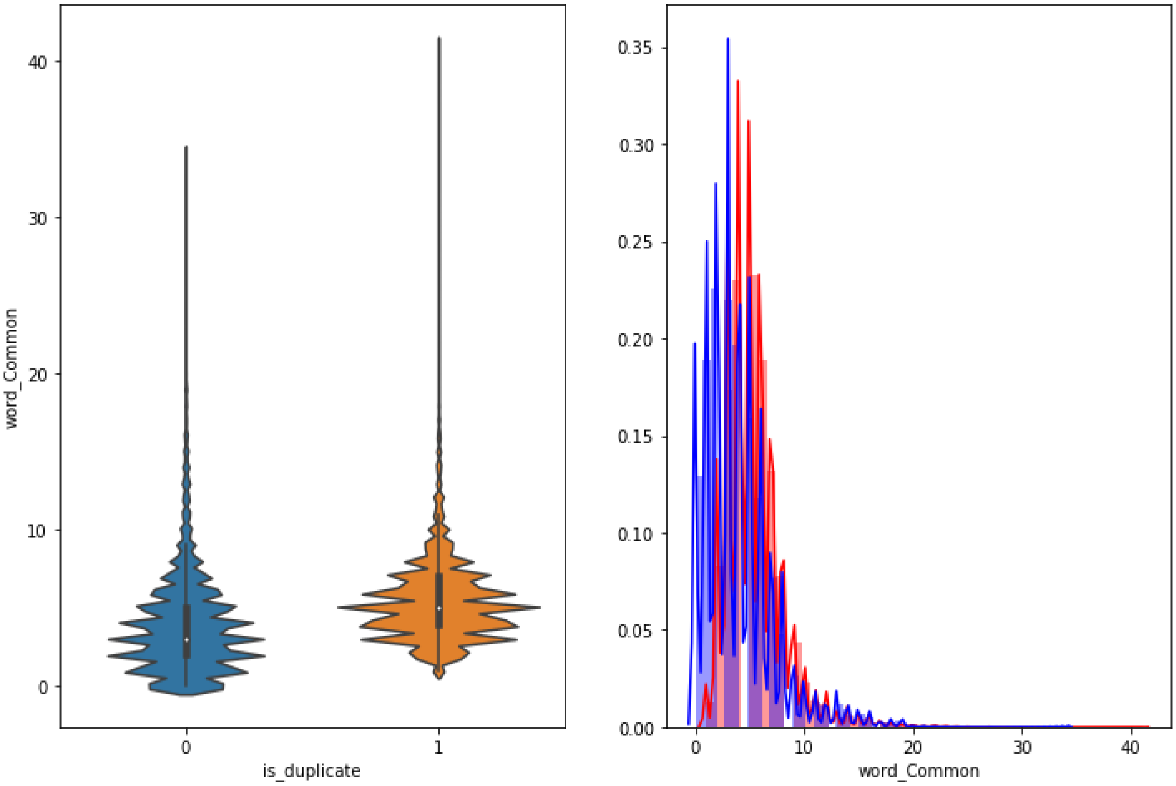
The distributions for normalized word_share have some overlap on the far right-hand side, i.e., there are quite a lot of questions with high word similarity

The average word share and Common no. of words of qid1 and qid2 is more when they are duplicate(Similar)

4.3.3 Feature: word_Common

In [0]:

```
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", c
olor = 'red')
sns.distplot(df[df['is_duplicate'] == 0.0]['word_Common'][0:] , label = "0" ,
color = 'blue' )
plt.show()
```



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

5.0 EDA: Advanced Feature Extraction

5.1 Preprocessing of Text

Preprocessing:

```
    Removing html tags

    Removing Punctuations

    Performing stemming

    Removing Stopwords

   Expanding contractions etc.
```

In [0]:

```python
# To get the results in 4 decemal points

import nltk
nltk.download('stopwords')

SAFE_DIV = 0.0001

STOP_WORDS = stopwords.words("english")
```

```
[nltk_data] Downloading package stopwords to /root/nltk_data...
[nltk_data]   Unzipping corpora/stopwords.zip.
```

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

In [0]:

```
def preprocess(x):
    x = str(x).lower()
    x = x.replace(",000,000", "m").replace(",000", "k").replace("′", "'").repl
ace("’", "'")\
                           .replace("won't", "will not").replace("cannot", "ca
n 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").rep
lace("'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)


    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
```

5.2 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 Q2
  csc_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 Q2
  ctc_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 Q2
  ctc_max = common_token_count / (max(len(q1_tokens), len(q2_tokens))

- **last_word_eq** : Check if First word of both questions is equal or not
  last_word_eq = int(q1_tokens[-1] == q2_tokens[-1])

- **first_word_eq** : Check if First word of both questions is equal or not
  first_word_eq = int(q1_tokens[0] == q2_tokens[0])

- **abs_len_diff** : Abs. length difference
  abs_len_diff = abs(len(q1_tokens) - len(q2_tokens))

- **mean_len** : Average Token Length of both Questions
  mean_len = (len(q1_tokens) + len(q2_tokens))/2

- **fuzz_ratio** : https://github.com/seatgeek/fuzzywuzzy#usage (https://github.com/seatgeek/fuzzywuzzy#usage) http://chairnerd.seatgeek.com/fuzzywuzzy-fuzzy-string-matching-in-python/ (http://chairnerd.seatgeek.com/fuzzywuzzy-fuzzy-string-matching-in-python/)

- **fuzz_partial_ratio** : https://github.com/seatgeek/fuzzywuzzy#usage (https://github.com/seatgeek/fuzzywuzzy#usage) http://chairnerd.seatgeek.com/fuzzywuzzy-fuzzy-string-matching-in-python/ (http://chairnerd.seatgeek.com/fuzzywuzzy-fuzzy-string-matching-in-python/)

- **token_sort_ratio** : https://github.com/seatgeek/fuzzywuzzy#usage (https://github.com/seatgeek/fuzzywuzzy#usage) http://chairnerd.seatgeek.com/fuzzywuzzy-fuzzy-string-matching-in-python/ (http://chairnerd.seatgeek.com/fuzzywuzzy-fuzzy-string-matching-in-python/)

- **token_set_ratio** : https://github.com/seatgeek/fuzzywuzzy#usage (https://github.com/seatgeek/fuzzywuzzy#usage) http://chairnerd.seatgeek.com/fuzzywuzzy-fuzzy-string-matching-in-python/ (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 Q2
  longest_substr_ratio = len(longest common substring) / (min(len(q1_tokens), len(q2_tokens))

In [0]:

```
!pip install Distance
```

```
Collecting Distance
  Downloading https://files.pythonhosted.org/packages/5c/1a/883e47df323437aef
a0d0a92ccfb38895d9416bd0b56262c2e46a47767b8/Distance-0.1.3.tar.gz (180kB)
     |████████████████████████████████| 184kB 4.9MB/s
Building wheels for collected packages: Distance
  Building wheel for Distance (setup.py) ... done
  Stored in directory: /root/.cache/pip/wheels/d5/aa/e1/dbba9e7b6d397d645d0f1
2db1c66dbae9c5442b39b001db18e
Successfully built Distance
Installing collected packages: Distance
Successfully installed Distance-0.1.3
```

In [0]:

```
import distance
```

In [0]:

```
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_DIV)
    token_features[1] = common_word_count / (max(len(q1_words), len(q2_words))
+ SAFE_DIV)
    token_features[2] = common_stop_count / (min(len(q1_stops), len(q2_stops))
+ SAFE_DIV)
    token_features[3] = common_stop_count / (max(len(q1_stops), len(q2_stops))
+ SAFE_DIV)
    token_features[4] = common_token_count / (min(len(q1_tokens), len(q2_token
s)) + SAFE_DIV)
    token_features[5] = common_token_count / (max(len(q1_tokens), len(q2_token
s)) + SAFE_DIV)

    # 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
```

In [0]:

```
# 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)
```

In [0]:

```
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["question2"]), axis=1)

    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-matching-in-python/
    # https://stackoverflow.com/questions/31806695/when-to-use-which-fuzz-function-to-compare-2-strings
    # https://github.com/seatgeek/fuzzywuzzy
    print("fuzzy features..")

    df["token_set_ratio"]       = df.apply(lambda x: fuzz.token_set_ratio(x["question1"], x["question2"]), axis=1)
    # The token sort approach involves tokenizing the string in question, sorting the tokens alphabetically, and
    # then joining them back into a string We then compare the transformed strings with a simple ratio().
    df["token_sort_ratio"]      = df.apply(lambda x: fuzz.token_sort_ratio(x["question1"], x["question2"]), axis=1)
    df["fuzz_ratio"]            = df.apply(lambda x: fuzz.QRatio(x["question1"], x["question2"]), axis=1)
    df["fuzz_partial_ratio"]    = df.apply(lambda x: fuzz.partial_ratio(x["question1"], x["question2"]), axis=1)
    df["longest_substr_ratio"]  = df.apply(lambda x: get_longest_substr_ratio(x["question1"], x["question2"]), axis=1)
    return df
```

In [0]:

```
if os.path.isfile('/content/drive/My Drive/ML_Assignment/nlp_features_train.cs
v'):
    df = pd.read_csv("/content/drive/My Drive/ML_Assignment/nlp_features_trai
n.csv",encoding='latin-1')
    df.fillna('')
else:
    print("Extracting features for train:")
    df = pd.read_csv("/content/drive/My Drive/Quora/train.csv")
    df = extract_features(df)
    df.to_csv("/content/drive/My Drive/ML_Assignment/nlp_features_train.csv",
index=False)
```

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

6.0 Analysis of extracted features

6.1 Plotting Word clouds

In [0]:

```
df_duplicate = df[df['is_duplicate'] == 1]
dfp_nonduplicate = df[df['is_duplicate'] == 0]

# Converting 2d array of q1 and q2 and flatten the array: like {{1,2},{3,4}} t
o {1,2,3,4}
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('/content/drive/My Drive/ML_Assignment/train_p.txt', p, delimiter='
', fmt='%s')
np.savetxt('/content/drive/My Drive/ML_Assignment/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
```

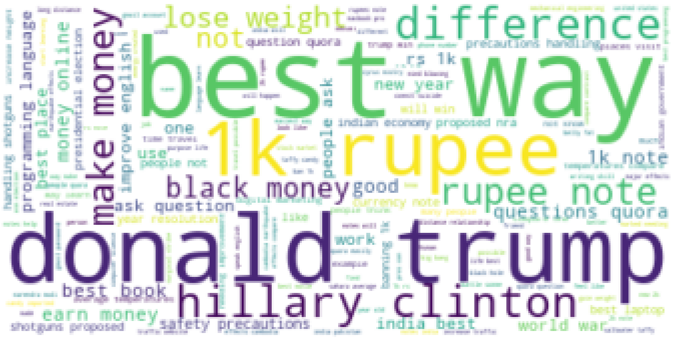
```
In [0]: # reading the text files and removing the Stop Words:
        d = path.dirname('.')

        textp_w = open(path.join(d, '/content/drive/My Drive/ML_Assignment/train_p.tx
        t')).read()
        textn_w = open(path.join(d, '/content/drive/My Drive/ML_Assignment/train_n.tx
        t')).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 [0]: wc = WordCloud(background_color="white", max_words=len(textp_w), stopwords=sto
        pwords)
        wc.generate(textp_w)
        print ("Word Cloud for Duplicate Question pairs")
        plt.imshow(wc, interpolation='bilinear')
        plt.axis("off")
        plt.show()
```

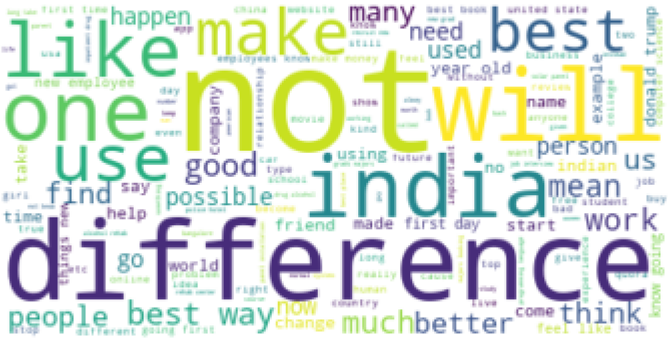
```
Word Cloud for Duplicate Question pairs
```



Word Clouds generated from non duplicate pair question's text

In [0]:
```
wc = WordCloud(background_color="white", max_words=len(textn_w),stopwords=stop
words)
# 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()
```

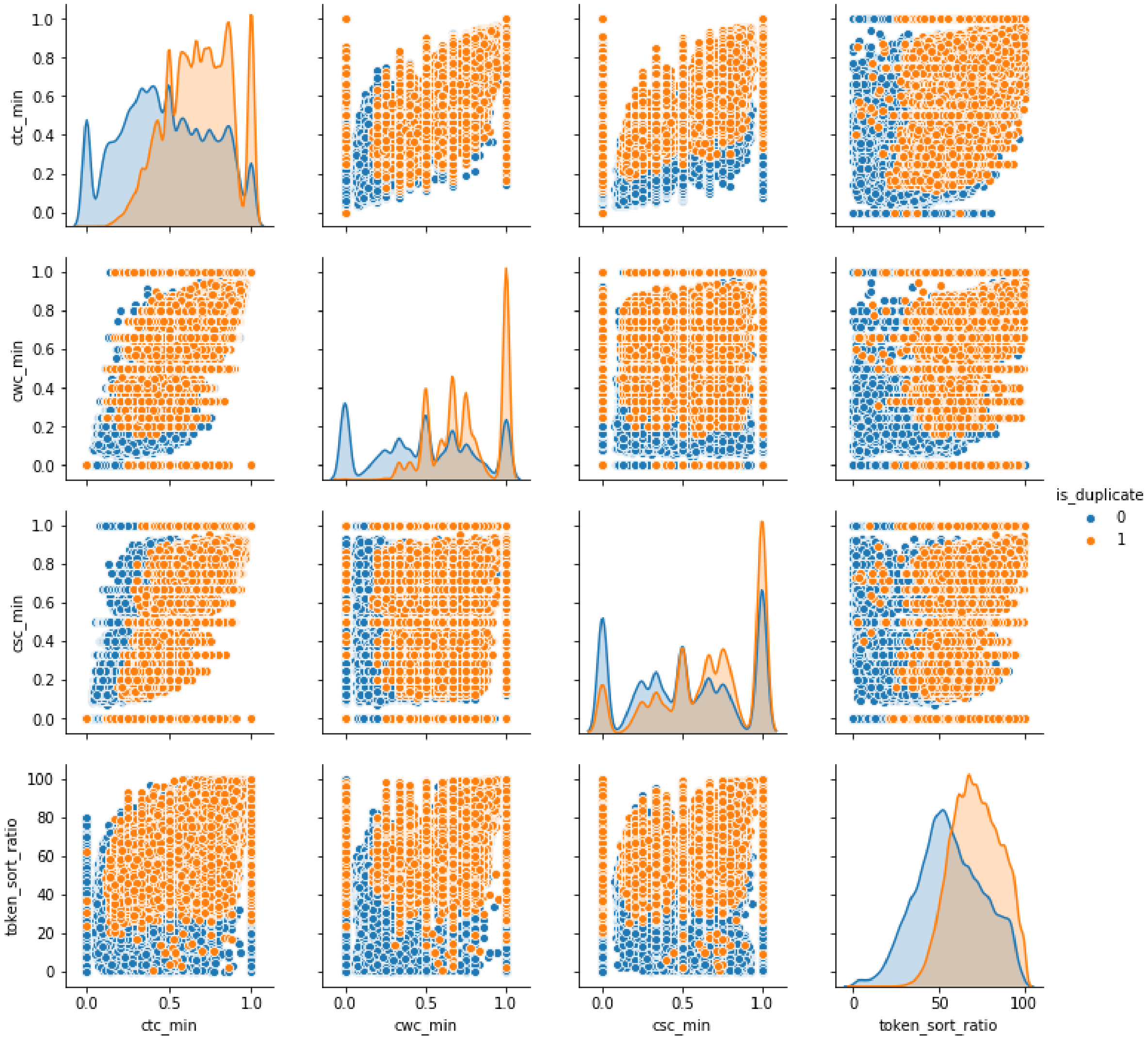
```
Word Cloud for non-Duplicate Question pairs:
```



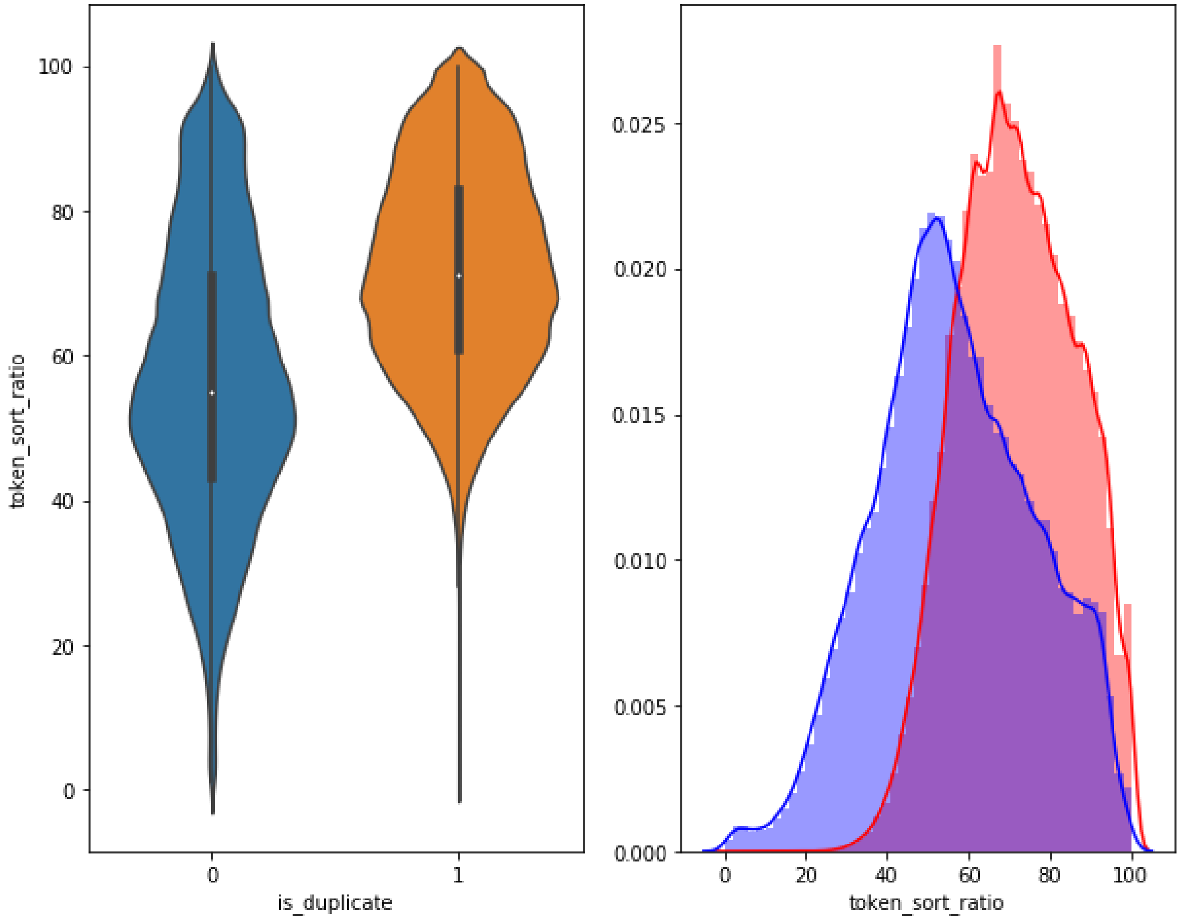
6.2 Pair plot of features ['ctc_min', 'cwc_min', 'csc_min', 'token_sort_ratio']

In [0]:

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

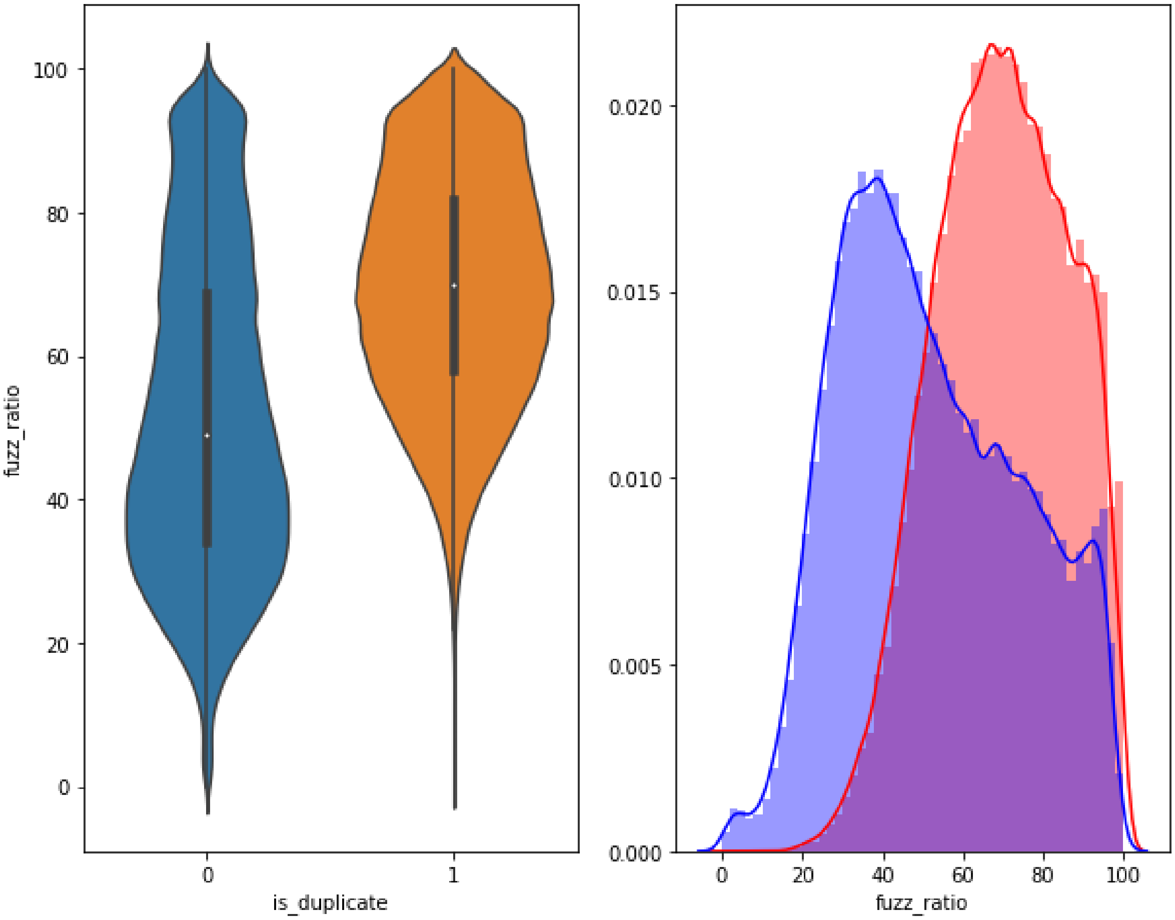


In [0]:
```
# Distribution of the token_sort_ratio
plt.figure(figsize=(10, 8))

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", color = 'red')
sns.distplot(df[df['is_duplicate'] == 0.0]['token_sort_ratio'][0:] , label =
"0" , color = 'blue' )
plt.show()
```



In [0]:

```
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 = 'red')
sns.distplot(df[df['is_duplicate'] == 0.0]['fuzz_ratio'][0:] , label = "0" , color = 'blue' )
plt.show()
```



6.3 Visualization

In [0]:

```
# Using TSNE for Dimentionality reduction for 15 Features(Generated after cleaning the data) to 3 dimention

from sklearn.preprocessing import MinMaxScaler

dfp_subsampled = df[0:5000]
X = MinMaxScaler().fit_transform(dfp_subsampled[['cwc_min', 'cwc_max', 'csc_min', 'csc_max' , 'ctc_min' , 'ctc_max' , 'last_word_eq', 'first_word_eq' , 'abs_len_diff' , 'mean_len' , 'token_set_ratio' , 'token_sort_ratio' ,  'fuzz_ratio' , 'fuzz_partial_ratio' , 'longest_substr_ratio']])
y = dfp_subsampled['is_duplicate'].values
```

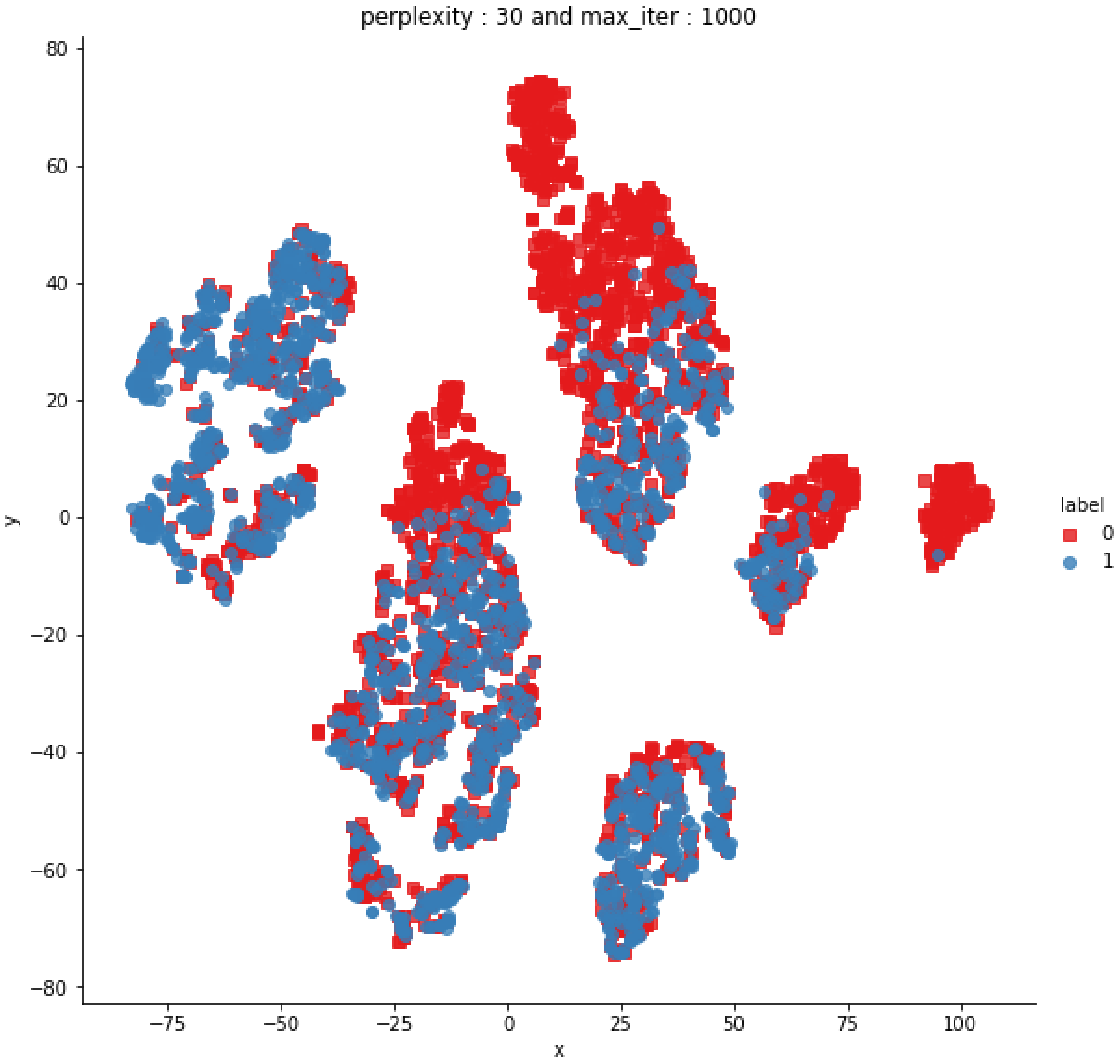
```
In [0]: tsne2d = TSNE(
            n_components=2,
            init='random', # pca
            random_state=101,
            method='barnes_hut',
            n_iter=1000,
            verbose=2,
            angle=0.5
        ).fit_transform(X)
```

```
[t-SNE] Computing 91 nearest neighbors...
[t-SNE] Indexed 5000 samples in 0.013s...
[t-SNE] Computed neighbors for 5000 samples in 0.383s...
[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 0.303s
[t-SNE] Iteration 50: error = 81.2911148, gradient norm = 0.0457501 (50 itera
tions in 2.987s)
[t-SNE] Iteration 100: error = 70.6044159, gradient norm = 0.0086692 (50 iter
ations in 2.054s)
[t-SNE] Iteration 150: error = 68.9124908, gradient norm = 0.0056016 (50 iter
ations in 1.935s)
[t-SNE] Iteration 200: error = 68.1010742, gradient norm = 0.0047585 (50 iter
ations in 2.015s)
[t-SNE] Iteration 250: error = 67.5907974, gradient norm = 0.0033576 (50 iter
ations in 2.108s)
[t-SNE] KL divergence after 250 iterations with early exaggeration: 67.590797
[t-SNE] Iteration 300: error = 1.7929677, gradient norm = 0.0011899 (50 itera
tions in 2.156s)
[t-SNE] Iteration 350: error = 1.3937442, gradient norm = 0.0004817 (50 itera
tions in 2.142s)
[t-SNE] Iteration 400: error = 1.2280033, gradient norm = 0.0002773 (50 itera
tions in 2.201s)
[t-SNE] Iteration 450: error = 1.1383208, gradient norm = 0.0001865 (50 itera
tions in 2.142s)
[t-SNE] Iteration 500: error = 1.0834006, gradient norm = 0.0001423 (50 itera
tions in 2.121s)
[t-SNE] Iteration 550: error = 1.0474092, gradient norm = 0.0001144 (50 itera
tions in 2.145s)
[t-SNE] Iteration 600: error = 1.0231259, gradient norm = 0.0000995 (50 itera
tions in 2.189s)
[t-SNE] Iteration 650: error = 1.0066353, gradient norm = 0.0000895 (50 itera
tions in 2.191s)
[t-SNE] Iteration 700: error = 0.9954656, gradient norm = 0.0000805 (50 itera
tions in 2.207s)
[t-SNE] Iteration 750: error = 0.9871529, gradient norm = 0.0000719 (50 itera
tions in 2.228s)
[t-SNE] Iteration 800: error = 0.9801921, gradient norm = 0.0000657 (50 itera
tions in 2.246s)
[t-SNE] Iteration 850: error = 0.9743395, gradient norm = 0.0000631 (50 itera
tions in 2.251s)
[t-SNE] Iteration 900: error = 0.9693972, gradient norm = 0.0000606 (50 itera
tions in 2.237s)
[t-SNE] Iteration 950: error = 0.9654404, gradient norm = 0.0000594 (50 itera
tions in 2.227s)
[t-SNE] Iteration 1000: error = 0.9622302, gradient norm = 0.0000565 (50 iter
ations in 2.224s)
[t-SNE] KL divergence after 1000 iterations: 0.962230
```

In [0]:

```
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",markers=['s','o'])
plt.title("perplexity : {} and max_iter : {}".format(30, 1000))
plt.show()
```

```
/usr/local/lib/python3.6/dist-packages/seaborn/regression.py:546: UserWarnin
g:

The `size` paramter has been renamed to `height`; please update your code.
```



7. Machine Learning Models

In [0]:

```python
#prepro_features_train.csv (Simple Preprocessing Feartures)
#nlp_features_train.csv (NLP Features)
if os.path.isfile('/content/drive/My Drive/ML_Assignment/nlp_features_train.csv'):
    dfnlp = pd.read_csv("/content/drive/My Drive/ML_Assignment/nlp_features_train.csv",encoding='latin-1')
else:
    print("download nlp_features_train.csv from drive or run previous notebook")

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

In [0]:

```python
df1 = dfnlp.drop(['qid1','qid2','question1','question2','is_duplicate'],axis=1)
df2 = dfppro.drop(['qid1','qid2','question1','question2','is_duplicate'],axis=1)
df3 = dfnlp[['id','question1','question2']]
duplicate = dfnlp.is_duplicate
```

In [0]:

```python
df1.columns
```

Out[0]:

```
Index(['id', 'cwc_min', 'cwc_max', 'csc_min', 'csc_max', 'ctc_min', 'ctc_max',
       'last_word_eq', 'first_word_eq', 'abs_len_diff', 'mean_len',
       'token_set_ratio', 'token_sort_ratio', 'fuzz_ratio',
       'fuzz_partial_ratio', 'longest_substr_ratio'],
      dtype='object')
```

In [0]:

```python
df2.columns
```

Out[0]:

```
Index(['id', 'freq_qid1', 'freq_qid2', 'q1len', 'q2len', 'q1_n_words',
       'q2_n_words', 'word_Common', 'word_Total', 'word_share', 'freq_q1+q2',
       'freq_q1-q2'],
      dtype='object')
```

In [0]:

```python
df3.columns
```

Out[0]:

```
Index(['id', 'question1', 'question2'], dtype='object')
```

In [0]:

```python
df3 = df3.fillna(' ')
df4 = pd.DataFrame()
df4['Text'] = df3.question1 + ' ' + df3.question2
df4['id'] = df3.id
```

In [0]:
```
df2['id']=df1['id']
df4['id']=df1['id']
df5  = df1.merge(df2, on='id',how='left')
final  = df5.merge(df4, on='id',how='left')
```

In [0]:
```
final.columns
```

Out[0]:
```
Index(['id', 'cwc_min', 'cwc_max', 'csc_min', 'csc_max', 'ctc_min', 'ctc_ma
x',
       'last_word_eq', 'first_word_eq', 'abs_len_diff', 'mean_len',
       'token_set_ratio', 'token_sort_ratio', 'fuzz_ratio',
       'fuzz_partial_ratio', 'longest_substr_ratio', 'freq_qid1', 'freq_qid
2',
       'q1len', 'q2len', 'q1_n_words', 'q2_n_words', 'word_Common',
       'word_Total', 'word_share', 'freq_q1+q2', 'freq_q1-q2', 'Text'],
      dtype='object')
```

In [0]:
```
final = final.drop('id',axis=1)
```

7.1 Random train test split(70:30)

In [0]:
```
from sklearn.model_selection import train_test_split
X_train_tf,X_test_tf, y_train_tf, y_test_tf = train_test_split(final,duplicate
, test_size=0.3,random_state=13)
```

In [0]:
```
print("Number of data points in train data :",X_train_tf.shape)
print("Number of data points in test data :",X_test_tf.shape)
```

```
Number of data points in train data : (283003, 27)
Number of data points in test data : (121287, 27)
```

In [26]:
```
from sklearn.feature_extraction.text import TfidfVectorizer

tfidf_vect = TfidfVectorizer(ngram_range=(1,3),max_features=200000,min_df=0.00
0032)
train_tfidf = tfidf_vect.fit_transform(X_train_tf.Text)
test_tfidf = tfidf_vect.transform(X_test_tf.Text)
print('No of Tfidf features',len(tfidf_vect.get_feature_names()))
```

```
No of Tfidf features 122820
```

In [0]:
```
X_train_tf = X_train_tf.drop('Text',axis=1)
X_test_tf = X_test_tf.drop('Text',axis=1)
```

In [0]:
```
from scipy.sparse import hstack
X_train1 = hstack((X_train_tf.values,train_tfidf))
X_test1 = hstack((X_test_tf.values,test_tfidf))
```

In [0]:

```
X_train1
```

Out[0]:

```
<283003x122846 sparse matrix of type '<class 'numpy.float64'>'
	with 16061987 stored elements in COOrdinate format>
```

In [0]:

```
# 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 a
re predicted class j

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

    # 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 two diamensional array
    # 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 th
at row
    # C = [[1, 2],-
    #     [3, 4]]
    # C.sum(axis = 0)  axis=0 corresonds to columns and axis=1 corresponds to
 rows in two diamensional array
    # 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, ytick
labels=labels)
    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, ytick
labels=labels)
    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, ytick
labels=labels)
    plt.xlabel('Predicted Class')
    plt.ylabel('Original Class')
    plt.title("Recall matrix")

    plt.show()
```

7.2 Logistic Regression with hyperparameter tuning

7.2.1 Hyper-Parameter Tuning

In [0]:

```
from sklearn.linear_model import SGDClassifier
from sklearn.metrics import confusion_matrix
from sklearn.metrics import log_loss
from sklearn.calibration import CalibratedClassifierCV

alpha = [10 ** x for x in range(-5, 2)] # hyperparam for SGD classifier.

# read more about SGDClassifier() at http://scikit-learn.org/stable/modules/generated/sklearn.linear_model.SGDClassifier.html
# ------------------------------
# default parameters
# SGDClassifier(loss='hinge', penalty='l2', alpha=0.0001, l1_ratio=0.15, fit_intercept=True, max_iter=None, tol=None,
# shuffle=True, verbose=0, epsilon=0.1, n_jobs=1, random_state=None, learning_rate='optimal', eta0=0.0, power_t=0.5,
# class_weight=None, warm_start=False, average=False, n_iter=None)

# some of methods
# fit(X, y[, coef_init, intercept_init, …])     Fit linear model with Stochastic Gradient Descent.
# predict(X)    Predict class labels for samples in X.



log_error_array=[]
for i in alpha:
    clf = SGDClassifier(alpha=i, penalty='l2', loss='log', random_state=42)
    clf.fit(X_train1, y_train_tf)
    sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
    sig_clf.fit(X_train1, y_train_tf)
    predict_y = sig_clf.predict_proba(X_test1)
    log_error_array.append(log_loss(y_test_tf, predict_y, labels=clf.classes_, eps=1e-15))
    print('For values of alpha = ', i, "The log loss is:",log_loss(y_test_tf, predict_y, labels=clf.classes_, eps=1e-15))
```

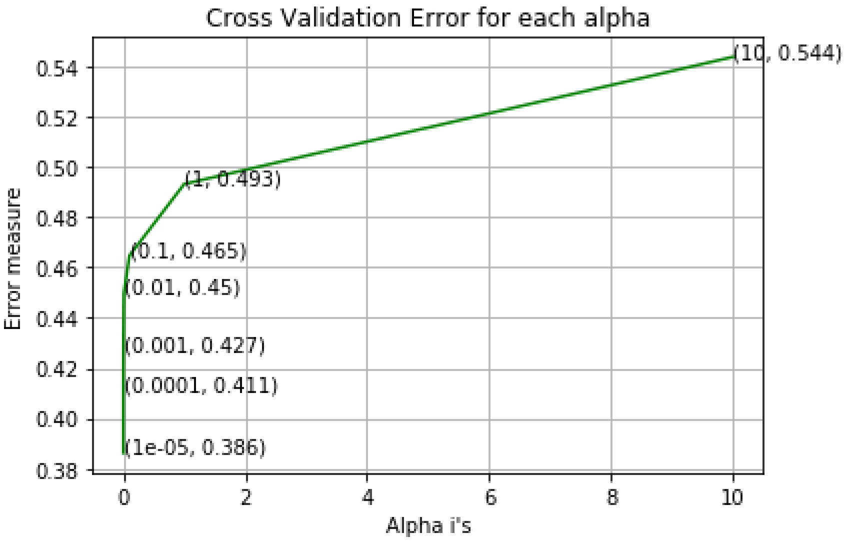
```
/usr/local/lib/python3.6/dist-packages/sklearn/model_selection/_split.py:197
8: FutureWarning:

The default value of cv will change from 3 to 5 in version 0.22. Specify it e
xplicitly to silence this warning.


For values of alpha =  1e-05 The log loss is: 0.38623914881517596

/usr/local/lib/python3.6/dist-packages/sklearn/model_selection/_split.py:197
8: FutureWarning:

The default value of cv will change from 3 to 5 in version 0.22. Specify it e
xplicitly to silence this warning.


For values of alpha =  0.0001 The log loss is: 0.4111481284848784

/usr/local/lib/python3.6/dist-packages/sklearn/model_selection/_split.py:197
8: FutureWarning:

The default value of cv will change from 3 to 5 in version 0.22. Specify it e
xplicitly to silence this warning.


For values of alpha =  0.001 The log loss is: 0.42689999873675494

/usr/local/lib/python3.6/dist-packages/sklearn/model_selection/_split.py:197
8: FutureWarning:

The default value of cv will change from 3 to 5 in version 0.22. Specify it e
xplicitly to silence this warning.


For values of alpha =  0.01 The log loss is: 0.44990204615421514

/usr/local/lib/python3.6/dist-packages/sklearn/model_selection/_split.py:197
8: FutureWarning:

The default value of cv will change from 3 to 5 in version 0.22. Specify it e
xplicitly to silence this warning.


For values of alpha =  0.1 The log loss is: 0.4646282585440264

/usr/local/lib/python3.6/dist-packages/sklearn/model_selection/_split.py:197
8: FutureWarning:

The default value of cv will change from 3 to 5 in version 0.22. Specify it e
xplicitly to silence this warning.


For values of alpha =  1 The log loss is: 0.49319818487236194
```

```
/usr/local/lib/python3.6/dist-packages/sklearn/model_selection/_split.py:197
8: FutureWarning:

The default value of cv will change from 3 to 5 in version 0.22. Specify it e
xplicitly to silence this warning.


For values of alpha =  10 The log loss is: 0.5438487664049481
```

7.2.2 Plot

In [0]:

```
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()
```



7.2.3 Training the model

In [0]:
```
best_alpha = np.argmin(log_error_array)
clf = SGDClassifier(alpha=alpha[best_alpha], penalty='l2', loss='log', random_
state=42)
clf.fit(X_train1, y_train_tf)
sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
sig_clf.fit(X_train1, y_train_tf)
```

```
/usr/local/lib/python3.6/dist-packages/sklearn/model_selection/_split.py:197
8: FutureWarning:

The default value of cv will change from 3 to 5 in version 0.22. Specify it e
xplicitly to silence this warning.
```

Out[0]:
```
CalibratedClassifierCV(base_estimator=SGDClassifier(alpha=1e-05, average=Fals
e,
                                                    class_weight=None,
                                                    early_stopping=False,
                                                    epsilon=0.1, eta0=0.0,
                                                    fit_intercept=True,
                                                    l1_ratio=0.15,
                                                    learning_rate='optimal',
                                                    loss='log', max_iter=100
0,
                                                    n_iter_no_change=5,
                                                    n_jobs=None, penalty='l
2',
                                                    power_t=0.5,
                                                    random_state=42,
                                                    shuffle=True, tol=0.001,
                                                    validation_fraction=0.1,
                                                    verbose=0,
                                                    warm_start=False),
                       cv='warn', method='sigmoid')
```

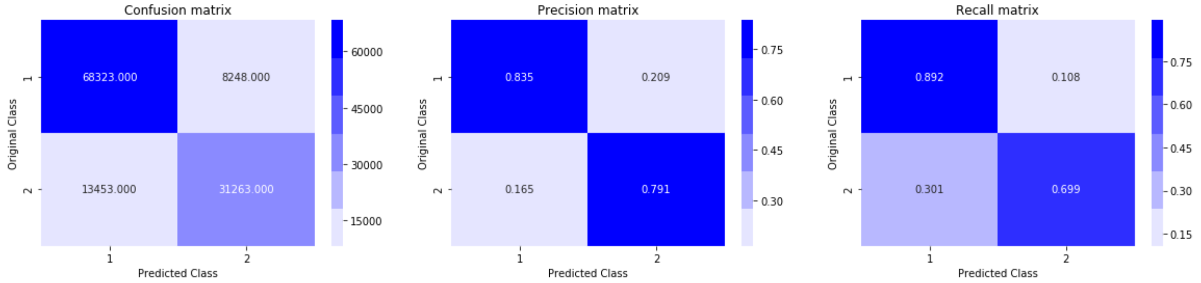
In [0]:
```
predict_y = sig_clf.predict_proba(X_train1)
print('For values of best alpha = ', alpha[best_alpha], "The train log loss i
s:",log_loss(y_train_tf, predict_y, labels=clf.classes_, eps=1e-15))

predict_y = sig_clf.predict_proba(X_test1)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss i
s:",log_loss(y_test_tf, predict_y, labels=clf.classes_, eps=1e-15))

predicted_y =np.argmax(predict_y,axis=1)
print("Total number of data points :", len(predicted_y))
```

```
For values of best alpha =  1e-05 The train log loss is: 0.3818035869208524
For values of best alpha =  1e-05 The test log loss is: 0.38623914881517596
Total number of data points : 121287
```

7.2.4 Confusion Matrix

In [0]:

```
plot_confusion_matrix(y_test_tf, predicted_y)
```



7.3 Linear SVM with hyperparameter tuning

7.3.1 Hyper-Parameter Tuning

In [30]:

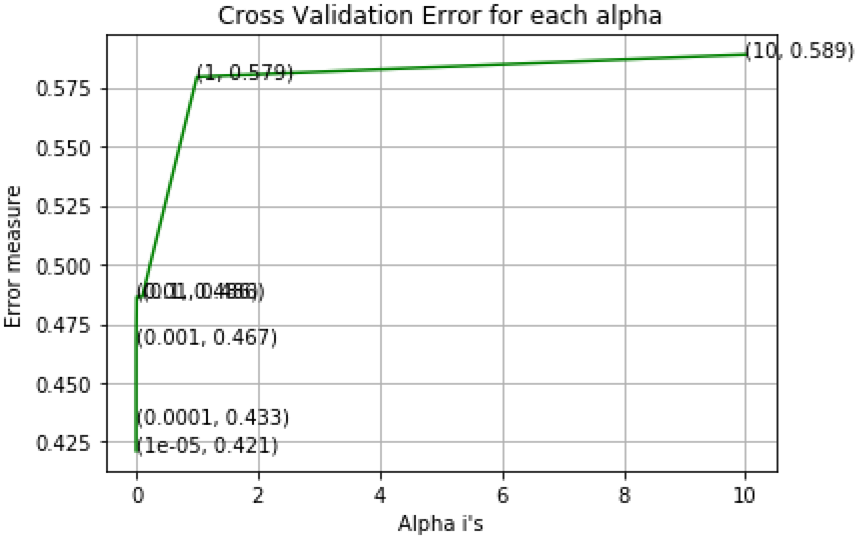
```
from sklearn.linear_model import SGDClassifier
from sklearn.metrics import confusion_matrix
from sklearn.metrics import log_loss
from sklearn.calibration import CalibratedClassifierCV

alpha = [10 ** x for x in range(-5, 2)] # hyperparam for SGD classifier.

# read more about SGDClassifier() at http://scikit-learn.org/stable/modules/ge
nerated/sklearn.linear_model.SGDClassifier.html
# ------------------------------
# default parameters
# SGDClassifier(loss=’hinge’, penalty=’l2’, alpha=0.0001, l1_ratio=0.15, fit_i
ntercept=True, max_iter=None, tol=None,
# shuffle=True, verbose=0, epsilon=0.1, n_jobs=1, random_state=None, learning_
rate=’optimal’, eta0=0.0, power_t=0.5,
# class_weight=None, warm_start=False, average=False, n_iter=None)

# some of methods
# fit(X, y[, coef_init, intercept_init, …])     Fit linear model with Stochast
ic Gradient Descent.
# predict(X)    Predict class labels for samples in X.

log_error_array=[]
for i in alpha:
    clf = SGDClassifier(alpha=i, penalty='l1', loss='hinge', random_state=42)
    clf.fit(X_train1, y_train_tf)
    sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
    sig_clf.fit(X_train1, y_train_tf)
    predict_y = sig_clf.predict_proba(X_test1)
    log_error_array.append(log_loss(y_test_tf, predict_y, labels=clf.classes_,
eps=1e-15))
    print('For values of alpha = ', i, "The log loss is:",log_loss(y_test_tf,
predict_y, labels=clf.classes_, eps=1e-15))
```

```
/usr/local/lib/python3.6/dist-packages/sklearn/model_selection/_split.py:197
8: FutureWarning:

The default value of cv will change from 3 to 5 in version 0.22. Specify it e
xplicitly to silence this warning.

/usr/local/lib/python3.6/dist-packages/sklearn/calibration.py:453: RuntimeWar
ning:

overflow encountered in exp

/usr/local/lib/python3.6/dist-packages/sklearn/calibration.py:455: RuntimeWar
ning:

invalid value encountered in multiply

/usr/local/lib/python3.6/dist-packages/sklearn/calibration.py:453: RuntimeWar
ning:

overflow encountered in exp

/usr/local/lib/python3.6/dist-packages/sklearn/calibration.py:455: RuntimeWar
ning:

invalid value encountered in multiply

/usr/local/lib/python3.6/dist-packages/sklearn/calibration.py:453: RuntimeWar
ning:

overflow encountered in exp

/usr/local/lib/python3.6/dist-packages/sklearn/calibration.py:455: RuntimeWar
ning:

invalid value encountered in multiply


For values of alpha =  1e-05 The log loss is: 0.42124503639436617

/usr/local/lib/python3.6/dist-packages/sklearn/model_selection/_split.py:197
8: FutureWarning:

The default value of cv will change from 3 to 5 in version 0.22. Specify it e
xplicitly to silence this warning.


For values of alpha =  0.0001 The log loss is: 0.43304992470768194

/usr/local/lib/python3.6/dist-packages/sklearn/model_selection/_split.py:197
8: FutureWarning:

The default value of cv will change from 3 to 5 in version 0.22. Specify it e
xplicitly to silence this warning.


For values of alpha =  0.001 The log loss is: 0.4673372051580693
```

```
/usr/local/lib/python3.6/dist-packages/sklearn/linear_model/stochastic_gradie
nt.py:561: ConvergenceWarning:

Maximum number of iteration reached before convergence. Consider increasing m
ax_iter to improve the fit.

/usr/local/lib/python3.6/dist-packages/sklearn/model_selection/_split.py:197
8: FutureWarning:

The default value of cv will change from 3 to 5 in version 0.22. Specify it e
xplicitly to silence this warning.

/usr/local/lib/python3.6/dist-packages/sklearn/linear_model/stochastic_gradie
nt.py:561: ConvergenceWarning:

Maximum number of iteration reached before convergence. Consider increasing m
ax_iter to improve the fit.

/usr/local/lib/python3.6/dist-packages/sklearn/calibration.py:453: RuntimeWar
ning:

overflow encountered in exp

/usr/local/lib/python3.6/dist-packages/sklearn/calibration.py:455: RuntimeWar
ning:

invalid value encountered in multiply


For values of alpha =  0.01 The log loss is: 0.48645355970672305

/usr/local/lib/python3.6/dist-packages/sklearn/model_selection/_split.py:197
8: FutureWarning:

The default value of cv will change from 3 to 5 in version 0.22. Specify it e
xplicitly to silence this warning.


For values of alpha =  0.1 The log loss is: 0.48645809998786416

/usr/local/lib/python3.6/dist-packages/sklearn/model_selection/_split.py:197
8: FutureWarning:

The default value of cv will change from 3 to 5 in version 0.22. Specify it e
xplicitly to silence this warning.


For values of alpha =  1 The log loss is: 0.5794309516525658

/usr/local/lib/python3.6/dist-packages/sklearn/model_selection/_split.py:197
8: FutureWarning:

The default value of cv will change from 3 to 5 in version 0.22. Specify it e
xplicitly to silence this warning.


For values of alpha =  10 The log loss is: 0.5888447150012679
```

7.3.2 Plot

In [31]:
```
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()
```



7.3.3 Training the model

In [32]:

```
best_alpha = np.argmin(log_error_array)
clf = SGDClassifier(alpha=alpha[best_alpha], penalty='l1', loss='hinge', rando
m_state=42)
clf.fit(X_train1, y_train_tf)
sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
sig_clf.fit(X_train1, y_train_tf)
```

```
/usr/local/lib/python3.6/dist-packages/sklearn/model_selection/_split.py:197
8: FutureWarning:

The default value of cv will change from 3 to 5 in version 0.22. Specify it e
xplicitly to silence this warning.

/usr/local/lib/python3.6/dist-packages/sklearn/calibration.py:453: RuntimeWar
ning:

overflow encountered in exp

/usr/local/lib/python3.6/dist-packages/sklearn/calibration.py:455: RuntimeWar
ning:

invalid value encountered in multiply

/usr/local/lib/python3.6/dist-packages/sklearn/calibration.py:453: RuntimeWar
ning:

overflow encountered in exp

/usr/local/lib/python3.6/dist-packages/sklearn/calibration.py:455: RuntimeWar
ning:

invalid value encountered in multiply

/usr/local/lib/python3.6/dist-packages/sklearn/calibration.py:453: RuntimeWar
ning:

overflow encountered in exp

/usr/local/lib/python3.6/dist-packages/sklearn/calibration.py:455: RuntimeWar
ning:

invalid value encountered in multiply
```

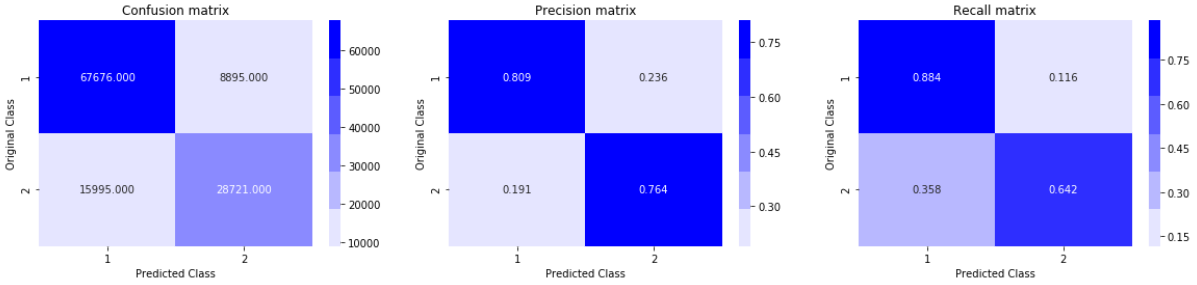
```
Out[32]: CalibratedClassifierCV(base_estimator=SGDClassifier(alpha=1e-05, average=Fals
         e,
                                                             class_weight=None,
                                                             early_stopping=False,
                                                             epsilon=0.1, eta0=0.0,
                                                             fit_intercept=True,
                                                             l1_ratio=0.15,
                                                             learning_rate='optimal',
                                                             loss='hinge', max_iter=10
         00,
                                                             n_iter_no_change=5,
                                                             n_jobs=None, penalty='l
         1',
                                                             power_t=0.5,
                                                             random_state=42,
                                                             shuffle=True, tol=0.001,
                                                             validation_fraction=0.1,
                                                             verbose=0,
                                                             warm_start=False),
                                cv='warn', method='sigmoid')
```

In [33]:
```
predict_y = sig_clf.predict_proba(X_train1)
print('For values of best alpha = ', alpha[best_alpha], "The train log loss i
s:",log_loss(y_train_tf, predict_y, labels=clf.classes_, eps=1e-15))

predict_y = sig_clf.predict_proba(X_test1)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss i
s:",log_loss(y_test_tf, predict_y, labels=clf.classes_, eps=1e-15))

predicted_y =np.argmax(predict_y,axis=1)
print("Total number of data points :", len(predicted_y))
```

```
For values of best alpha =  1e-05 The train log loss is: 0.41970659828576473
For values of best alpha =  1e-05 The test log loss is: 0.42124503639436617
Total number of data points : 121287
```

7.3.4 Confusion Matrix

In [34]:
```
plot_confusion_matrix(y_test_tf, predicted_y)
```



7.4 XGBoost

In [0]:
```
XGBData = final.head(20000)
XGB_Y=duplicate.head(20000)
```

In [36]:
```
XGBData.head(2)
```

Out[36]:

	cwc_min	cwc_max	csc_min	csc_max	ctc_min	ctc_max	last_word_eq	first_word_eq	abs
0	0.999980	0.833319	0.999983	0.999983	0.916659	0.785709	0.0	1.0	
1	0.799984	0.399996	0.749981	0.599988	0.699993	0.466664	0.0	1.0	

In [0]:

```
from sklearn.model_selection import train_test_split
X_train_tf,X_test_tf, y_train_tf, y_test_tf = train_test_split(XGBData,XGB_Y,test_size=0.3,random_state=13)
```

In [38]:

```
from sklearn.feature_extraction.text import TfidfVectorizer
tfidf_vect = TfidfVectorizer(ngram_range=(1,3),max_features=500,min_df=0.000032)
train_tfidf = tfidf_vect.fit_transform(X_train_tf.Text)
test_tfidf = tfidf_vect.transform(X_test_tf.Text)
print('No of Tfidf features',len(tfidf_vect.get_feature_names()))
```

```
No of Tfidf features 500
```

In [0]:

```
X_train_tf = X_train_tf.drop('Text',axis=1)
X_test_tf = X_test_tf.drop('Text',axis=1)
```

In [0]:

```
from scipy.sparse import hstack
X_train1 = hstack((X_train_tf.values,train_tfidf))
X_test1 = hstack((X_test_tf.values,test_tfidf))
```

In [41]:

```
from scipy.stats import randint as sp_randint
import xgboost as xgb
from numpy.random import uniform
from sklearn.model_selection import RandomizedSearchCV


param_dist = {"max_depth": sp_randint(2,5),
              "n_estimators":sp_randint(300,600)
             }

model_rs_xgb1 = RandomizedSearchCV(xgb.XGBClassifier(n_jobs=-1,random_state=25
), param_distributions=param_dist,
                                   n_iter=30,scoring='neg_log_loss',cv=5,n_job
s=-1)
model_rs_xgb1.fit(X_train1,y_train_tf)
```

Out[41]:

```
RandomizedSearchCV(cv=5, error_score='raise-deprecating',
                   estimator=XGBClassifier(base_score=0.5, booster='gbtree',
                                           colsample_bylevel=1,
                                           colsample_bynode=1,
                                           colsample_bytree=1, gamma=0,
                                           learning_rate=0.1, max_delta_step=
0,
                                           max_depth=3, min_child_weight=1,
                                           missing=None, n_estimators=100,
                                           n_jobs=-1, nthread=None,
                                           objective='binary:logistic',
                                           random_state=25, reg_alpha...
                                           seed=None, silent=None, subsample=
1,
                                           verbosity=1),
                   iid='warn', n_iter=30, n_jobs=-1,
                   param_distributions={'max_depth': <scipy.stats._distn_infr
astructure.rv_frozen object at 0x7f403ffef668>,
                                        'n_estimators': <scipy.stats._distn_i
nfrastructure.rv_frozen object at 0x7f402cbef5c0>},
                   pre_dispatch='2*n_jobs', random_state=None, refit=True,
                   return_train_score=False, scoring='neg_log_loss', verbose=
0)
```

In [0]:

```
best=model_rs_xgb1.best_params_
```

In [43]:

```
model= xgb.XGBClassifier(n_estimators=best['n_estimators'],max_depth=best['max
_depth'])
model.fit(X_train1,y_train_tf)
```

Out[43]:

```
XGBClassifier(base_score=0.5, booster='gbtree', colsample_bylevel=1,
              colsample_bynode=1, colsample_bytree=1, gamma=0,
              learning_rate=0.1, max_delta_step=0, max_depth=4,
              min_child_weight=1, missing=None, n_estimators=419, n_jobs=1,
              nthread=None, objective='binary:logistic', random_state=0,
              reg_alpha=0, reg_lambda=1, scale_pos_weight=1, seed=None,
              silent=None, subsample=1, verbosity=1)
```

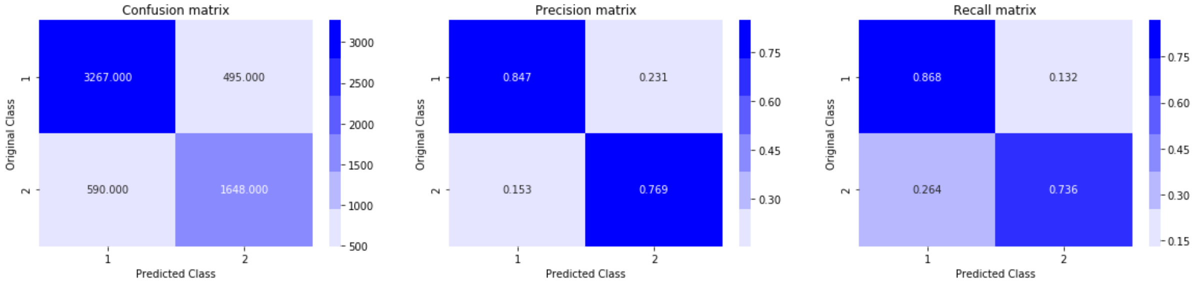
In [51]:

```
from sklearn.metrics import log_loss
predict_y = model.predict_proba(X_train1)
print('For best value of n_estimators and max_depth respectively = ', best['n_estimators'],' , ',best['max_depth'], "The train log loss is:",log_loss(y_train_tf, predict_y, labels=model.classes_, eps=1e-15))

predict_y = model.predict_proba(X_test1)
print('\nFor best value of n_estimators and max_depth respectively =  ', best['n_estimators'],' , ',best['max_depth'], "The test log loss is:",log_loss(y_test_tf, predict_y, labels=model.classes_, eps=1e-15))

predicted_y =np.argmax(predict_y,axis=1)
print("\nTotal number of data points :", len(predicted_y))
```

```
For best value of n_estimators and max_depth respectively =  419  ,  4 The train log loss is: 0.2505693500059259

For best value of n_estimators and max_depth respectively =   419  ,  4 The test log loss is: 0.3543509956041001

Total number of data points : 6000
```

In [50]:

```
from sklearn.metrics import confusion_matrix
plot_confusion_matrix(y_test_tf, predicted_y)
```



8.0 Conclusion

1.0 Report Of Different Model

In [4]:

```python
from prettytable import PrettyTable
x=PrettyTable()
x.field_names =['Machine Learning Algorithm' , 'Train Log-Loss','Test Log-Loss']
x.add_row(['Logistic Regression',0.38,0.38])
x.add_row(['Linear Support Vector Machine',0.41,0.42])
x.add_row(['XGBoost',0.25,0.34])

print(x)
```

```
+-------------------------------+----------------+---------------+
|   Machine Learning Algorithm  | Train Log-Loss | Test Log-Loss |
+-------------------------------+----------------+---------------+
|      Logistic Regression      |      0.38      |      0.38     |
| Linear Support Vector Machine |      0.41      |      0.42     |
|            XGBoost            |      0.25      |      0.34     |
+-------------------------------+----------------+---------------+
```

1. 404K data points have been used in case of Logistic Regression and Linear SVM.

1. Model is Underfit in case of XGBoost.