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

Useful Links

- Discussions : 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
- Blog 1 : 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

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. Machine Learning Probelm

2.1 Data

2.1.1 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

- Size of Train.csv - 60MB
- Number of rows in Train.csv = 404,290

2.1.2 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?","What 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 happen 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
geologist?","1"
"11","23","24","How do I read and find my YouTube comments?","How can I see all my Youtube
comments?","1"
```

2.2 Mapping the real world problem to an ML problem

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

2.2.2 Performance Metric

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

Metric(s):

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

2.3 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.

3. Exploratory Data Analysis

In [1]:

```
%matplotlib inline
import warnings
warnings.filterwarnings("ignore")

import pandas as pd
import matplotlib.pyplot as plt
import re
import time
import warnings
import sqlite3
from sqlalchemy import create_engine # database connection
import csv
import os
warnings.filterwarnings("ignore")
import datetime as dt
import numpy as np
from nltk.corpus import stopwords
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.neighbors import KNeighborsClassifier
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.multiclass import OneVsRestClassifier
from sklearn.svm import SVC
from collections import Counter, defaultdict
from sklearn.calibration import CalibratedClassifierCV
from sklearn.naive_bayes import MultinomialNB
from sklearn.naive_bayes import GaussianNB
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.ensemble import RandomForestClassifier



from sklearn.model_selection import cross_val_score
from sklearn.linear_model import SGDClassifier

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

from sklearn.model_selection import RandomizedSearchCV
import scipy.stats as st
```

3.1 Reading data and basic stats

In [2]:

```
df = pd.read_csv("train.csv")

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

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

In [3]:

```
df.head()
```

Out[3]:

	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 [4]:

```
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
```

3.2 Distribution of data points among output classes

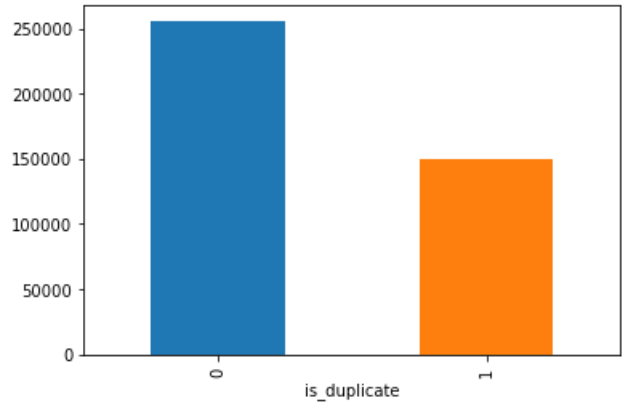
- Number of duplicate(smilar) and non-duplicate(non similar) questions

In [5]:

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

Out[5]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x27aef61bf28>
```



In [6]:

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

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

In [7]:

```
print('~> 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)))
```

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

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

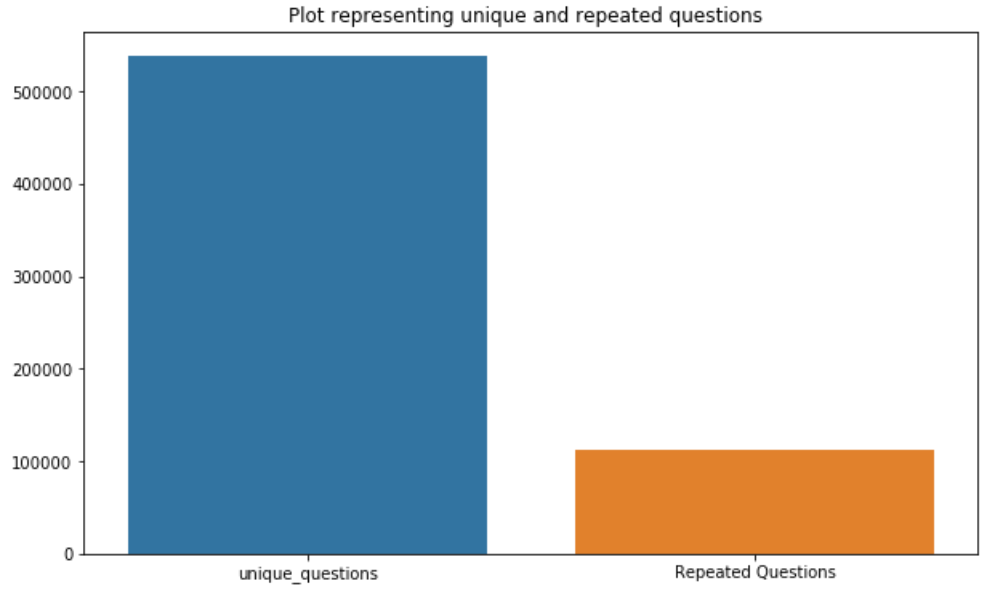
In [8]:

```
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 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(qids.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 (20.77953945937505%)

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

In [9]:

```
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()
```



quantiles size for Training Data, number of words

Given that to feed the model the size of the input has to be standard, it's required to check the size of the questions.

In [10]:

```
qt = pd.concat([df['question1'], df['question2']])
qtlen = qt.apply(lambda x: len(str(x).split(' ')))
q_train = qtlen.quantile([0.25, 0.5, 0.75, 0.99])
print("Quantiles Train: ")
print(q_train)
```

```
Quantiles Train:
0.25     7.0
0.50    10.0
0.75    13.0
0.99    31.0
dtype: float64
```

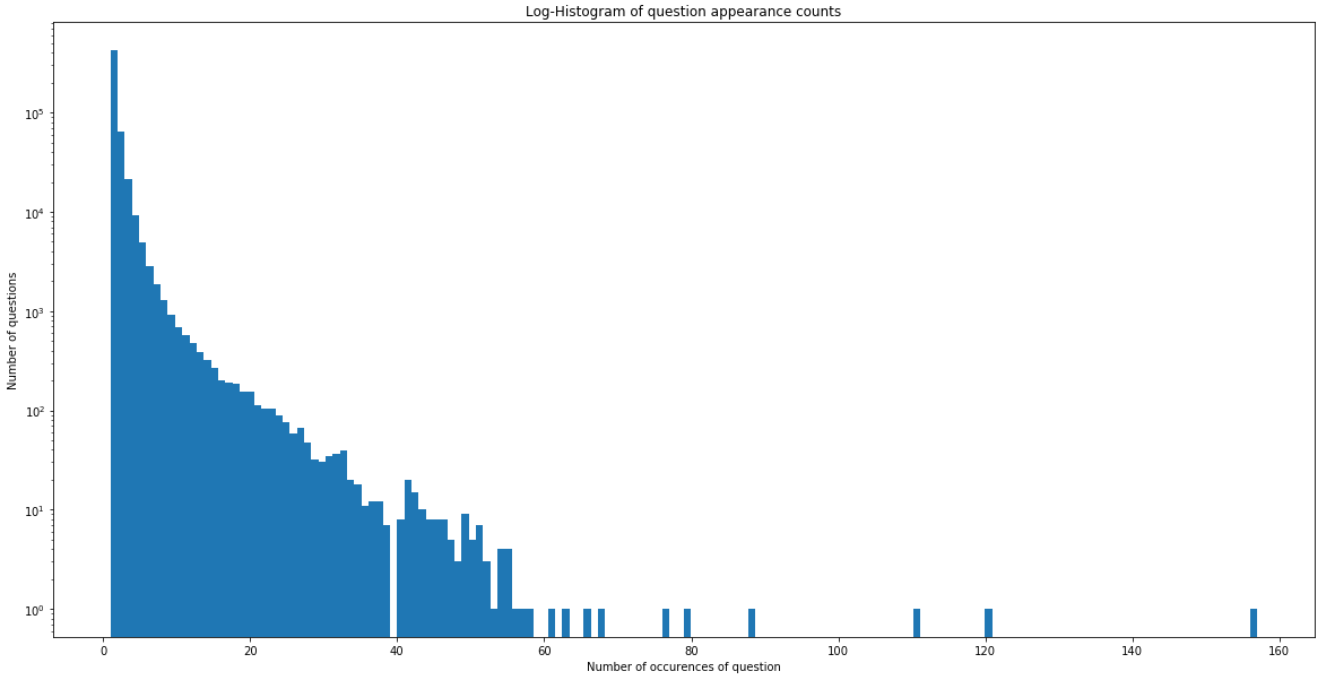
We can see that the mean of words per question is 10 and that the 99 percent of the words are covered by a length of 31 words, so using 32 words as input lenght for questions is good enought.

In [11]:

```
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(max(qids.value_counts(
)))
```

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



Counting Open and yes/no questions

From this we will come to know how many questions are classified as yes/no questions present in the dataset.

In [12]:

```
def isOpenQuestion(q):
    yesNoQuestionsInitializers = ['is', 'are', 'should', 'do', 'does', 'can']
    openQuestionInitializer = ['what', 'how', 'why', 'who', 'when', 'where', 'which', "what's", "ho
w's", "why's", "who's", "when's", "where's"]
    isOpen = any( str(q).lower().startswith(i) for i in openQuestionInitializer)
    isYesNo = any( str(q).lower().startswith(i) for i in yesNoQuestionsInitializers)
    if isOpen:
        return 0
    elif isYesNo:
        return 1
    else:
        return 2

df['Q1TypeOfQuestion'] = df['question1'].apply(isOpenQuestion)
df['Q2TypeOfQuestion'] = df['question2'].apply(isOpenQuestion)
```

In [13]:

```
numberOfYesNoQuestions = df[df['Q1TypeOfQuestion'] == 1].shape[0] + df[df['Q2TypeOfQuestion'] == 1]
.shape[0]
print("Number of yes/no questions: ", numberOfYesNoQuestions)
```

```
Number of yes/no questions:  109003
```

In [14]:

```
numberOfOpenQuestions = df[df['Q1TypeOfQuestion'] == 0].shape[0] + df[df['Q2TypeOfQuestion'] == 0].
shape[0]
print("Number of Open questions: ", numberOfOpenQuestions)
```

```
Number of Open questions:  607027
```

In [20]:

```
df=df.drop(['Q1TypeOfQuestion','Q2TypeOfQuestion'],axis=1)
```

From this analysis we can conclude that the number of open questions in the dataset is bigger than the number of yes/no questions.

In [22]:

```
#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
```

In [23]:

```
# 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: []
```

3.3 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 [13]:

```
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[13]:

	id	qid1	qid2	question1	question2	is_duplicate	freq_qid1	freq_qid2	q1len	q2len	q1_n_words	q2_n_words	word_
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	14	12	10.0
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	8	13	4.0
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	14	10	4.0
3	3	7	8	Why am I mentally very lonely? How can I solve...	Find the remainder when [math]23^{24}[/math] i...	0	1	1	50	65	11	9	0.0
4	4	9	10	Which one dissolve in water quikly sugar, salt...	Which fish would survive in salt water?	0	3	1	76	39	13	7	2.0

In [14]:

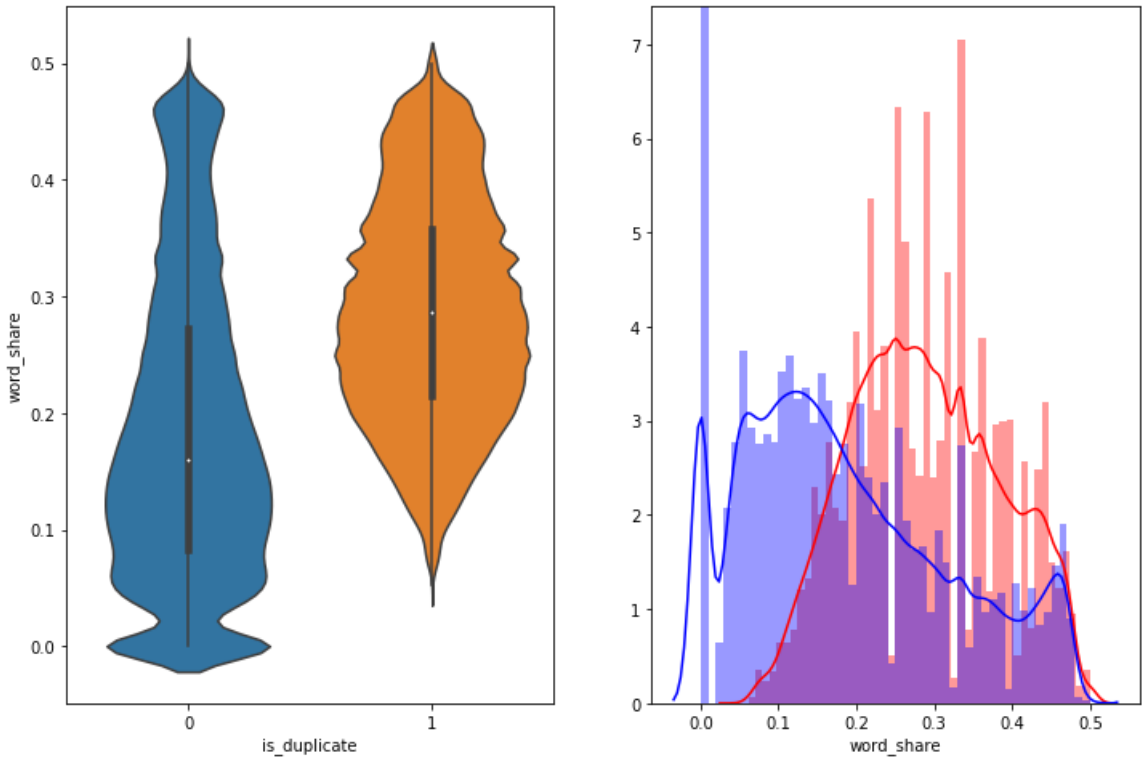
```
print ("Minimum length of the questions in question1 : " , min(df['q1_n_words']))

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']== 1].shape[0])
print ("Number of Questions with minimum length [question2] :", df[df['q2_n_words']== 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
```

In [15]:

```
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' )
plt.show()
```

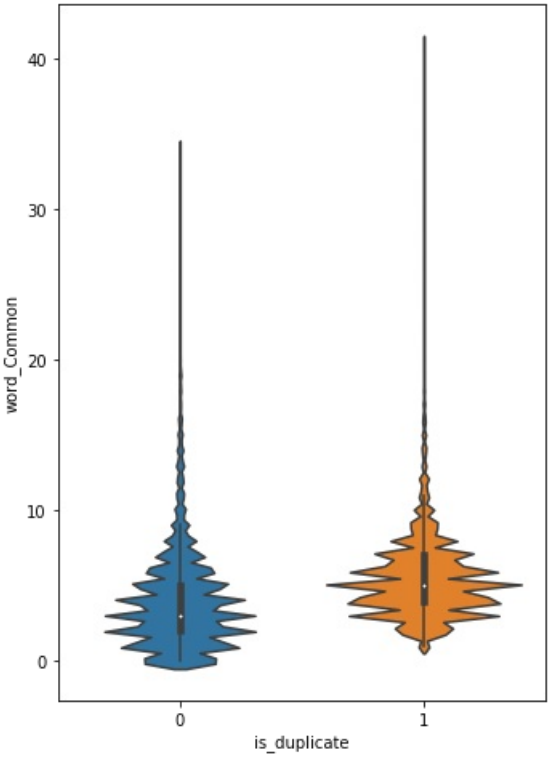
```
C:\ProgramData\Anaconda3\lib\site-packages\matplotlib\axes\_axes.py:6462: UserWarning: The
'normed' kwarg is deprecated, and has been replaced by the 'density' kwarg.
  warnings.warn("The 'normed' kwarg is deprecated, and has been "
C:\ProgramData\Anaconda3\lib\site-packages\matplotlib\axes\_axes.py:6462: UserWarning: The
'normed' kwarg is deprecated, and has been replaced by the 'density' kwarg.
  warnings.warn("The 'normed' kwarg is deprecated, and has been "
```

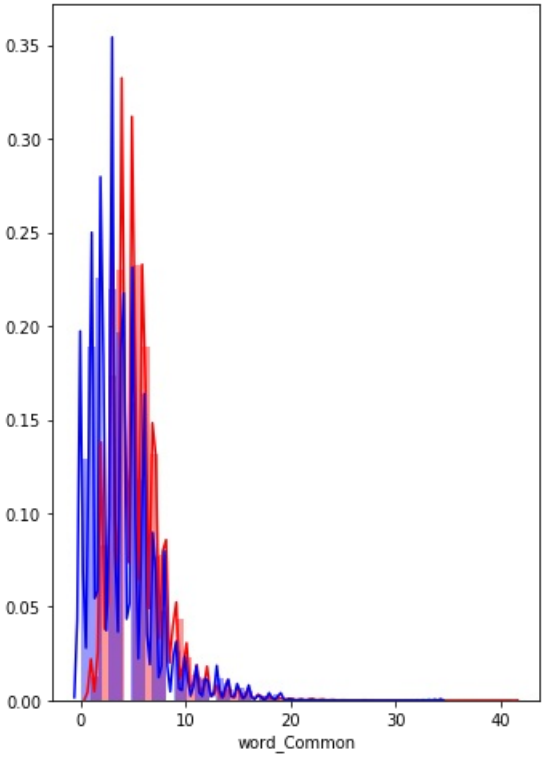


In [16]:

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

```
C:\ProgramData\Anaconda3\lib\site-packages\matplotlib\axes\_axes.py:6462: UserWarning: The
'normed' kwarg is deprecated, and has been replaced by the 'density' kwarg.
  warnings.warn("The 'normed' kwarg is deprecated, and has been "
C:\ProgramData\Anaconda3\lib\site-packages\matplotlib\axes\_axes.py:6462: UserWarning: The
'normed' kwarg is deprecated, and has been replaced by the 'density' kwarg.
  warnings.warn("The 'normed' kwarg is deprecated, and has been "
```





3.4 Preprocessing of Text

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

In [17]:

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


    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
```

In [18]:

```
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_tokens)) + SAFE_DIV)
    token_features[5] = common_token_count / (max(len(q1_tokens), len(q2_tokens)) + 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

# 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["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-st
rings
    # 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 alpha
betically, and
    # then joining them back into a string We then compare the transformed strings with a simple r
atio().
    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"]), a
is=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["qu
estion2"]), axis=1)
    return df
```

3.5 : EDA: Advanced Feature Extraction.

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 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 Q2
  longest_substr_ratio = len(longest common substring) / (min(len(q1_tokens), len(q2_tokens))

In [19]:

```
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)
```

Out[19]:

	id	qid1	qid2	question1	question2	is_duplicate	cwc_min	cwc_max	csc_min	csc_max	...	ctc_max	last_word_eq	f
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	0.999980	0.833319	0.999983	0.999983	...	0.785709	0.0	1
1	1	3	4	what is the story of kohinoor koh i noor dia...	what would happen if the indian government sto...	0	0.799984	0.399996	0.749981	0.599988	...	0.466664	0.0	1

2 rows × 21 columns

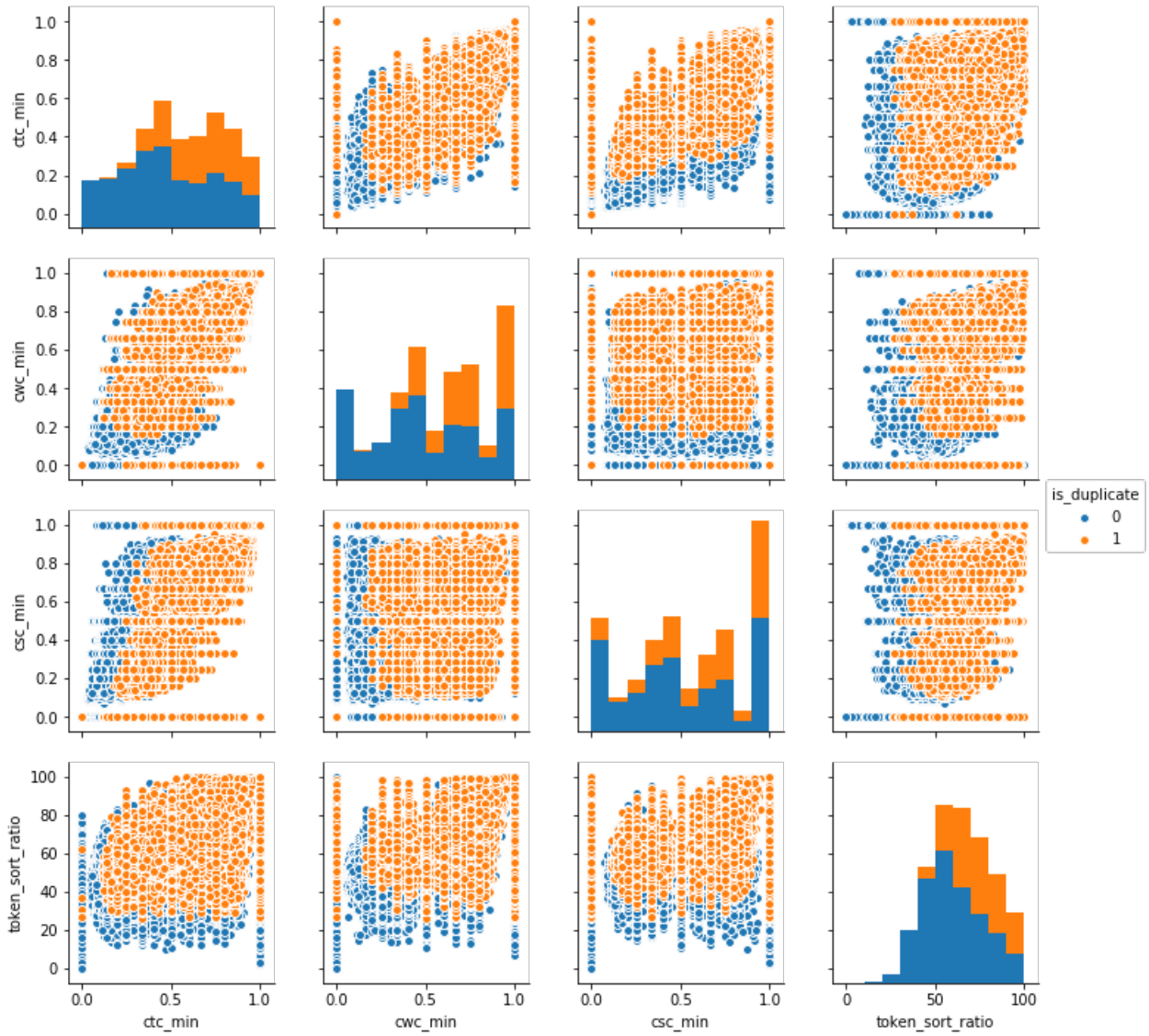
In [29]:

```
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}} to {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))
```

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

In [28]:

```
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()
```



3.6 Featurizing text data with tfidf vectors

In [2]:

```
df_nlp = pd.read_csv("nlp_features_train.csv",encoding='latin-1')
df_ppro = pd.read_csv("df_fe_without_preprocessing_train.csv",encoding='latin-1')
```

In [3]:

```
df_nlp.head()
```

Out[3]:

	id	qid1	qid2	question1	question2	is_duplicate	cwc_min	cwc_max	csc_min	csc_max	...	ctc_max	last_word_eq	f
0	0	1	2	what is the step by step guide to	what is the step by step guide to invest in	0	0.999980	0.833319	0.999983	0.999983	...	0.785709	0.0	1

	id	qid1	qid2	question1	question2	is_duplicate	cwc_min	cwc_max	csc_min	csc_max	...	ctc_max	last_word_eq	f
1	1	3	4	what is the story of kohinoor koh i noor dia...	what would happen if the indian government sto...	0	0.799984	0.399996	0.749981	0.599988	...	0.466664	0.0	1
2	2	5	6	how can i increase the speed of my internet co...	how can internet speed be increased by hacking...	0	0.399992	0.333328	0.399992	0.249997	...	0.285712	0.0	1
3	3	7	8	why am i mentally very lonely how can i solve...	find the remainder when math 23 24 math i...	0	0.000000	0.000000	0.000000	0.000000	...	0.000000	0.0	0
4	4	9	10	which one dissolve in water quikly sugar salt...	which fish would survive in salt water	0	0.399992	0.199998	0.999950	0.666644	...	0.307690	0.0	1

5 rows × 21 columns

In [4]:

```
df_ppro.head()
```

Out[4]:

	id	qid1	qid2	question1	question2	is_duplicate	freq_qid1	freq_qid2	q1len	q2len	q1_n_words	q2_n_words	word_
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	14	12	10.0
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	8	13	4.0
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	14	10	4.0
3	3	7	8	Why am I mentally very lonely? How can I solve...	Find the remainder when [math]23^{24} [/math] i...	0	1	1	50	65	11	9	0.0

	id	qid1	qid2	question1	question2	is_duplicate	freq_qid1	freq_qid2	q1len	q2len	q1_n_words	q2_n_words	word_
4	4	9	10	Which one dissolve in water quikly sugar, salt...	Which fish would survive in salt water?	0	3	1	76	39	13	7	2.0

In [5]:

```
df1 = df_nlp.drop(['qid1','qid2'],axis=1)
df2 = df_ppro.drop(['qid1','qid2','question1','question2','is_duplicate'],axis=1)
df  = df1.merge(df2, on='id',how='left')
```

In [6]:

```
df.head()
```

Out[6]:

	id	question1	question2	is_duplicate	cwc_min	cwc_max	csc_min	csc_max	ctc_min	ctc_max	...	freq_qid2	q1len
0	0	what is the step by step guide to invest in sh...	what is the step by step guide to invest in sh...	0	0.999980	0.833319	0.999983	0.999983	0.916659	0.785709	...	1	66
1	1	what is the story of kohinoor koh i noor dia...	what would happen if the indian government sto...	0	0.799984	0.399996	0.749981	0.599988	0.699993	0.466664	...	1	51
2	2	how can i increase the speed of my internet co...	how can internet speed be increased by hacking...	0	0.399992	0.333328	0.399992	0.249997	0.399996	0.285712	...	1	73
3	3	why am i mentally very lonely how can i solve...	find the remainder when math 23 24 math i...	0	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	...	1	50
4	4	which one dissolve in water quikly sugar salt...	which fish would survive in salt water	0	0.399992	0.199998	0.999950	0.666644	0.571420	0.307690	...	1	76

5 rows × 30 columns

In [7]:

```
df.shape
```

Out[7]:

```
(404290, 30)
```

In [8]:

```
v = df['is_duplicate']
df.drop(['id','is_duplicate'], axis=1, inplace=True)
```

In [9]:

```
X_train,X_test, y_train, y_test = train_test_split(df,v, stratify=v, test_size=0.3)
```

In [10]:

```
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_len)
print("-"*10, "Distribution of output variable in train 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:  0.6308025003268517 Class 1:  0.36919749967314835
---------- Distribution of output variable in train data ----------
Class 0:  0.3691986775169639 Class 1:  0.3691986775169639
```

In [11]:

```
print(" train data :",X_train.shape)
print(" test data :",X_test.shape)
```

```
 train data : (283003, 28)
 test data : (121287, 28)
```

In [12]:

```
tfidfvect = TfidfVectorizer()
tfidf_train_q1 = tfidfvect.fit_transform(X_train['question1'].values.astype('U'))
tfidf_test_q1 = tfidfvect.transform(X_test['question1'].values.astype('U'))
tfidf_train_q2 = tfidfvect.fit_transform(X_train['question2'].values.astype('U'))
tfidf_test_q2 = tfidfvect.transform(X_test['question2'].values.astype('U'))
```

In [13]:

```
train_tfidf = hstack((tfidf_train_q1,tfidf_train_q2))
test_tfidf = hstack((tfidf_test_q1,tfidf_test_q2))
```

In [14]:

```
X_train.drop(['question1','question2'], axis=1, inplace=True)
X_test.drop(['question1','question2'], axis=1, inplace=True)
```

In [15]:

```
X_train = hstack((X_train, train_tfidf)).tocsr()
X_test = hstack((X_test, test_tfidf)).tocsr()
```

In [16]:

```
print(X_train.shape)
print(X_test.shape)
```

```
(283003, 111849)
(121287, 111849)
```

4. Machine Learning Models

In [17]:

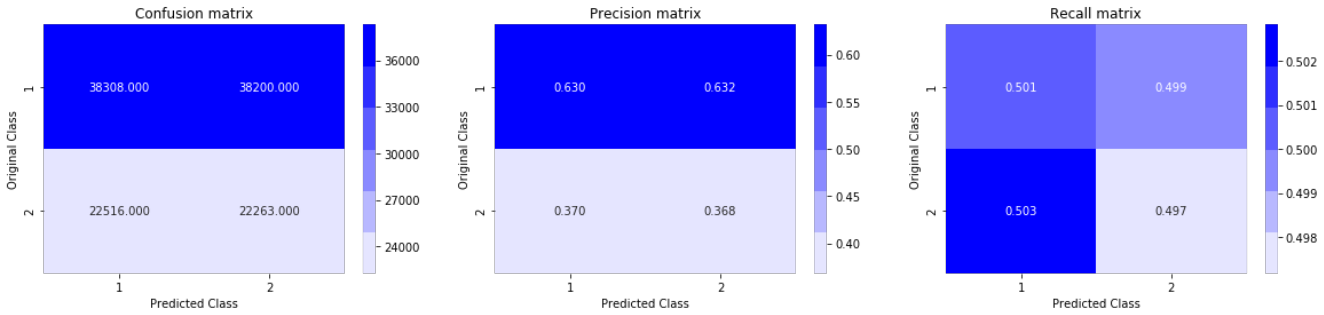
```
# This function plots the confusion matrices given y_i, y_i_hat.
def plot_confusion_matrix(test_y, predict_y):
    C = confusion_matrix(test_y, predict_y)
    # C = 9,9 matrix, each cell (i,j) represents number of points of class i are predicted class j

    A =(((C.T)/(C.sum(axis=1))).T)
    #divid each element of the confusion matrix with the sum of elements in that 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 that 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, yticklabels=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, yticklabels=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, yticklabels=labels)
    plt.xlabel('Predicted Class')
    plt.ylabel('Original Class')
    plt.title("Recall matrix")

    plt.show()
```

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

In [18]:

```
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-15))

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

```
Log loss on Test Data using Random Model 0.8862462076871358
```



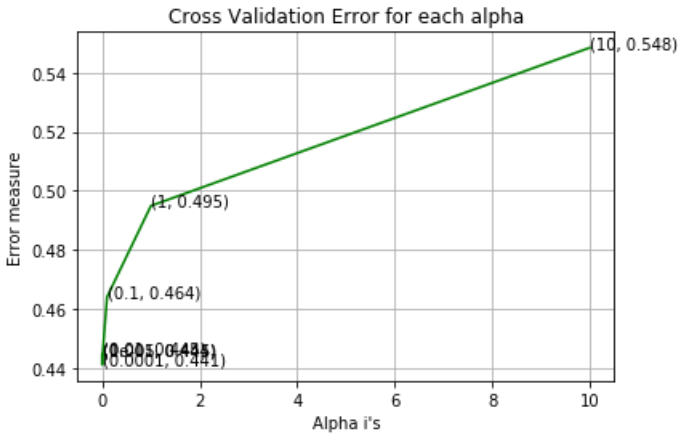
4.2 Logistic Regression with hyperparameter tuning

In [19]:

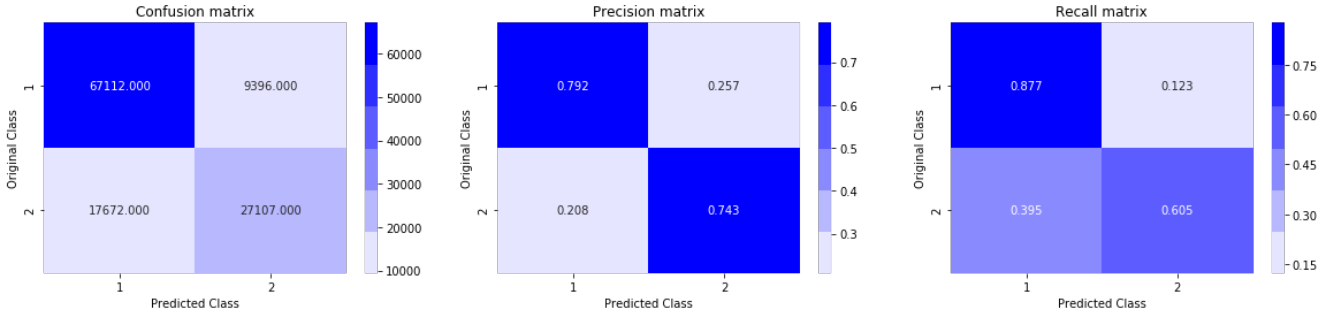
```
alpha = [10 ** x for x in range(-5, 2)] # hyperparam for SGD classifier.

# 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_i
ter=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.

#-------------------------------
# video link:
#-------------------------------


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

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()


best_alpha = np.argmin(log_error_array)
clf = SGDClassifier(alpha=alpha[best_alpha], penalty='l2', loss='log', random_state=42)
clf.fit(X_train, y_train)
sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
sig_clf.fit(X_train, y_train)

predict_y = sig_clf.predict_proba(X_train)
print('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(y_train,
predict_y, labels=clf.classes_, eps=1e-15))
predict_y = sig_clf.predict_proba(X_test)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_loss(y_test, p
redict_y, labels=clf.classes_, eps=1e-15))
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 alpha =  1e-05 The log loss is: 0.4445148481416354
For values of alpha =  0.0001 The log loss is: 0.4410669749574732
For values of alpha =  0.001 The log loss is: 0.444363020774173
For values of alpha =  0.01 The log loss is: 0.4448832561027464
For values of alpha =  0.1 The log loss is: 0.4640659618251598
For values of alpha =  1 The log loss is: 0.4949132669850326
For values of alpha =  10 The log loss is: 0.5484322866185438
```




```
For values of best alpha =  0.0001 The train log loss is: 0.4411467177984719
For values of best alpha =  0.0001 The test log loss is: 0.4410669749574732
Total number of data points : 121287
```



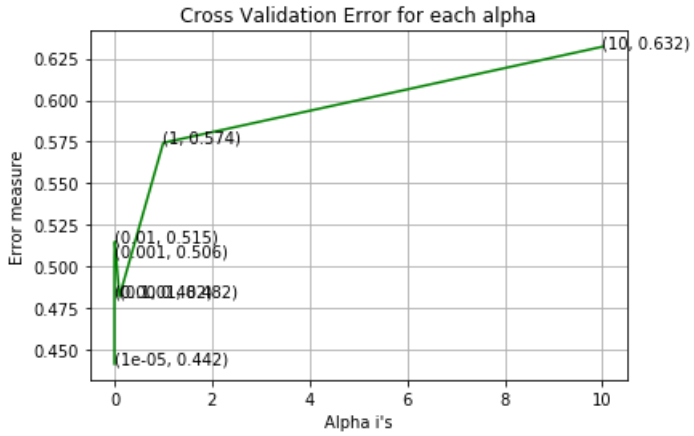
4.3 Linear SVM with hyperparameter tuning

In [20]:

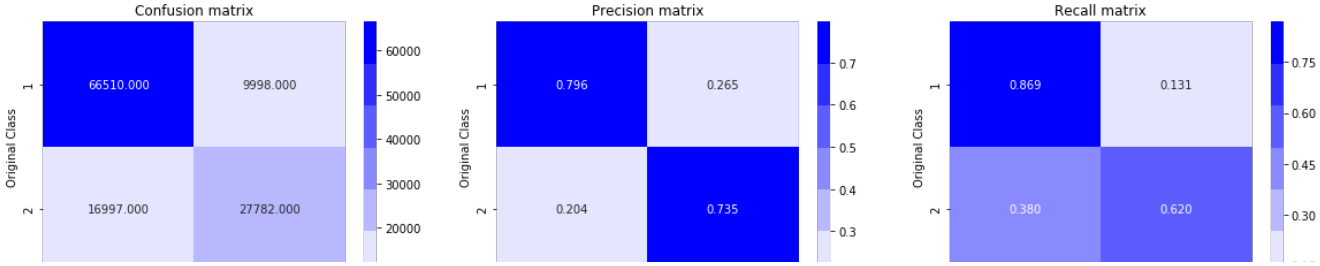
```
alpha = [10 ** x for x in range(-5, 2)] # hyperparam for SGD classifier.

# 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_i
ter=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.

#-------------------------------
# video link:
#-------------------------------


log_error_array=[]
for i in alpha:
```

```
    clf = SGDClassifier(alpha=i, penalty='l1', loss='hinge', random_state=42)
    clf.fit(X_train, y_train)
    sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
    sig_clf.fit(X_train, y_train)
    predict_y = sig_clf.predict_proba(X_test)
    log_error_array.append(log_loss(y_test, predict_y, labels=clf.classes_, eps=1e-15))
    print('For values of alpha = ', i, "The log loss is:",log_loss(y_test, predict_y, labels=clf.cl
asses_, eps=1e-15))

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()


best_alpha = np.argmin(log_error_array)
clf = SGDClassifier(alpha=alpha[best_alpha], penalty='l1', loss='hinge', random_state=42)
clf.fit(X_train, y_train)
sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
sig_clf.fit(X_train, y_train)

predict_y = sig_clf.predict_proba(X_train)
print('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(y_train,
predict_y, labels=clf.classes_, eps=1e-15))
predict_y = sig_clf.predict_proba(X_test)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_loss(y_test, p
redict_y, labels=clf.classes_, eps=1e-15))
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 alpha =  1e-05 The log loss is: 0.44153451248416864
For values of alpha =  0.0001 The log loss is: 0.48184493382396903
For values of alpha =  0.001 The log loss is: 0.5058924051802607
For values of alpha =  0.01 The log loss is: 0.5150092837462765
For values of alpha =  0.1 The log loss is: 0.48187314449021706
For values of alpha =  1 The log loss is: 0.5743607320235956
For values of alpha =  10 The log loss is: 0.6320999506082345
```




```
For values of best alpha =  1e-05 The train log loss is: 0.44174927441950507
For values of best alpha =  1e-05 The test log loss is: 0.44153451248416864
Total number of data points : 121287
```



In [6]:

```
# avoid decoding problems
daf = 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 ---------------------
daf['question1'] = daf['question1'].apply(lambda x: str(x))
daf['question2'] = daf['question2'].apply(lambda x: str(x))
```

In [7]:

```
daf.head()
```

Out[7]:

	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

4.4 XGBoost with hyperparameter tuning

In [8]:

```
from sklearn.feature_extraction.text import TfidfVectorizer
from sklearn.feature_extraction.text import CountVectorizer
# merge texts
questions = list(daf['question1']) + list(daf['question2'])

tfidf = TfidfVectorizer(lowercase=False, )
tfidf.fit_transform(questions)

# dict key:word and value:tf-idf score
word2tfidf = dict(zip(tfidf.get_feature_names(), tfidf.idf_))
```

4.5 Featurizing text data with tfidf weighted word-vectors

In [5]:

```
import spacy
from tqdm import tqdm
nlp = spacy.load('en')
vecs1 = []
# https://github.com/noamraph/tqdm
# tqdm is used to print the progress bar
for qu1 in tqdm(list(daf['question1'])):
    doc1 = nlp(qu1)
    # 384 is the number of dimensions of vectors
    mean_vec1 = np.zeros([len(doc1), 384])
    for word1 in doc1:
        # word2vec
```

```
        vec1 = word1.vector
        # fetch df score
        try:
            idf = word2tfidf[str(word1)]
        except:
            idf = 0
        # compute final vec
        mean_vec1 += vec1 * idf
    mean_vec1 = mean_vec1.mean(axis=0)
    vecs1.append(mean_vec1)
daf['q1_feats_m'] = list(vecs1)
```

```
100%|██████████████████████████████████████████████████████████████████████████████| 404290/404290
[2:52:10<00:00, 39.13it/s]
```

In [6]:

```
vecs2 = []
for qu2 in tqdm(list(daf['question2'])):
    doc2 = nlp(qu2)
    mean_vec2 = np.zeros([len(doc2), 384])
    for word2 in doc2:
        # word2vec
        vec2 = word2.vector
        # fetch df score
        try:
            idf = word2tfidf[str(word2)]
        except:
            #print word
            idf = 0
        # compute final vec
        mean_vec2 += vec2 * idf
    mean_vec2 = mean_vec2.mean(axis=0)
    vecs2.append(mean_vec2)
daf['q2_feats_m'] = list(vecs2)
```

```
100%|██████████████████████████████████████████████████████████████████████████████| 404290/404290
[3:14:34<00:00, 34.63it/s]
```

In [7]:

```
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 notebook")
```

In [2]:

```
#http://www.sqlitetutorial.net/sqlite-python/create-tables/
def create_connection(db_file):
    """ create a database connection to the SQLite database
        specified by db_file
    :param db_file: database file
    :return: Connection object or None
    """
    try:
        conn = sqlite3.connect(db_file)
        return conn
    except Error as e:
        print(e)

    return None


def checkTableExists(dbcon):
    cursr = dbcon.cursor()
    str = "select name from sqlite_master where type='table'"
    table_names = cursr.execute(str)
```

```
    print("Tables in the databse:")
    tables =table_names.fetchall()
    print(tables[0][0])
    return(len(tables))
```

In [3]:

```
read_db = 'train.db'
conn_r = create_connection(read_db)
checkTableExists(conn_r)
conn_r.close()
```

```
Tables in the databse:
data
```

In [4]:

```
# try to sample data according to the computing power you have
if os.path.isfile(read_db):
    conn_r = create_connection(read_db)
    if conn_r is not None:
        # for selecting first 0.5M rows
        # data = pd.read_sql_query("""SELECT * FROM data LIMIT 50001;""", conn_r)

        # for selecting random points
        data = pd.read_sql_query("SELECT * From data ORDER BY RANDOM() LIMIT 50001;", conn_r)
        conn_r.commit()
        conn_r.close()
```

In [5]:

```
# remove the first row
data.drop(data.index[0], inplace=True)
y_true = data['is_duplicate']
data.drop(['Unnamed: 0', 'id','index','is_duplicate'], axis=1, inplace=True)
```

In [6]:

```
data.head()
```

Out[6]:

	cwc_min	cwc_max	csc_min	csc_max	ctc_min	ctc_max
1	0.499987500312492	0.499987500312492	0.0	0.0	0.333327777870369	0.249996875039062
2	0.799984000319994	0.666655555740738	0.33332222259258	0.166663888935184	0.555549382784636	0.454541322351615
3	0.0	0.0	0.0	0.0	0.0	0.0
4	0.499975001249937	0.33332222259258	0.0	0.0	0.166663888935184	0.14285510206997
5	0.699993000069999	0.699993000069999	0.666655555740738	0.571420408279882	0.647055017323428	0.578944321345677

5 rows × 794 columns

4.6 Converting strings to numerics

In [7]:

```
# after we read from sql table each entry was read it as a string
# we convert all the features into numaric before we apply any model
cols = list(data.columns)
for i in cols:
```

```
    data[i] = data[i].apply(pd.to_numeric)
    print(i)
```

```
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
freq_qid1
freq_qid2
q1len
q2len
q1_n_words
q2_n_words
word_Common
word_Total
word_share
freq_q1+q2
freq_q1-q2
0_x
1_x
2_x
3_x
4_x
5_x
6_x
7_x
8_x
9_x
10_x
11_x
12_x
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```

In [8]:

```
# https://stackoverflow.com/questions/7368789/convert-all-strings-in-a-list-to-int
y_true = list(map(int, y_true.values))
```

In [9]:

```
X_train,X_test, y_train, y_test = train_test_split(data, y_true, stratify=y_true, test_size=0.3)
```

In [10]:

```
print("Number of data points in train data :",X_train.shape)
print("Number of data points in test data :",X_test.shape)
```

```
Number of data points in train data : (35000, 794)
Number of data points in test data : (15000, 794)
```

In [11]:

```
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_len)
print("-"*10, "Distribution of output variable in train 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:  0.6296857142857143 Class 1:  0.3703142857142857
---------- Distribution of output variable in train data ----------
Class 0:  0.37033333333333335 Class 1:  0.37033333333333335
```

In [20]:

```
# 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 predicted class j

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

```
    #divid each element of the confusion matrix with the sum of elements in that 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 that 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, yticklabels=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, yticklabels=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, yticklabels=labels)
    plt.xlabel('Predicted Class')
    plt.ylabel('Original Class')
    plt.title("Recall matrix")

    plt.show()
```

In [13]:

```
import xgboost as xgb
param_grid = {
        'silent': [False],
        'max_depth': [4],
        'learning_rate': [0.001, 0.01, 0.1, 0.2],
        'subsample': [0.5, 0.6, 0.7, 0.8],
        'colsample_bytree': [0.4, 0.5, 0.6, 0.7, 0.8],
        'colsample_bylevel': [0.4, 0.5, 0.6, 0.7, 0.8],
        'min_child_weight': [0.5, 1.0, 3.0, 5.0],
        'gamma': [0, 0.25, 0.5, 1.0],
        'n_estimators': [100]}
fit_params = {'eval_metric': 'logloss',
              'early_stopping_rounds': 10,
              'eval_set': [(X_train, y_train)]
              }

clf = xgb.XGBClassifier()
```

In [14]:

```
rsclf = RandomizedSearchCV(clf, param_grid, n_iter=20,
                           n_jobs=1, verbose=0, cv=2,
                           fit_params=fit_params,
```

```
                            fit_params=fit_params,
                            scoring='neg_log_loss', refit=False, random_state=42)
```

In [15]:

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

```
C:\ProgramData\Anaconda3\lib\site-packages\sklearn\model_selection\_search.py:584:
DeprecationWarning: "fit_params" as a constructor argument was deprecated in version 0.19 and will
be removed in version 0.21. Pass fit parameters to the "fit" method instead.
  '"fit" method instead.', DeprecationWarning)
```

```
[10:39:42] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[0] validation_0-logloss:0.689286
Will train until validation_0-logloss hasn't improved in 10 rounds.
[10:39:42] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 26 extra nodes, 0 pruned nodes
, max_depth=4
[1] validation_0-logloss:0.685605
[10:39:42] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[2] validation_0-logloss:0.681718
[10:39:43] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[3] validation_0-logloss:0.67826
[10:39:43] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 pruned nodes
, max_depth=4
[4] validation_0-logloss:0.675206
[10:39:44] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[5] validation_0-logloss:0.671797
[10:39:44] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 26 extra nodes, 0 pruned nodes
, max_depth=4
[6] validation_0-logloss:0.668277
[10:39:44] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[7] validation_0-logloss:0.664403
[10:39:45] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 pruned nodes
, max_depth=4
[8] validation_0-logloss:0.661019
[10:39:45] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 pruned nodes
, max_depth=4
[9] validation_0-logloss:0.658237
[10:39:46] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 pruned nodes
, max_depth=4
[10] validation_0-logloss:0.654577
[10:39:46] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 pruned nodes
, max_depth=4
[11] validation_0-logloss:0.652249
[10:39:46] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 pruned nodes
, max_depth=4
[12] validation_0-logloss:0.649008
[10:39:47] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[13] validation_0-logloss:0.645983
[10:39:47] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[14] validation_0-logloss:0.642854
[10:39:48] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 pruned nodes
, max_depth=4
[15] validation_0-logloss:0.639725
[10:39:48] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[16] validation_0-logloss:0.636693
[10:39:48] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[17] validation_0-logloss:0.633611
[10:39:49] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[18] validation_0-logloss:0.631441
[10:39:49] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[19] validation_0-logloss:0.628479
[10:39:50] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 pruned nodes
, max_depth=4
```

```
[20] validation_0-logloss:0.625921
[10:39:50] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[21] validation_0-logloss:0.623277
[10:39:51] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 pruned nodes
, max_depth=4
[22] validation_0-logloss:0.620296
[10:39:51] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 pruned nodes
, max_depth=4
[23] validation_0-logloss:0.617605
[10:39:51] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[24] validation_0-logloss:0.615171
[10:39:52] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[25] validation_0-logloss:0.612671
[10:39:52] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[26] validation_0-logloss:0.610287
[10:39:53] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[27] validation_0-logloss:0.607593
[10:39:53] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[28] validation_0-logloss:0.605006
[10:39:53] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[29] validation_0-logloss:0.602557
[10:39:54] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[30] validation_0-logloss:0.600729
[10:39:54] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[31] validation_0-logloss:0.597995
[10:39:55] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[32] validation_0-logloss:0.595715
[10:39:55] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 pruned nodes
, max_depth=4
[33] validation_0-logloss:0.593145
[10:39:55] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 pruned nodes
, max_depth=4
[34] validation_0-logloss:0.590521
[10:39:56] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 pruned nodes
, max_depth=4
[35] validation_0-logloss:0.588208
[10:39:56] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 26 extra nodes, 0 pruned nodes
, max_depth=4
[36] validation_0-logloss:0.585859
[10:39:57] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 pruned nodes
, max_depth=4
[37] validation_0-logloss:0.583985
[10:39:57] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[38] validation_0-logloss:0.581707
[10:39:58] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[39] validation_0-logloss:0.579156
[10:39:58] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[40] validation_0-logloss:0.577129
[10:39:58] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[41] validation_0-logloss:0.575208
[10:39:59] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[42] validation_0-logloss:0.572974
[10:39:59] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 pruned nodes
, max_depth=4
[43] validation_0-logloss:0.570847
[10:40:00] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[44] validation_0-logloss:0.568791
[10:40:00] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 pruned nodes
, max_depth=4
[45] validation_0-logloss:0.56675
[10:40:01] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
```

```
, max_depth=4
[340] train-logloss:0.238748 valid-logloss:0.339276
[13:01:45] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[13:01:46] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 18 extra nodes, 0 pruned nodes
, max_depth=4
[13:01:48] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[13:01:50] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 pruned nodes
, max_depth=4
[13:01:52] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 pruned nodes
, max_depth=4
[13:01:53] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 24 extra nodes, 0 pruned nodes
, max_depth=4
[13:01:55] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[13:01:56] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 26 extra nodes, 0 pruned nodes
, max_depth=4
[13:01:58] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[13:02:00] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[350] train-logloss:0.236163 valid-logloss:0.339186
[13:02:02] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[13:02:03] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[13:02:05] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[13:02:06] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[13:02:08] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[13:02:10] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 pruned nodes
, max_depth=4
[13:02:11] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[13:02:13] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 26 extra nodes, 0 pruned nodes
, max_depth=4
[13:02:14] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 pruned nodes
, max_depth=4
[13:02:16] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[360] train-logloss:0.233638 valid-logloss:0.338983
[13:02:18] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[13:02:19] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[13:02:21] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 pruned nodes
, max_depth=4
[13:02:23] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 24 extra nodes, 0 pruned nodes
, max_depth=4
[13:02:24] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[13:02:26] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[13:02:28] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[13:02:29] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 16 extra nodes, 0 pruned nodes
, max_depth=4
[13:02:31] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 26 extra nodes, 0 pruned nodes
, max_depth=4
[13:02:33] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[370] train-logloss:0.231074 valid-logloss:0.338818
[13:02:34] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[13:02:36] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[13:02:38] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 16 extra nodes, 2 pruned nodes
, max_depth=4
[13:02:39] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[13:02:41] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[13:02:43] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
```

```
[13:02:44] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 26 extra nodes, 0 pruned nodes
, max_depth=4
[13:02:46] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[13:02:48] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[13:02:50] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[380] train-logloss:0.228402 valid-logloss:0.338769
[13:02:51] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[13:02:53] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 pruned nodes
, max_depth=4
[13:02:54] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[13:02:56] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 26 extra nodes, 0 pruned nodes
, max_depth=4
[13:02:58] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[13:03:00] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[13:03:01] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 22 extra nodes, 0 pruned nodes
, max_depth=4
[13:03:03] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 pruned nodes
, max_depth=4
[13:03:05] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[13:03:06] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 22 extra nodes, 0 pruned nodes
, max_depth=4
[390] train-logloss:0.225857 valid-logloss:0.33877
[13:03:08] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 22 extra nodes, 0 pruned nodes
, max_depth=4
[13:03:10] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 26 extra nodes, 0 pruned nodes
, max_depth=4
[13:03:11] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[13:03:13] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[13:03:15] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[13:03:16] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[13:03:18] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 pruned nodes
, max_depth=4
[13:03:19] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[13:03:21] src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 pruned nodes
, max_depth=4
[399] train-logloss:0.223587 valid-logloss:0.338839
The test log loss is: 0.33883880992521176
```

In [26]:

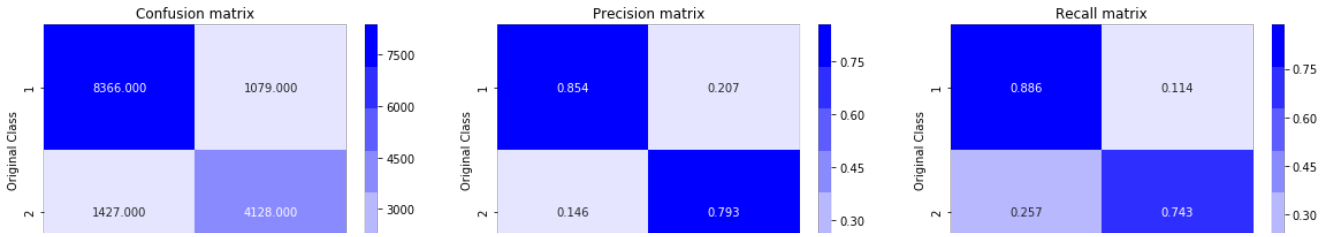
```
print("The test log loss is:",log_loss(y_test, predict_y, eps=1e-15))
```

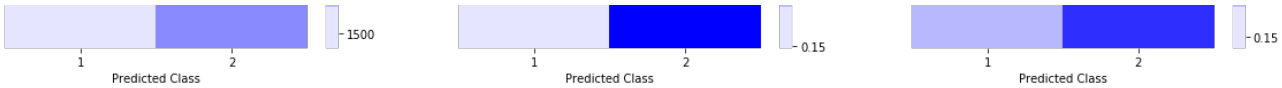
```
The test log loss is: 0.33883880992521176
```

In [27]:

```
predicted_y =np.array(predict_y>0.5,dtype=int)
print("Total number of data points :", len(predicted_y))
plot_confusion_matrix(y_test, predicted_y)
```

```
Total number of data points : 15000
```





In [6]:

```
models = pd.DataFrame({'vectorizer': ['TFIDF', "TFIDF", " TFIDF weight w2v"], 'Model' : ["Logistic Regression","Linear SVM","Tunned Xgboost"],'Test logloss': [0.44,0.44,0.33]}, columns = ["vectorizer","Model", "Test logloss"])
models
```

Out[6]:

	vectorizer	Model	Test logloss
0	TFIDF	Logistic Regression	0.44
1	TFIDF	Linear SVM	0.44
2	TFIDF weight w2v	Tunned Xgboost	0.33

Observation:

1.Exploratory data analysis of the dataset.

2.Basic feature extraction before cleaning of the data.

3.Preprocessing of text(stopword removal,special characters removal,stemming etc).

4.Exploratory data analysis of advance features extraction.

5.Featuresized text data with tfidf vectors.

6.constructed a randam worst model to compare it with other models

7.performed logistic regression and linear svm for tfidf vectors ,metric as logloss.

8.plotted confusion matrix,precision matrix and recall matrix for logistic regression and lr svm.

9.Featuresized text data for tfidf weighted word vectors.

10.Tunned Xgboost by performing hyperparameter tunning to get better results.

11.plotted confusion matrix,precision matrix and recall matrix for Xgbost.

11 Recall is high in xgboost qhen compared to both logistic regression and lr svm

12.From performace table we can see Tunned Xgboost gives minimized test logloss when compared to other model.