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
- 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

2.2.1 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.

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]:

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

import re
from nltk.corpus import stopwords
import distance
from nltk.stem import PorterStemmer
from bs4 import BeautifulSoup
import re
from nltk.corpus import stopwords
# This package is used for finding longest common subsequence between two strings
# you can write your own dp code for this
```

```
import distance
from nltk.stem import PorterStemmer
from bs4 import BeautifulSoup
from fuzzywuzzy import fuzz
from sklearn.manifold import TSNE
# Import the Required lib packages for WORD-Cloud generation
# https://stackoverflow.com/questions/45625434/how-to-install-wordcloud-in-python3-6
from wordcloud import WordCloud, STOPWORDS
from os import path
from PIL import Image
```

3.1 Reading data and basic stats

In [7]:

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

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

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

In [8]:

```
df.head()
```

Out[8]:

	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 [10]:

```
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.

3.2.1 Distribution of data points among output classes

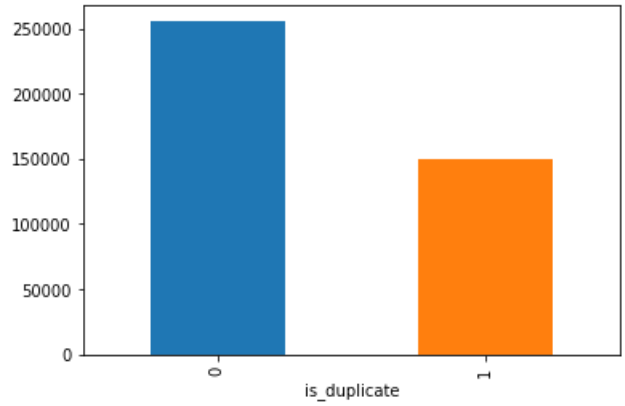
- Number of duplicate(smilar) and non-duplicate(non similar) questions

In [12]:

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

Out[12]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x7f91bf360128>
```



In [13]:

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

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

In [14]:

```
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%
```

3.2.2 Number of unique questions

In [15]:

```
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

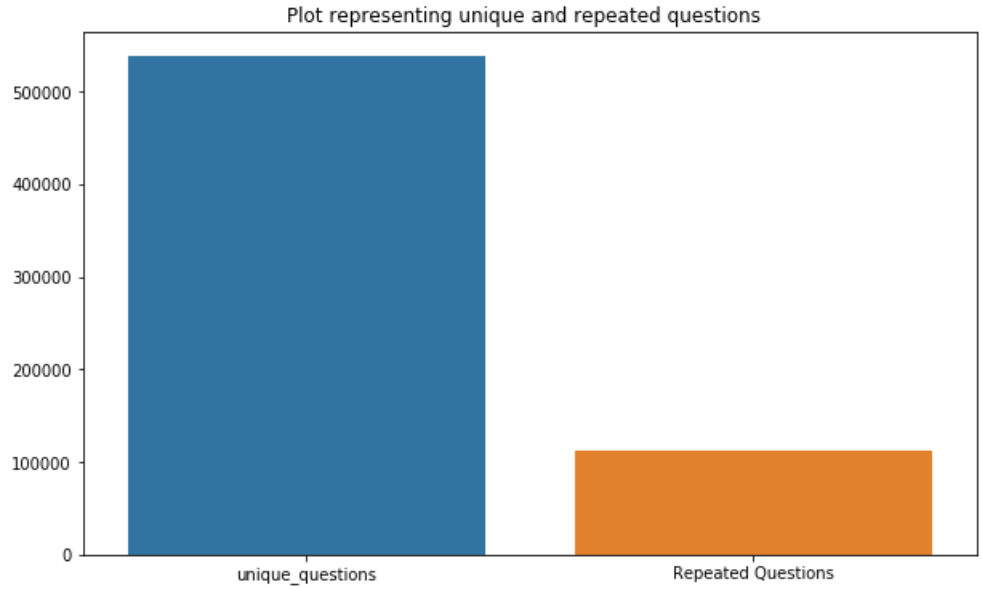
Number of unique questions that appear more than one time: 111780 (20.77953945937505%)
```

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

In [16]:

```
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()
```



3.2.3 Checking for Duplicates

In [18]:

```
#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
```

3.2.4 Number of occurrences of each question

In [19]:

```
plt.figure(figsize=(20, 10))

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

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

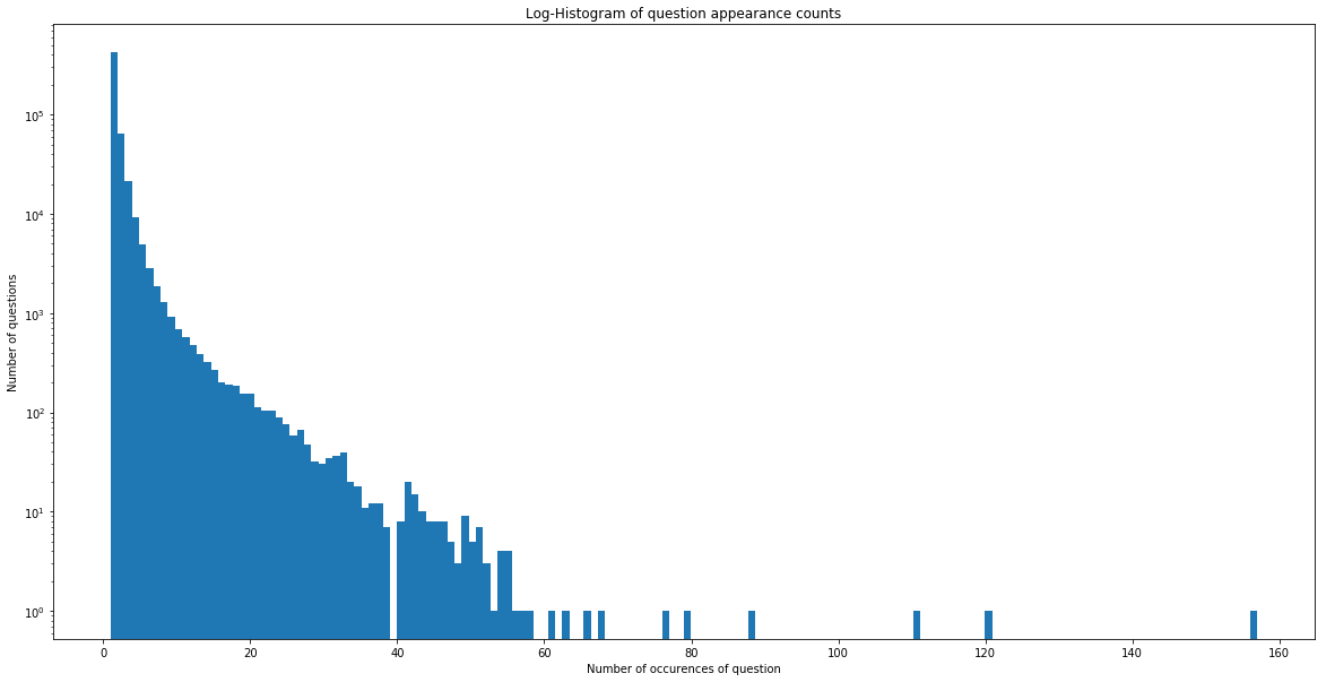
plt.title('Log-Histogram of question appearance counts')

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
```



3.2.5 Checking for NULL values

In [21]:

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

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

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

- There are three rows with null values, one in question1 and the other two in question2

In [22]:

```
# 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 [23]:

```
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[23]:

	id	qid1	qid2	question1	question2	is_duplicate	freq_qid1	freq_qid2	q1len	q2len	q1_n_words	q2_n_words	word_Common
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
				Which one									

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

3.3.1 Analysis of some of the extracted features

- Here are some questions have only one single words.

In [24]:

```
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
```

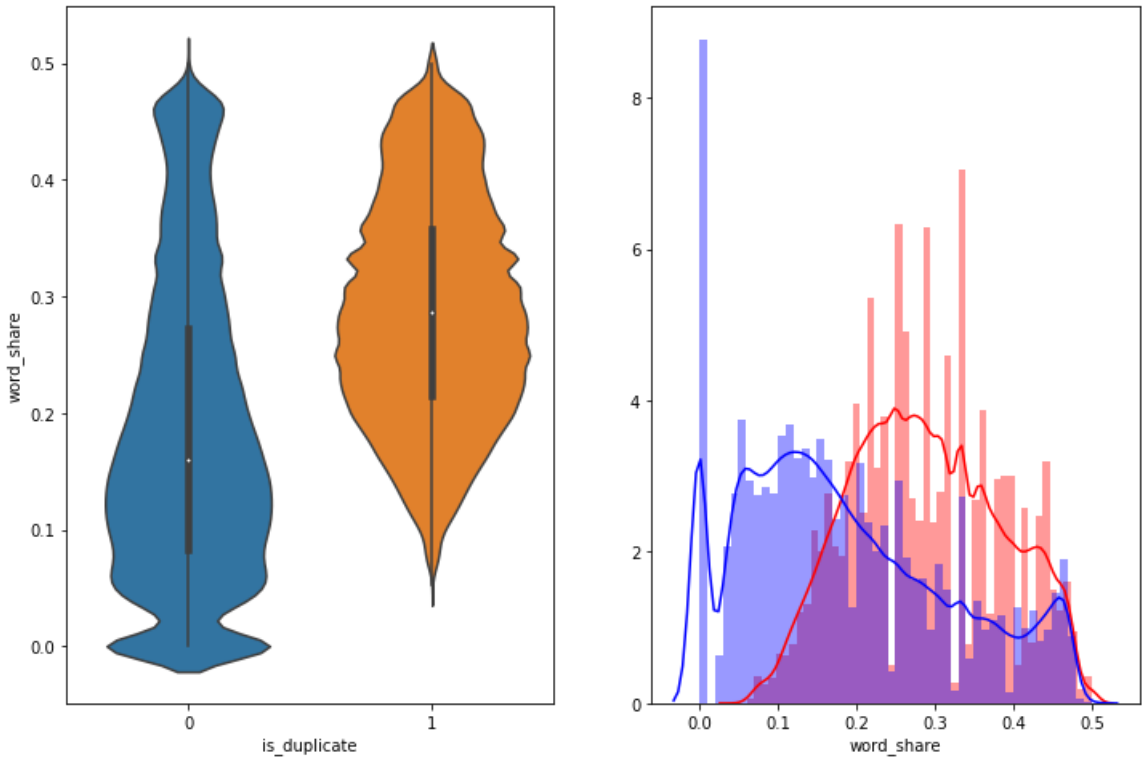
3.3.1.1 Feature: word_share

In [25]:

```
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()
```



- 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

with high word similarity

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

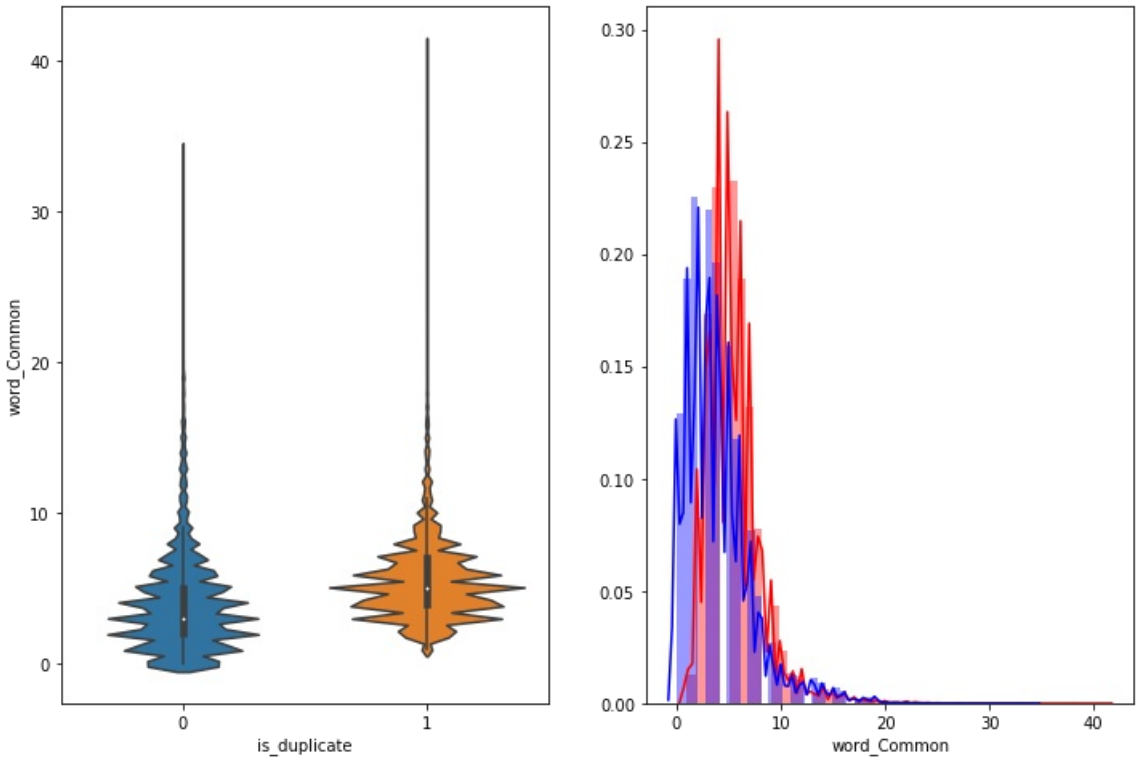
3.3.1.2 Feature: word_Common

In [26]:

```
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()
```



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

3.4 Preprocessing of Text

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

In [27]:

```
# To get the results in 4 decemal points
SAFE_DIV = 0.0001

STOP_WORDS = stopwords.words("english")


def preprocess(x):
    x = str(x).lower()
    x = x.replace(",000,000", "m").replace(",000", "k").replace("’", "'").replace("‘", "'")\
                           .replace("won't", "will not").replace("cannot", "can not").replace("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
```

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

3.5 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** : 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 [28]:

```
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
```

In [29]:

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

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

Out[29]:

	id	qid1	qid2	question1	question2	is_duplicate	cwc_min	cwc_max	csc_min	csc_max	...	ctc_max	last_word_eq	first_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	0.999980	0.833319	0.999983	0.999983	...	0.785709	0.0	

	id	qid1	qid2	question1	question2	is_duplicate	cwc_min	cwc_max	csc_min	csc_max	...	ctc_max	last_word_eq	first_word_
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	

2 rows × 21 columns

3.5.1 Analysis of extracted features

3.5.1.1 Plotting Word clouds

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

In [31]:

```
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))

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

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

In [32]:

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

textp_w = open(path.join(d, 'train_p.txt')).read()
textn_w = open(path.join(d, 'train_n.txt')).read()
stopwords = set(STOPWORDS)
stopwords.add("said")
stopwords.add("br")
stopwords.add(" ")
stopwords.remove("not")

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

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

Word Clouds generated from duplicate pair question's text

In [33]:

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

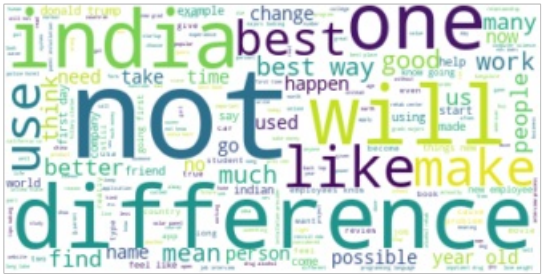
```
plt.show()
```

Word Cloud for Duplicate Question pairs

In [34]:

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

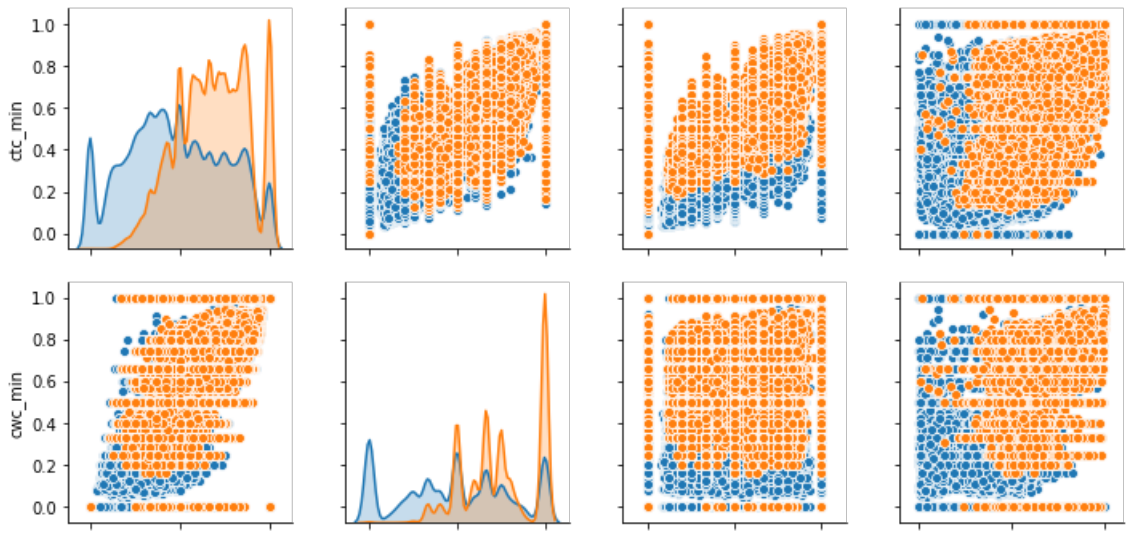
Word Cloud for non-Duplicate Question pairs:

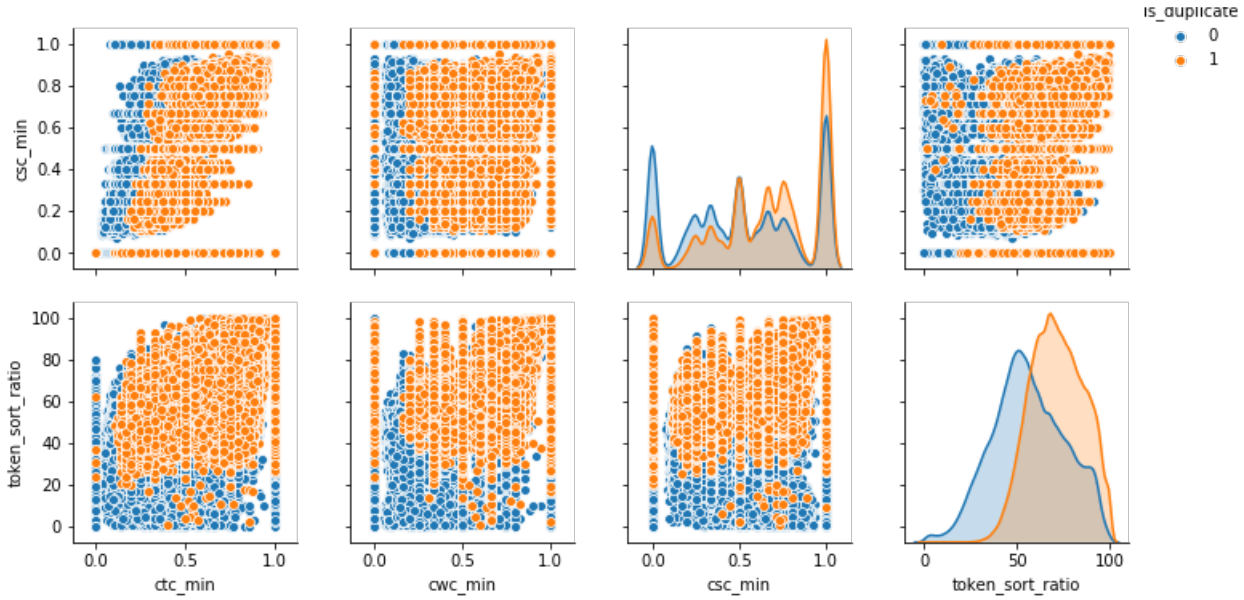


3.5.1.2 Pair plot of features ['ctc_min', 'cwc_min', 'csc_min', 'token_sort_ratio']

In [35]:

```
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()
```



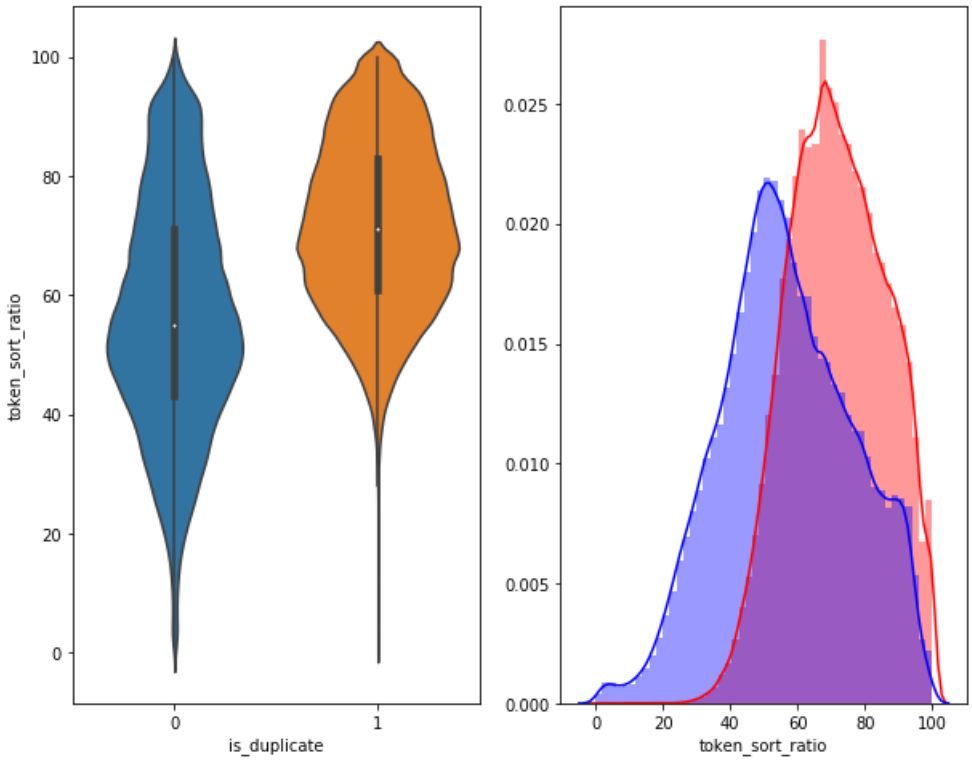


In [36]:

```
# 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()
```



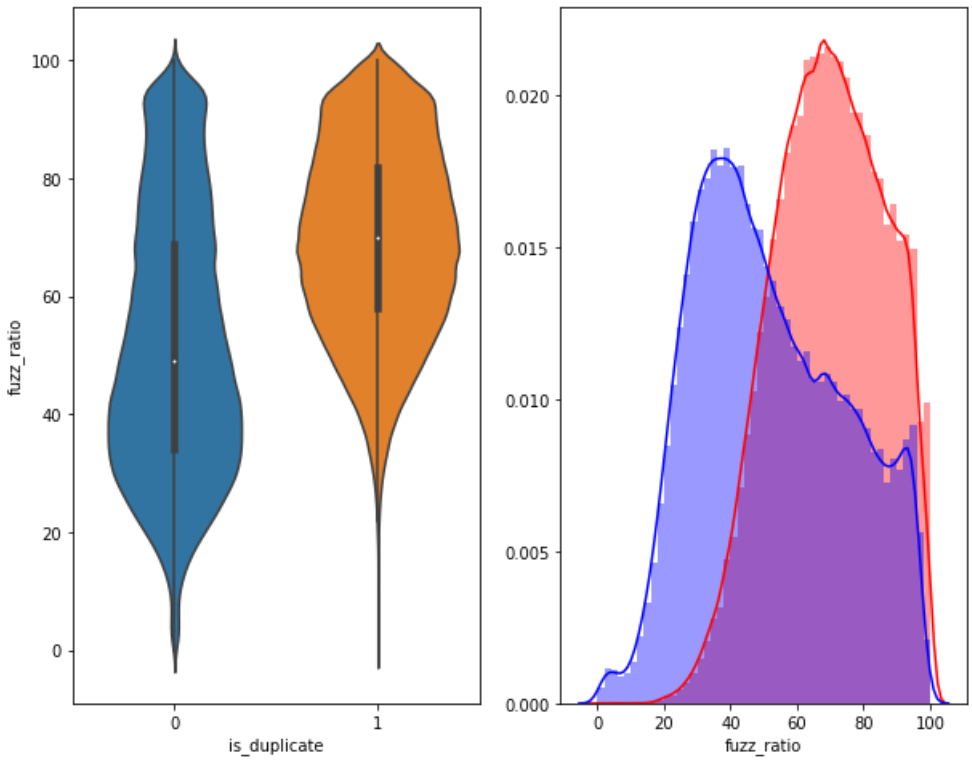
In [37]:

```
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()
```



3.5.2 Visualization

In [38]:

```
# Using TSNE for Dimentionality reduction for 15 Features(Generated after cleaning the data) to 2 and 3 dimensions

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 [39]:

```
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)
```

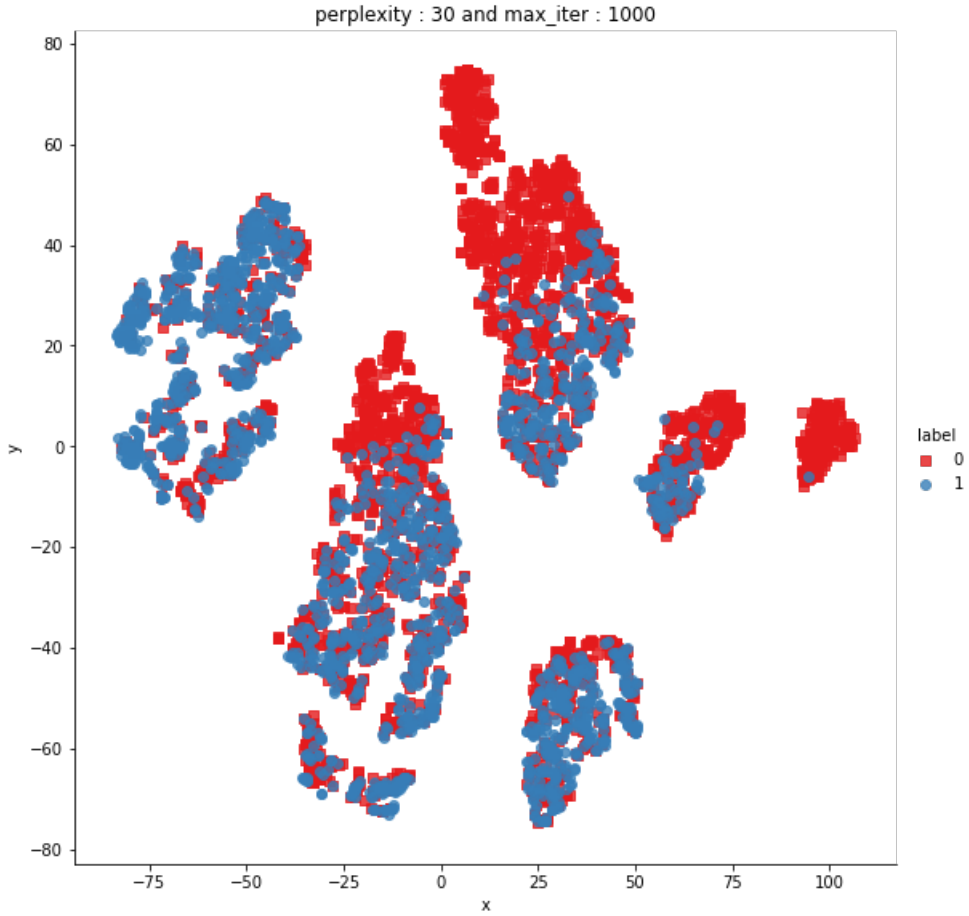
```
[t-SNE] Computing 91 nearest neighbors...
[t-SNE] Indexed 5000 samples in 0.028s...
[t-SNE] Computed neighbors for 5000 samples in 0.356s...
[t-SNE] Computed conditional probabilities for sample 1000 / 5000
[t-SNE] Computed conditional probabilities for sample 2000 / 5000
[t-SNE] Computed conditional 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 0.489s
[t-SNE] Iteration 50: error = 81.2897949, gradient norm = 0.0455700 (50 iterations in 5.088s)
[t-SNE] Iteration 100: error = 70.6164398, gradient norm = 0.0095177 (50 iterations in 3.951s)
[t-SNE] Iteration 150: error = 68.9172134, gradient norm = 0.0056736 (50 iterations in 3.835s)
```

```
[t-SNE] Iteration 200: error = 68.1004639, gradient norm = 0.0049672 (50 iterations in 3.928s)
[t-SNE] Iteration 250: error = 67.5914536, gradient norm = 0.0039700 (50 iterations in 4.025s)
[t-SNE] KL divergence after 250 iterations with early exaggeration: 67.591454
[t-SNE] Iteration 300: error = 1.7926962, gradient norm = 0.0011878 (50 iterations in 4.226s)
[t-SNE] Iteration 350: error = 1.3936826, gradient norm = 0.0004807 (50 iterations in 4.184s)
[t-SNE] Iteration 400: error = 1.2281071, gradient norm = 0.0002778 (50 iterations in 4.203s)
[t-SNE] Iteration 450: error = 1.1385784, gradient norm = 0.0001864 (50 iterations in 4.284s)
[t-SNE] Iteration 500: error = 1.0835493, gradient norm = 0.0001437 (50 iterations in 4.208s)
[t-SNE] Iteration 550: error = 1.0471643, gradient norm = 0.0001152 (50 iterations in 4.199s)
[t-SNE] Iteration 600: error = 1.0231258, gradient norm = 0.0001007 (50 iterations in 4.225s)
[t-SNE] Iteration 650: error = 1.0069925, gradient norm = 0.0000892 (50 iterations in 4.262s)
[t-SNE] Iteration 700: error = 0.9953420, gradient norm = 0.0000804 (50 iterations in 4.267s)
[t-SNE] Iteration 750: error = 0.9866475, gradient norm = 0.0000728 (50 iterations in 4.279s)
[t-SNE] Iteration 800: error = 0.9796536, gradient norm = 0.0000658 (50 iterations in 4.266s)
[t-SNE] Iteration 850: error = 0.9737327, gradient norm = 0.0000618 (50 iterations in 4.250s)
[t-SNE] Iteration 900: error = 0.9688665, gradient norm = 0.0000594 (50 iterations in 4.259s)
[t-SNE] Iteration 950: error = 0.9644679, gradient norm = 0.0000589 (50 iterations in 4.251s)
[t-SNE] Iteration 1000: error = 0.9610358, gradient norm = 0.0000559 (50 iterations in 4.236s)
[t-SNE] Error after 1000 iterations: 0.961036
```

In [40]:

```
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()
```



In [46]:

```
#Trying with different parameters
tsne2d_1 = TSNE(
    n_components=2,
    init='random', # pca
    random_state=101,
    method='barnes_hut',
    n_iter=2000,
```

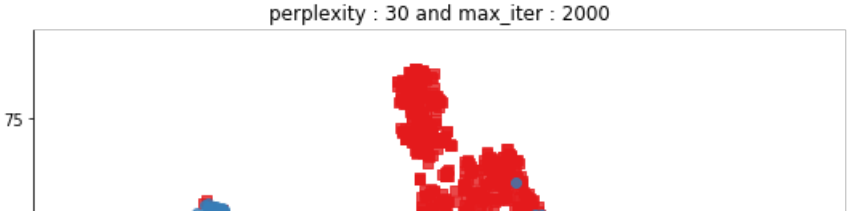
```
    verbose=2,
    angle=0.5
).fit_transform(X)
```

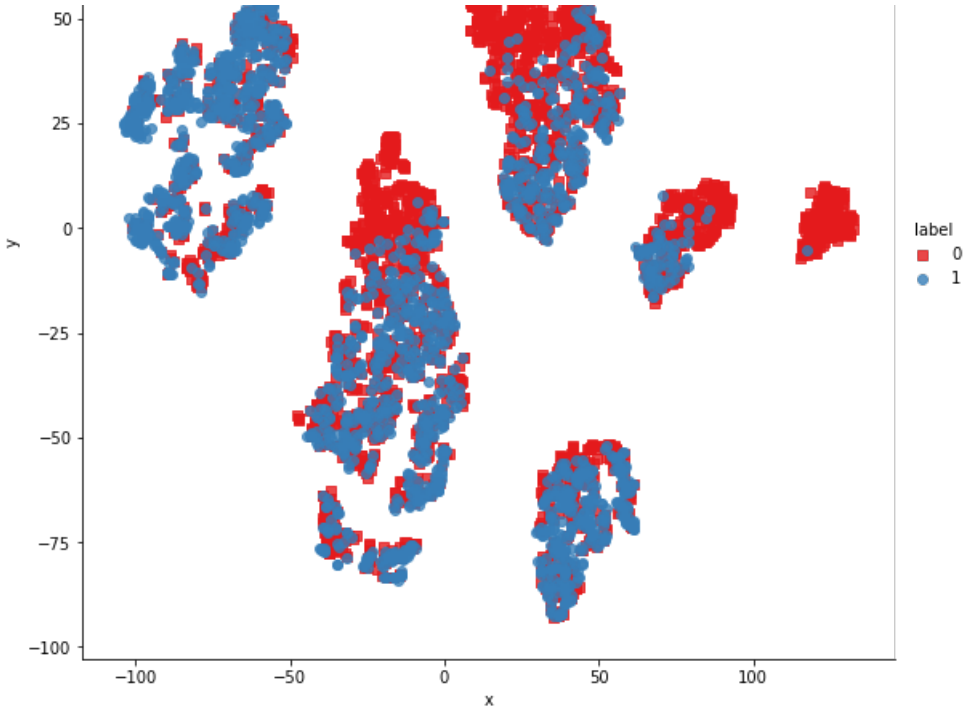
```
[t-SNE] Computing 91 nearest neighbors...
[t-SNE] Indexed 5000 samples in 0.008s...
[t-SNE] Computed neighbors for 5000 samples in 0.363s...
[t-SNE] Computed conditional probabilities for sample 1000 / 5000
[t-SNE] Computed conditional probabilities for sample 2000 / 5000
[t-SNE] Computed conditional 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 0.340s
[t-SNE] Iteration 50: error = 81.2897949, gradient norm = 0.0455700 (50 iterations in 5.166s)
[t-SNE] Iteration 100: error = 70.6164398, gradient norm = 0.0095177 (50 iterations in 3.983s)
[t-SNE] Iteration 150: error = 68.9172134, gradient norm = 0.0056736 (50 iterations in 3.887s)
[t-SNE] Iteration 200: error = 68.1004639, gradient norm = 0.0049672 (50 iterations in 4.047s)
[t-SNE] Iteration 250: error = 67.5914536, gradient norm = 0.0039700 (50 iterations in 4.120s)
[t-SNE] KL divergence after 250 iterations with early exaggeration: 67.591454
[t-SNE] Iteration 300: error = 1.7926962, gradient norm = 0.0011878 (50 iterations in 4.332s)
[t-SNE] Iteration 350: error = 1.3936826, gradient norm = 0.0004807 (50 iterations in 4.278s)
[t-SNE] Iteration 400: error = 1.2281071, gradient norm = 0.0002778 (50 iterations in 4.235s)
[t-SNE] Iteration 450: error = 1.1385784, gradient norm = 0.0001864 (50 iterations in 4.255s)
[t-SNE] Iteration 500: error = 1.0835493, gradient norm = 0.0001437 (50 iterations in 4.276s)
[t-SNE] Iteration 550: error = 1.0471643, gradient norm = 0.0001152 (50 iterations in 4.290s)
[t-SNE] Iteration 600: error = 1.0231258, gradient norm = 0.0001007 (50 iterations in 4.328s)
[t-SNE] Iteration 650: error = 1.0069925, gradient norm = 0.0000892 (50 iterations in 4.400s)
[t-SNE] Iteration 700: error = 0.9953420, gradient norm = 0.0000804 (50 iterations in 4.353s)
[t-SNE] Iteration 750: error = 0.9866475, gradient norm = 0.0000728 (50 iterations in 4.350s)
[t-SNE] Iteration 800: error = 0.9796536, gradient norm = 0.0000658 (50 iterations in 4.336s)
[t-SNE] Iteration 850: error = 0.9737327, gradient norm = 0.0000618 (50 iterations in 4.329s)
[t-SNE] Iteration 900: error = 0.9688665, gradient norm = 0.0000594 (50 iterations in 4.328s)
[t-SNE] Iteration 950: error = 0.9644679, gradient norm = 0.0000589 (50 iterations in 4.321s)
[t-SNE] Iteration 1000: error = 0.9610358, gradient norm = 0.0000559 (50 iterations in 4.349s)
[t-SNE] Iteration 1050: error = 0.9580597, gradient norm = 0.0000548 (50 iterations in 4.334s)
[t-SNE] Iteration 1100: error = 0.9553435, gradient norm = 0.0000529 (50 iterations in 4.339s)
[t-SNE] Iteration 1150: error = 0.9530139, gradient norm = 0.0000485 (50 iterations in 4.322s)
[t-SNE] Iteration 1200: error = 0.9508933, gradient norm = 0.0000530 (50 iterations in 4.315s)
[t-SNE] Iteration 1250: error = 0.9491470, gradient norm = 0.0000486 (50 iterations in 4.326s)
[t-SNE] Iteration 1300: error = 0.9475195, gradient norm = 0.0000466 (50 iterations in 4.357s)
[t-SNE] Iteration 1350: error = 0.9459193, gradient norm = 0.0000445 (50 iterations in 4.337s)
[t-SNE] Iteration 1400: error = 0.9443618, gradient norm = 0.0000420 (50 iterations in 4.323s)
[t-SNE] Iteration 1450: error = 0.9428130, gradient norm = 0.0000435 (50 iterations in 4.326s)
[t-SNE] Iteration 1500: error = 0.9413453, gradient norm = 0.0000414 (50 iterations in 4.379s)
[t-SNE] Iteration 1550: error = 0.9399194, gradient norm = 0.0000399 (50 iterations in 4.339s)
[t-SNE] Iteration 1600: error = 0.9384849, gradient norm = 0.0000405 (50 iterations in 4.314s)
[t-SNE] Iteration 1650: error = 0.9370704, gradient norm = 0.0000394 (50 iterations in 4.310s)
[t-SNE] Iteration 1700: error = 0.9357622, gradient norm = 0.0000386 (50 iterations in 4.361s)
[t-SNE] Iteration 1750: error = 0.9346933, gradient norm = 0.0000400 (50 iterations in 4.337s)
[t-SNE] Iteration 1800: error = 0.9337534, gradient norm = 0.0000398 (50 iterations in 4.430s)
[t-SNE] Iteration 1850: error = 0.9328931, gradient norm = 0.0000358 (50 iterations in 4.554s)
[t-SNE] Iteration 1900: error = 0.9319998, gradient norm = 0.0000359 (50 iterations in 4.521s)
[t-SNE] Iteration 1950: error = 0.9309730, gradient norm = 0.0000353 (50 iterations in 4.344s)
[t-SNE] Iteration 2000: error = 0.9301456, gradient norm = 0.0000403 (50 iterations in 4.318s)
[t-SNE] Error after 2000 iterations: 0.930146
```

In [47]:

```
df = pd.DataFrame({'x':tsne2d_1[:,0], 'y':tsne2d_1[:,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, 2000))
plt.show()
```





Observation:

There is not much change in the plot after increasing the iterations from 1000 to 2000

In [48]:

```
#
tsne3d = TSNE(
    n_components=3,
    init='random', # pca
    random_state=101,
    method='barnes_hut',
    n_iter=1000,
    verbose=2,
    angle=0.5
).fit_transform(X)
```

```
[t-SNE] Computing 91 nearest neighbors...
[t-SNE] Indexed 5000 samples in 0.008s...
[t-SNE] Computed neighbors for 5000 samples in 0.354s...
[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 0.333s
[t-SNE] Iteration 50: error = 80.5298615, gradient norm = 0.0306586 (50 iterations in 18.491s)
[t-SNE] Iteration 100: error = 69.3777008, gradient norm = 0.0037944 (50 iterations in 10.089s)
[t-SNE] Iteration 150: error = 67.9726028, gradient norm = 0.0017517 (50 iterations in 9.563s)
[t-SNE] Iteration 200: error = 67.4098892, gradient norm = 0.0013384 (50 iterations in 9.555s)
[t-SNE] Iteration 250: error = 67.0977859, gradient norm = 0.0009594 (50 iterations in 9.701s)
[t-SNE] KL divergence after 250 iterations with early exaggeration: 67.097786
[t-SNE] Iteration 300: error = 1.5276405, gradient norm = 0.0007237 (50 iterations in 12.093s)
[t-SNE] Iteration 350: error = 1.1820400, gradient norm = 0.0002119 (50 iterations in 14.811s)
[t-SNE] Iteration 400: error = 1.0407882, gradient norm = 0.0001023 (50 iterations in 14.548s)
[t-SNE] Iteration 450: error = 0.9688321, gradient norm = 0.0000652 (50 iterations in 14.196s)
[t-SNE] Iteration 500: error = 0.9303923, gradient norm = 0.0000554 (50 iterations in 13.928s)
[t-SNE] Iteration 550: error = 0.9110239, gradient norm = 0.0000524 (50 iterations in 13.890s)
[t-SNE] Iteration 600: error = 0.9016075, gradient norm = 0.0000421 (50 iterations in 14.007s)
[t-SNE] Iteration 650: error = 0.8924681, gradient norm = 0.0000360 (50 iterations in 14.145s)
[t-SNE] Iteration 700: error = 0.8837291, gradient norm = 0.0000353 (50 iterations in 14.222s)
[t-SNE] Iteration 750: error = 0.8771634, gradient norm = 0.0000316 (50 iterations in 14.145s)
[t-SNE] Iteration 800: error = 0.8718039, gradient norm = 0.0000295 (50 iterations in 14.066s)
[t-SNE] Iteration 850: error = 0.8669323, gradient norm = 0.0000276 (50 iterations in 14.086s)
[t-SNE] Iteration 900: error = 0.8628623, gradient norm = 0.0000262 (50 iterations in 14.134s)
[t-SNE] Iteration 950: error = 0.8591092, gradient norm = 0.0000241 (50 iterations in 14.114s)
```

```
[t-SNE] Iteration 1000: error = 0.8553245, gradient norm = 0.0000220 (50 iterations in 14.137s)
[t-SNE] Error after 1000 iterations: 0.855325
```

In [49]:

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

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

3.6 Featurizing text data with tfidf weighted word-vectors

In [50]:

```
from sklearn.preprocessing import normalize
from sklearn.feature_extraction.text import CountVectorizer
from sklearn.feature_extraction.text import TfidfVectorizer
```

In [52]:

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

# encode questions to unicode
df['question1'] = df['question1'].apply(lambda x: str(x))
df['question2'] = df['question2'].apply(lambda x: str(x))
```

In [53]:

```
df.head()
```

Out[53]:

	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 [54]:

```
questions = list(df['question1']) + list(df['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_))
```

- After we find TF-IDF scores, we convert each question to a weighted average of word2vec vectors by these scores.
- here we use a pre-trained GLOVE model which comes free with "Spacy". https://spacy.io/usage/vectors-similarity
- It is trained on Wikipedia and therefore, it is stronger in terms of word semantics.

In [66]:

```
import spacy
from tqdm import tqdm
# en_vectors_web_lg, which includes over 1 million unique vectors.
nlp = spacy.load('en_core_web_sm')

vecs1 = []
# https://github.com/noamraph/tqdm
# tqdm is used to print the progress bar
for qu1 in tqdm(list(df['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
```

```
        # compute final vec
        mean_vec1 += vec1 * idf
    mean_vec1 = mean_vec1.mean(axis=0)
    vecs1.append(mean_vec1)
df['q1_feats_m'] = list(vecs1)
```

```
100%|██████████| 404290/404290 [1:06:55<00:00, 100.69it/s]
```

In [67]:

```
vecs2 = []
for qu2 in tqdm(list(df['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)
df['q2_feats_m'] = list(vecs2)
```

```
100%|██████████| 404290/404290 [1:05:40<00:00, 102.59it/s]
```

In [68]:

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

In [69]:

```
df1 = dfnlp.drop(['qid1','qid2','question1','question2'],axis=1)
df2 = dfppro.drop(['qid1','qid2','question1','question2','is_duplicate'],axis=1)
df3 = df.drop(['qid1','qid2','question1','question2','is_duplicate'],axis=1)
df3_q1 = pd.DataFrame(df3.q1_feats_m.values.tolist(), index= df3.index)
df3_q2 = pd.DataFrame(df3.q2_feats_m.values.tolist(), index= df3.index)
```

In [70]:

```
# dataframe of nlp features
df1.head()
```

Out[70]:

	id	is_duplicate	cwc_min	cwc_max	csc_min	csc_max	ctc_min	ctc_max	last_word_eq	first_word_eq	abs_len_diff	mean_len
0	0	0	0.999980	0.833319	0.999983	0.999983	0.916659	0.785709	0.0	1.0	2.0	13.0
1	1	0	0.799984	0.399996	0.749981	0.599988	0.699993	0.466664	0.0	1.0	5.0	12.5
2	2	0	0.399992	0.333328	0.399992	0.249997	0.399996	0.285712	0.0	1.0	4.0	12.0
3	3	0	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0	0.0	2.0	12.0
4	4	0	0.399992	0.199998	0.999950	0.666644	0.571420	0.307690	0.0	1.0	6.0	10.0

In [71]:

```
# data before preprocessing
df2.head()
```

Out[71]:

	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

	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
0	0	1	1	66	57	14	12	10.0	23.0	0.434783	2	0
1	1	4	1	51	88	8	13	4.0	20.0	0.200000	5	3
2	2	1	1	73	59	14	10	4.0	24.0	0.166667	2	0
3	3	1	1	50	65	11	9	0.0	19.0	0.000000	2	0
4	4	3	1	76	39	13	7	2.0	20.0	0.100000	4	2

In [72]:

```
# Questions 1 tfidf weighted word2vec
df3_q1.head()
```

Out[72]:

	0	1	2	3	4	5	6	7	8	9	...	374
0	121.929932	100.083909	72.497893	115.641794	-48.370882	34.619062	-172.057790	-92.502619	113.223317	50.562433	...	12.397644
1	-78.070943	54.843787	82.738472	98.191860	-51.234856	55.013505	-39.140728	-82.692345	45.161482	-9.556285	...	-21.987077
2	-5.355019	73.671803	14.376363	104.130241	1.433539	35.229114	-148.519384	-97.124593	41.972190	50.948728	...	3.027700
3	5.778362	-34.712030	48.999616	59.699200	40.661257	-41.658736	-36.808593	24.170664	0.235597	-29.407294	...	13.100006
4	51.138199	38.587305	123.639489	53.333049	-47.062726	37.356195	-298.722745	-106.421118	106.248904	65.880715	...	13.906532

5 rows × 384 columns

In [73]:

```
# Questions 2 tfidf weighted word2vec
df3_q2.head()
```

Out[73]:

	0	1	2	3	4	5	6	7	8	9	...	374
0	125.983307	95.636488	42.114704	95.449977	-37.386311	39.400091	-148.116074	-87.851475	110.371982	62.272814	...	16.165594
1	-106.871910	80.290334	79.066299	59.302089	-42.175328	117.616658	-144.364245	-127.131503	22.962527	25.397566	...	-4.901128
2	7.072871	15.513378	1.846906	85.937576	-33.808816	94.702334	-122.256851	-114.009526	53.922283	60.131814	...	8.359966
3	39.421531	44.136989	-24.010929	85.265870	-0.339022	-9.323147	-60.499652	-37.044766	49.407848	-23.350152	...	3.311411
4	31.950102	62.854113	1.778172	36.218766	-45.130874	66.674876	-106.342344	-22.901006	59.835942	62.663971	...	-2.403870

5 rows × 384 columns

In [74]:

```
print("Number of features in nlp dataframe :", df1.shape[1])
print("Number of features in preprocessed dataframe :", df2.shape[1])
print("Number of features in question1 w2v  dataframe :", df3_q1.shape[1])
print("Number of features in question2 w2v  dataframe :", df3_q2.shape[1])
print("Number of features in final dataframe  :", df1.shape[1]+df2.shape[1]+df3_q1.shape[1]+df3_q2.
shape[1])
```

```
Number of features in nlp dataframe : 17
Number of features in preprocessed dataframe : 12
Number of features in question1 w2v  dataframe : 384
Number of features in question2 w2v  dataframe : 384
Number of features in final dataframe  : 797
```

In [75]:

```
# storing the final features to csv file
if not os.path.isfile('final_features.csv'):
    df3_q1['id']=df1['id']
    df3_q2['id']=df1['id']
    df1  = df1.merge(df2, on='id',how='left')
    df2  = df3_q1.merge(df3_q2, on='id',how='left')
    result  = df1.merge(df2, on='id',how='left')
    result.to_csv('final_features.csv')
```

4. Machine Learning Models

4.1 Reading data from file and storing into sql table

In [2]:

```
from sqlalchemy import create_engine # database connection
import datetime as dt
#Creating db file from csv
if not os.path.isfile('train.db'):
    disk_engine = create_engine('sqlite:///train.db')
    start = dt.datetime.now()
    chunksize = 180000
    j = 0
    index_start = 1
    for df in pd.read_csv('final_features.csv', names=['Unnamed: 0','id','is_duplicate','cwc_min','
cwc_max','csc_min','csc_max','ctc_min','ctc_max','last_word_eq','first_word_eq','abs_len_diff','me
an_len','token_set_ratio','token_sort_ratio','fuzz_ratio','fuzz_partial_ratio','longest_substr_rati
o','freq_qid1','freq_qid2','q1len','q2len','q1_n_words','q2_n_words','word_Common','word_Total','w
ord_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','13_x','14_x',
'15_x','16_x','17_x','18_x','19_x','20_x','21_x','22_x','23_x','24_x','25_x','26_x','27_x','28_x','
29_x','30_x','31_x','32_x','33_x','34_x','35_x','36_x','37_x','38_x','39_x','40_x','41_x','42_x','4
3_x','44_x','45_x','46_x','47_x','48_x','49_x','50_x','51_x','52_x','53_x','54_x','55_x','56_x','57
_x','58_x','59_x','60_x','61_x','62_x','63_x','64_x','65_x','66_x','67_x','68_x','69_x','70_x','71_
x','72_x','73_x','74_x','75_x','76_x','77_x','78_x','79_x','80_x','81_x','82_x','83_x','84_x','85_x
','86_x','87_x','88_x','89_x','90_x','91_x','92_x','93_x','94_x','95_x','96_x','97_x','98_x','99_x'
,'100_x','101_x','102_x','103_x','104_x','105_x','106_x','107_x','108_x','109_x','110_x','111_x','
112_x','113_x','114_x','115_x','116_x','117_x','118_x','119_x','120_x','121_x','122_x','123_x','12
4_x','125_x','126_x','127_x','128_x','129_x','130_x','131_x','132_x','133_x','134_x','135_x','136_
x','137_x','138_x','139_x','140_x','141_x','142_x','143_x','144_x','145_x','146_x','147_x','148_x'
,'149_x','150_x','151_x','152_x','153_x','154_x','155_x','156_x','157_x','158_x','159_x','160_x','
161_x','162_x','163_x','164_x','165_x','166_x','167_x','168_x','169_x','170_x','171_x','172_x','17
3_x','174_x','175_x','176_x','177_x','178_x','179_x','180_x','181_x','182_x','183_x','184_x','185_
x','186_x','187_x','188_x','189_x','190_x','191_x','192_x','193_x','194_x','195_x','196_x','197_x'
,'198_x','199_x','200_x','201_x','202_x','203_x','204_x','205_x','206_x','207_x','208_x','209_x','
210_x','211_x','212_x','213_x','214_x','215_x','216_x','217_x','218_x','219_x','220_x','221_x','22
2_x','223_x','224_x','225_x','226_x','227_x','228_x','229_x','230_x','231_x','232_x','233_x','234_
x','235_x','236_x','237_x','238_x','239_x','240_x','241_x','242_x','243_x','244_x','245_x','246_x'
,'247_x','248_x','249_x','250_x','251_x','252_x','253_x','254_x','255_x','256_x','257_x','258_x','
259_x','260_x','261_x','262_x','263_x','264_x','265_x','266_x','267_x','268_x','269_x','270_x','27
1_x','272_x','273_x','274_x','275_x','276_x','277_x','278_x','279_x','280_x','281_x','282_x','283_
x','284_x','285_x','286_x','287_x','288_x','289_x','290_x','291_x','292_x','293_x','294_x','295_x'
,'296_x','297_x','298_x','299_x','300_x','301_x','302_x','303_x','304_x','305_x','306_x','307_x','
308_x','309_x','310_x','311_x','312_x','313_x','314_x','315_x','316_x','317_x','318_x','319_x','32
0_x','321_x','322_x','323_x','324_x','325_x','326_x','327_x','328_x','329_x','330_x','331_x','332_
x','333_x','334_x','335_x','336_x','337_x','338_x','339_x','340_x','341_x','342_x','343_x','344_x'
,'345_x','346_x','347_x','348_x','349_x','350_x','351_x','352_x','353_x','354_x','355_x','356_x','
357_x','358_x','359_x','360_x','361_x','362_x','363_x','364_x','365_x','366_x','367_x','368_x','36
9_x','370_x','371_x','372_x','373_x','374_x','375_x','376_x','377_x','378_x','379_x','380_x','381_
x','382_x','383_x','0_y','1_y','2_y','3_y','4_y','5_y','6_y','7_y','8_y','9_y','10_y','11_y','12_y'
,'13_y','14_y','15_y','16_y','17_y','18_y','19_y','20_y','21_y','22_y','23_y','24_y','25_y','26_y',
'27_y','28_y','29_y','30_y','31_y','32_y','33_y','34_y','35_y','36_y','37_y','38_y','39_y','40_y','
41_y','42_y','43_y','44_y','45_y','46_y','47_y','48_y','49_y','50_y','51_y','52_y','53_y','54_y','5
5_y','56_y','57_y','58_y','59_y','60_y','61_y','62_y','63_y','64_y','65_y','66_y','67_y','68_y','69
_y','70_y','71_y','72_y','73_y','74_y','75_y','76_y','77_y','78_y','79_y','80_y','81_y','82_y','83_
y','84_y','85_y','86_y','87_y','88_y','89_y','90_y','91_y','92_y','93_y','94_y','95_y','96_y','97_y
','98_y','99_y','100_y','101_y','102_y','103_y','104_y','105_y','106_y','107_y','108_y','109_y','11
0_y','111_y','112_y','113_y','114_y','115_y','116_y','117_y','118_y','119_y','120_y','121_y','122_
y','123_y','124_y','125_y','126_y','127_y','128_y','129_y','130_y','131_y','132_y','133_y','134_y'
,'135_y','136_y','137_y','138_y','139_y','140_y','141_y','142_y','143_y','144_y','145_y','146_y','
```

```
147_y','148_y','149_y','150_y','151_y','152_y','153_y','154_y','155_y','156_y','157_y','158_y','15
9_y','160_y','161_y','162_y','163_y','164_y','165_y','166_y','167_y','168_y','169_y','170_y','171_
y','172_y','173_y','174_y','175_y','176_y','177_y','178_y','179_y','180_y','181_y','182_y','183_y'
,'184_y','185_y','186_y','187_y','188_y','189_y','190_y','191_y','192_y','193_y','194_y','195_y','
196_y','197_y','198_y','199_y','200_y','201_y','202_y','203_y','204_y','205_y','206_y','207_y','20
8_y','209_y','210_y','211_y','212_y','213_y','214_y','215_y','216_y','217_y','218_y','219_y','220_
y','221_y','222_y','223_y','224_y','225_y','226_y','227_y','228_y','229_y','230_y','231_y','232_y'
,'233_y','234_y','235_y','236_y','237_y','238_y','239_y','240_y','241_y','242_y','243_y','244_y','
245_y','246_y','247_y','248_y','249_y','250_y','251_y','252_y','253_y','254_y','255_y','256_y','25
7_y','258_y','259_y','260_y','261_y','262_y','263_y','264_y','265_y','266_y','267_y','268_y','269_
y','270_y','271_y','272_y','273_y','274_y','275_y','276_y','277_y','278_y','279_y','280_y','281_y'
,'282_y','283_y','284_y','285_y','286_y','287_y','288_y','289_y','290_y','291_y','292_y','293_y','
294_y','295_y','296_y','297_y','298_y','299_y','300_y','301_y','302_y','303_y','304_y','305_y','30
6_y','307_y','308_y','309_y','310_y','311_y','312_y','313_y','314_y','315_y','316_y','317_y','318_
y','319_y','320_y','321_y','322_y','323_y','324_y','325_y','326_y','327_y','328_y','329_y','330_y'
,'331_y','332_y','333_y','334_y','335_y','336_y','337_y','338_y','339_y','340_y','341_y','342_y','
343_y','344_y','345_y','346_y','347_y','348_y','349_y','350_y','351_y','352_y','353_y','354_y','35
5_y','356_y','357_y','358_y','359_y','360_y','361_y','362_y','363_y','364_y','365_y','366_y','367_
y','368_y','369_y','370_y','371_y','372_y','373_y','374_y','375_y','376_y','377_y','378_y','379_y'
,'380_y','381_y','382_y','383_y'], chunksize=chunksize, iterator=True, encoding='utf-8', ):
        df.index += index_start
        j+=1
        print('{} rows'.format(j*chunksize))
        df.to_sql('data', disk_engine, if_exists='append')
        index_start = df.index[-1] + 1
```

In [3]:

```
#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 [4]:

```
import sqlite3
read_db = 'train.db'
conn_r = create_connection(read_db)
checkTableExists(conn_r)
conn_r.close()
```

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

In [5]:

```
if os.path.isfile(read_db):
    conn_r = create_connection(read_db)
    if conn_r is not None:
        data = pd.read_sql_query("SELECT * From data ORDER BY RANDOM() LIMIT 100001;", conn_r)
        conn_r.commit()
        conn_r.close()
```

In [6]:

```
# 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 [7]:

```
data.head()
```

Out[7]:

	cwc_min	cwc_max	csc_min	csc_max	ctc_min	ctc_max	last_word_eq
1	0.285710204139941	0.153844970423304	0.499987500312492	0.13333244445037	0.363633057881292	0.105262880887156	0.0
2	0.999985714489793	0.874989062636717	0.999980000399992	0.999980000399992	0.99999166673611	0.923069822539827	1.0
3	0.499987500312492	0.333327777870369	0.33332222259258	0.14285510206997	0.428565306209911	0.230767455634957	0.0
4	0.0	0.0	0.428565306209911	0.29999700003	0.230767455634957	0.107142474491163	0.0
5	0.66664444518516	0.499987500312492	0.599988000239995	0.499991666805553	0.555549382784636	0.454541322351615	1.0

5 rows × 794 columns

4.2 Converting strings to numerics

In [8]:

```
# 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
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In [9]:

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

4.3 Random train test split(70:30)

In [11]:

```
from sklearn.model_selection import train_test_split
X_train, X_test, y_train, y_test = train_test_split(data, y_true, stratify=y_true, test_size=0.3)
```

In [12]:

```
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 : (70000, 794)
Number of data points in test data : (30000, 794)
```

In [14]:

```
from collections import Counter, defaultdict
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:  0.6285714285714286 Class 1:  0.37142857142857144
---------- Distribution of output variable in train data ----------
Class 0:  0.37143333333333334 Class 1:  0.37143333333333334
```

In [15]:

```
# 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()
```

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

In [18]:

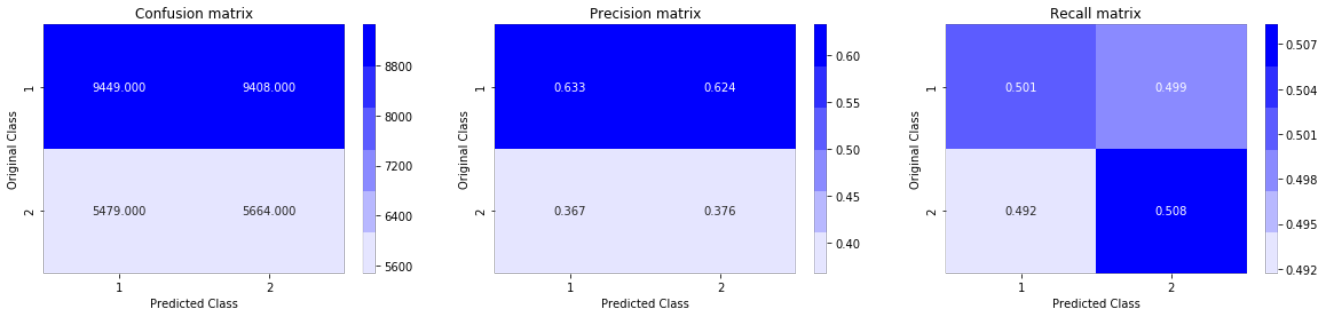
```
from sklearn.metrics.classification import accuracy_score, log_loss
from sklearn.metrics import confusion_matrix

# we need to generate 9 numbers and the sum of numbers should be 1
# one solution is to genarate 9 numbers and divide each of the numbers by their sum
# ref: https://stackoverflow.com/a/18662466/4084039
# we create a output array that has exactly same size as the CV data

predicted_y = np.zeros((test_len,2))
for i in range(test_len):
    rand_probs = np.random.rand(1,2)
    predicted_y[i] = ((rand_probs/sum(sum(rand_probs)))[0])
print("Log loss on Test Data using Random Model",log_loss(y_test, predicted_y, eps=1e-15))

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

```
Log loss on Test Data using Random Model 0.8812910323955873
```



4.4 Logistic Regression with hyperparameter tuning

In [21]:

```
from sklearn.linear_model import SGDClassifier
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_i
```

```
# 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:
#--------------------------------

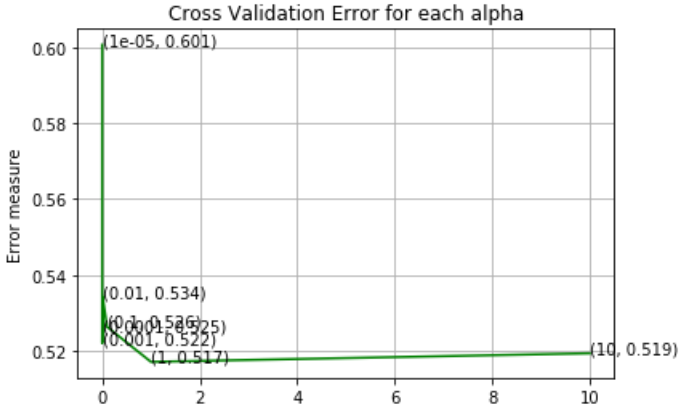

log_error_array=[]
for i in alpha:
    clf = SGDClassifier(alpha=i, penalty='l2', loss='log', random_state=42)
    clf.fit(X_train, y_train)
    sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
    sig_clf.fit(X_train, y_train)
    predict_y = sig_clf.predict_proba(X_test)
    log_error_array.append(log_loss(y_test, 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)

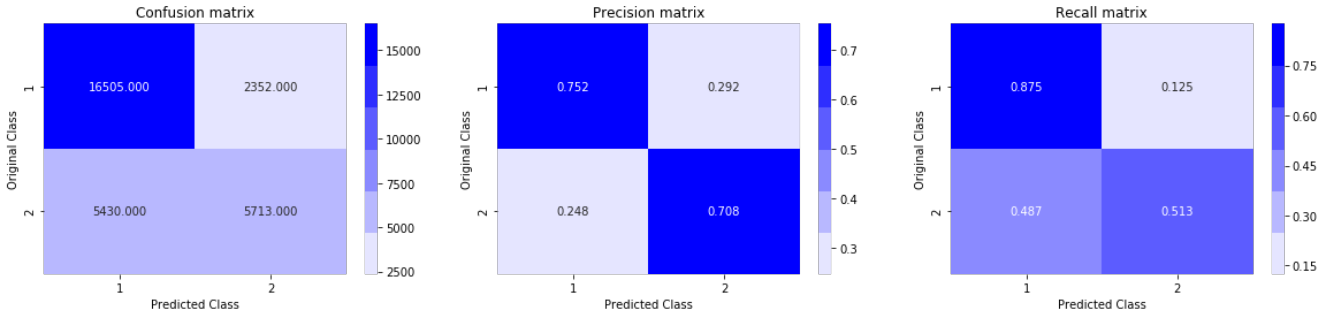
predict_y = sig_clf.predict_proba(X_train)
print('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(y_train,
predict_y, labels=clf.classes_, eps=1e-15))
predict_y = sig_clf.predict_proba(X_test)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss 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: 0.6006655170844521
For values of alpha =  0.0001 The log loss is: 0.5251853551818262
For values of alpha =  0.001 The log loss is: 0.522073497678028
For values of alpha =  0.01 The log loss is: 0.5342984841541478
For values of alpha =  0.1 The log loss is: 0.526364477366014
For values of alpha =  1 The log loss is: 0.5171410985697541
For values of alpha =  10 The log loss is: 0.5193927268268487
```



Alpha i's

```
For values of best alpha =  1 The train log loss is: 0.5089970061612473
For values of best alpha =  1 The test log loss is: 0.5171410985697541
Total number of data points : 30000
```



4.5 Linear SVM with hyperparameter tuning

In [22]:

```
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.


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))

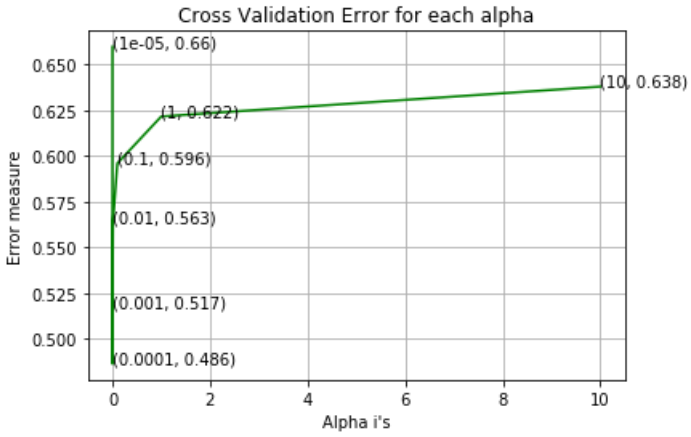
fig, ax = plt.subplots()
ax.plot(alpha, log_error_array,c='g')
for i, txt in enumerate(np.round(log_error_array,3)):
    ax.annotate((alpha[i],np.round(txt,3)), (alpha[i],log_error_array[i]))
plt.grid()
plt.title("Cross Validation Error for each alpha")
plt.xlabel("Alpha i's")
plt.ylabel("Error measure")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

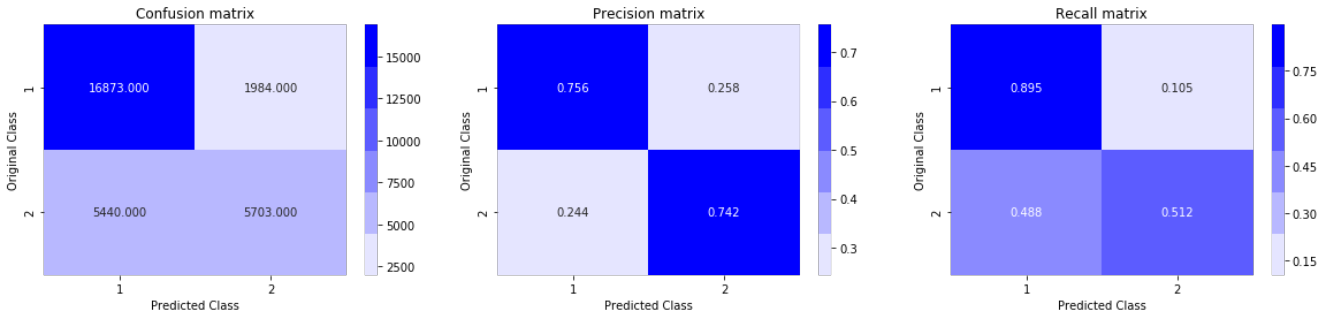
predict_y = sig_clf.predict_proba(X_train)
print('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(y_train,
predict_y, labels=clf.classes_, eps=1e-15))
predict_y = sig_clf.predict_proba(X_test)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_loss(y_test, p
redict_y, labels=clf.classes_, eps=1e-15))
```

```
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))
plot_confusion_matrix(y_test, predicted_y)
```

```
For values of alpha =  1e-05 The log loss is: 0.6597141204189816
For values of alpha =  0.0001 The log loss is: 0.48614706251166956
For values of alpha =  0.001 The log loss is: 0.5172527985436652
For values of alpha =  0.01 The log loss is: 0.5633373620425512
For values of alpha =  0.1 The log loss is: 0.5958782537226457
For values of alpha =  1 The log loss is: 0.6215492842471588
For values of alpha =  10 The log loss is: 0.637883887273433
```




```
For values of best alpha =  0.0001 The train log loss is: 0.47763640515097006
For values of best alpha =  0.0001 The test log loss is: 0.48614706251166956
Total number of data points : 30000
```



4.6 XGBoost

In [24]:

```
import xgboost as xgb
params = {}
params['objective'] = 'binary:logistic'
params['eval_metric'] = 'logloss'
params['eta'] = 0.02
params['max_depth'] = 4

d_train = xgb.DMatrix(X_train, label=y_train)
d_test = xgb.DMatrix(X_test, label=y_test)

watchlist = [(d_train, 'train'), (d_test, 'valid')]

bst = xgb.train(params, d_train, 400, watchlist, early_stopping_rounds=20, verbose_eval=10)

xgdmat = xgb.DMatrix(X_train,y_train)
predict_y = bst.predict(d_test)
print("The test log loss is:",log_loss(y_test, predict_y, labels=clf.classes_, eps=1e-15))
```

```
[17:18:50] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[0] train-logloss:0.68495 valid-logloss:0.684973
```

Multiple eval metrics have been passed: 'valid-logloss' will be used for early stopping.

Will train until valid-logloss hasn't improved in 20 rounds.
[17:18:51] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:18:52] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:18:52] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:18:53] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:18:54] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:18:55] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:18:56] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:18:56] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:18:57] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:18:58] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[10] train-logloss:0.615351 valid-logloss:0.615874
[17:18:59] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:00] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:00] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:01] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:02] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:03] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:04] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:05] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:05] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:06] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[20] train-logloss:0.564037 valid-logloss:0.565072
[17:19:07] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:08] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:09] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:09] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:10] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:11] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:12] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:13] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:13] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:14] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[30] train-logloss:0.5261 valid-logloss:0.527566
[17:19:15] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:16] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:16] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:17] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:18] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:19] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p

runed nodes, max_depth=4
[17:19:20] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:20] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:21] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:22] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[40] train-logloss:0.496999 valid-logloss:0.498839
[17:19:23] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:24] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:24] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:25] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:26] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:27] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:28] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:28] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:29] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:30] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[50] train-logloss:0.473874 valid-logloss:0.475949
[17:19:31] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:32] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:32] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:33] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:34] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:35] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:36] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:36] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:37] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:38] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[60] train-logloss:0.455641 valid-logloss:0.458122
[17:19:39] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:40] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:40] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:41] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:42] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:43] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:43] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:44] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:45] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:46] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[70] train-logloss:0.440871 valid-logloss:0.443607
[17:19:47] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:47] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4

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runed nodes, max_depth=4
[17:19:48] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:49] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:50] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:51] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:51] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:52] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:53] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:54] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[80] train-logloss:0.428911 valid-logloss:0.431963
[17:19:55] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:55] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:56] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:57] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:58] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:58] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:19:59] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:00] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:01] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:02] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[90] train-logloss:0.41908 valid-logloss:0.422446
[17:20:02] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:03] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:04] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:05] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:05] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:06] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:07] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:08] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:09] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:09] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[100] train-logloss:0.411025 valid-logloss:0.414707
[17:20:10] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:11] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:12] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:12] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:13] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:14] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:15] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:16] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:16] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
```

```
runed nodes, max_depth=4
[17:20:17] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[110] train-logloss:0.404197 valid-logloss:0.408181
[17:20:18] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:19] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:20] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:20] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:21] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:22] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:23] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:23] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:24] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:25] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[120] train-logloss:0.39854 valid-logloss:0.402729
[17:20:26] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:27] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:27] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:28] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:29] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:30] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:31] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:31] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:32] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:33] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[130] train-logloss:0.393687 valid-logloss:0.398239
[17:20:34] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:35] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:35] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:36] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:37] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:38] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:39] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:39] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:40] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
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[17:20:41] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[140] train-logloss:0.389479 valid-logloss:0.39439
[17:20:42] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:43] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:43] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:44] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:45] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:46] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
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[17:20:46] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:47] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
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[17:20:47] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:48] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:49] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[150] train-logloss:0.385731 valid-logloss:0.390978
[17:20:50] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
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[17:20:51] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
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[17:20:51] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:52] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:53] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:54] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:55] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:55] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
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[17:20:56] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:20:57] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[160] train-logloss:0.382417 valid-logloss:0.387966
[17:20:58] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
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[17:20:59] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
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[17:20:59] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
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[17:21:00] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:01] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:02] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:03] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:03] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
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[17:21:04] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:05] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[170] train-logloss:0.37958 valid-logloss:0.38548
[17:21:06] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
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[17:21:07] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
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[17:21:07] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
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[17:21:08] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:09] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:10] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:11] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
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[17:21:11] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
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[17:21:12] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:13] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[180] train-logloss:0.376982 valid-logloss:0.383157
[17:21:14] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:15] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4

runed nodes, max_depth=4
[17:21:15] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:16] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:17] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:18] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:18] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:19] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
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[17:21:20] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:21] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[190] train-logloss:0.374712 valid-logloss:0.381172
[17:21:22] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:22] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:23] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:24] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:25] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:26] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:26] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:27] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:28] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:29] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[200] train-logloss:0.372589 valid-logloss:0.379372
[17:21:29] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:30] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
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[17:21:31] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:32] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:33] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:33] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:34] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:35] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:36] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:37] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[210] train-logloss:0.370647 valid-logloss:0.377682
[17:21:37] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:38] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:39] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:40] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:41] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:41] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 24 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:42] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:43] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:44] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 24 extra nodes, 0 p
runed nodes, max_depth=4

runed nodes, max_depth=4
[17:21:45] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 24 extra nodes, 0 p
runed nodes, max_depth=4
[220] train-logloss:0.368774 valid-logloss:0.376066
[17:21:45] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:46] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 24 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:47] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:48] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 24 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:48] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:49] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 24 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:50] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:51] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:52] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 24 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:52] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[230] train-logloss:0.367046 valid-logloss:0.374615
[17:21:53] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 24 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:54] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:55] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 24 extra nodes, 0 p
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[17:21:56] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
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[17:21:56] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:57] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 24 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:58] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:59] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:21:59] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 24 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:00] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[240] train-logloss:0.365435 valid-logloss:0.37326
[17:22:01] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:02] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 24 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:03] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 24 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:03] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:04] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:05] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:06] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 24 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:07] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 24 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:07] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:08] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[250] train-logloss:0.363628 valid-logloss:0.371761
[17:22:09] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 24 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:10] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:11] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 24 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:11] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:12] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 24 extra nodes, 0 p
runed nodes, max_depth=4

[17:22:13] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:14] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:15] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 20 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:15] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:16] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[260] train-logloss:0.362036 valid-logloss:0.370481
[17:22:17] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 20 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:18] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:18] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 20 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:19] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:20] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:21] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 20 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:22] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:22] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:23] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:24] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[270] train-logloss:0.360414 valid-logloss:0.369152
[17:22:25] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 20 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:26] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:26] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:27] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:28] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 22 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:29] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:30] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:30] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:31] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 22 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:32] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[280] train-logloss:0.358907 valid-logloss:0.367971
[17:22:33] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:33] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:34] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 22 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:35] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:36] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:37] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 22 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:37] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:38] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:39] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:40] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[290] train-logloss:0.357485 valid-logloss:0.366907
[17:22:41] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:41] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 22 extra nodes, 0 p

runed nodes, max_depth=4
[17:22:42] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:43] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:44] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:45] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:45] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 26 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:46] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:47] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:48] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[300] train-logloss:0.356016 valid-logloss:0.365798
[17:22:48] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 22 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:49] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:50] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:51] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:52] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:53] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:53] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:54] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:55] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:56] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 22 extra nodes, 0 p
runed nodes, max_depth=4
[310] train-logloss:0.354586 valid-logloss:0.364759
[17:22:57] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:57] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:58] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:22:59] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:00] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:01] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:01] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:02] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:03] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 22 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:04] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[320] train-logloss:0.353233 valid-logloss:0.363748
[17:23:05] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:06] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:06] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 22 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:07] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:08] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:09] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:10] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:10] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:11] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 20 extra nodes, 0 p

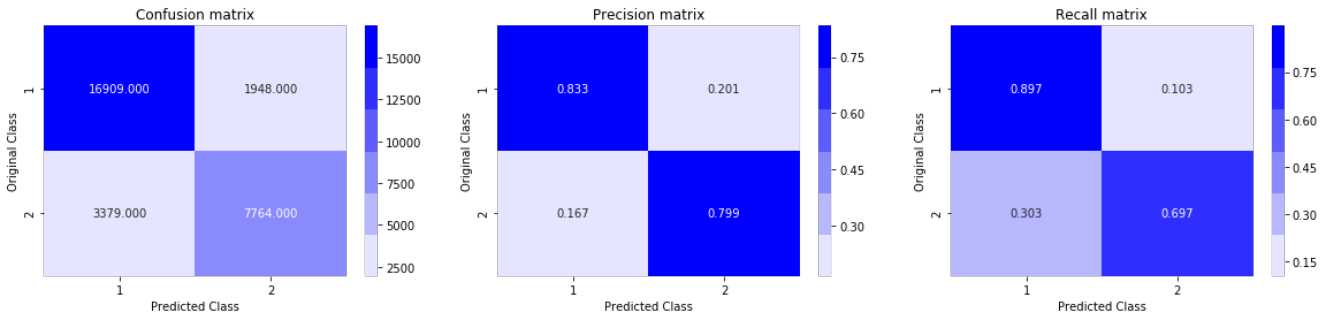
```
runed nodes, max_depth=4
[17:23:12] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[330] train-logloss:0.351978 valid-logloss:0.362874
[17:23:13] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:14] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:15] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:15] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:16] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 20 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:17] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:18] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:19] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:19] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:20] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[340] train-logloss:0.350768 valid-logloss:0.362009
[17:23:21] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:22] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 16 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:23] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:23] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:24] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:25] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:26] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:27] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 16 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:28] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:28] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[350] train-logloss:0.349667 valid-logloss:0.361284
[17:23:29] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:30] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 20 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:31] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:32] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:32] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:33] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 16 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:34] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:35] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:36] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:36] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 16 extra nodes, 0 p
runed nodes, max_depth=4
[360] train-logloss:0.348535 valid-logloss:0.360492
[17:23:37] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:38] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:39] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:40] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:41] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 26 extra nodes, 0 p
runed nodes, max_depth=4
```

```
[17:23:41] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 16 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:42] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:43] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:44] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:44] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[370] train-logloss:0.347464 valid-logloss:0.359753
[17:23:45] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:46] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:47] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:48] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:48] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:49] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:50] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 16 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:51] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:52] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 18 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:52] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[380] train-logloss:0.346492 valid-logloss:0.359142
[17:23:53] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 16 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:54] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:55] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:56] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:56] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:57] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:58] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:23:59] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 16 extra nodes, 0 p
runed nodes, max_depth=4
[17:24:00] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 18 extra nodes, 0 p
runed nodes, max_depth=4
[17:24:00] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[390] train-logloss:0.345497 valid-logloss:0.358462
[17:24:01] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:24:02] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[17:24:03] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:24:04] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 16 extra nodes, 0 p
runed nodes, max_depth=4
[17:24:04] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:24:05] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:24:06] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:24:07] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 30 extra nodes, 0 p
runed nodes, max_depth=4
[17:24:08] /workspace/src/tree/updater_prune.cc:74: tree pruning end, 1 roots, 28 extra nodes, 0 p
runed nodes, max_depth=4
[399] train-logloss:0.344569 valid-logloss:0.357887
The test log loss is: 0.35788663754366185
```

In [25]:

```
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 : 30000
```



5.1 XGBoost with hyperparameter tuning

In [35]:

```
from xgboost import XGBClassifier
from sklearn.model_selection import RandomizedSearchCV

params = {'n_estimators': [10,20,50,100,500], 'max_depth':[1, 5, 10, 15, 20]}

clf = XGBClassifier(objective='binary:logistic', eval_metric='logloss', n_jobs= -1)
model = RandomizedSearchCV(clf, params, cv=3, scoring='neg_log_loss', n_jobs= -1)
model.fit(X_train,y_train)

#Optimal value of depth
optimal_depth = model.best_estimator_.max_depth
print("\nThe optimal value of depth is : ",optimal_depth)

#Optimal value of number of estimators
optimal_estimators = model.best_estimator_.n_estimators
print("\nThe optimal value of depth is : ",optimal_estimators)

print('Log loss is :', model.best_score_)
```

```
The optimal value of depth is :  5

The optimal value of depth is :  500
Log loss is : -0.3337186777321428
```

Correction: The optimal value of depth is : 5 and The optimal value of estimators* are : 500

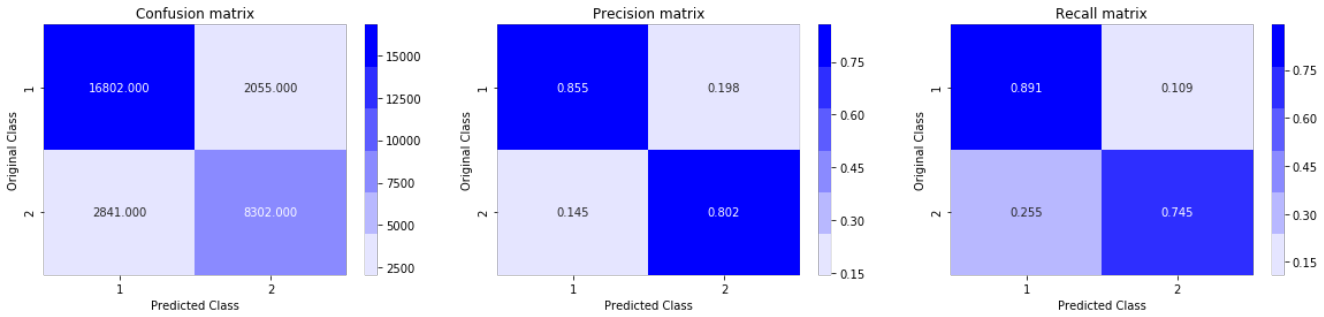
5.1.1 XGBoost with optimal hyperparameters

In [37]:

```
clf = XGBClassifier(max_depth=5,objective='binary:logistic',eval_metric='logloss',
n_estimators=500, n_jobs=-1)
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("Log loss for tfidf train data : ",log_loss(y_train, predict_y,  eps=1e-15))

predict_y = sig_clf.predict_proba(X_test)
print("Log loss for tfidf test data : ",log_loss(y_test, predict_y,  eps=1e-15))
predicted_y =np.argmax(predict_y,axis=1)
plot_confusion_matrix(y_test, predicted_y)
```

```
Log loss for tfidf train data :  0.1867460755323528
Log loss for tfidf test data :  0.343841158138813
```



5.2 TFIDF Vectorization

In [52]:

```
df = pd.read_csv("train.csv", usecols= ['id','question1','question2','is_duplicate'])

# encode questions to unicode
df['question1'] = df['question1'].apply(lambda x: str(x))
df['question2'] = df['question2'].apply(lambda x: str(x))
```

In [53]:

```
print(df.shape)
df.head()
```

```
(404290, 4)
```

Out[53]:

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

In [54]:

```
col_names1 = ['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','freq_qid1', 'freq_qid2', 'q1len', 'q2len','q1_n_words', 'q2_n_words',
              'word_Common', 'word_Total', 'word_share', 'freq_q1+q2', 'freq_q1-q2']

data = pd.read_csv('final_features.csv',usecols=col_names1)
```

In [55]:

```
print("Rows: ",data.shape[0])
print("Dimensions: ",data.shape[1])
data.head()
```

```
Rows:  404290
Dimensions:  27
```

Out[55]:

	id	cwc_min	cwc_max	csc_min	csc_max	ctc_min	ctc_max	last_word_eq	first_word_eq	abs_len_diff	...	freq_qid2	q1len	q2
	id	cwc_min	cwc_max	csc_min	csc_max	ctc_min	ctc_max	last_word_eq	first_word_eq	abs_len_diff	...	freq_qid2	q1len	q2
0	0	0.999980	0.833319	0.999983	0.999983	0.916659	0.785709	0.0	1.0	2.0	...	1	66	
1	1	0.799984	0.399996	0.749981	0.599988	0.699993	0.466664	0.0	1.0	5.0	...	1	51	
2	2	0.399992	0.333328	0.399992	0.249997	0.399996	0.285712	0.0	1.0	4.0	...	1	73	
3	3	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0	0.0	2.0	...	1	50	
4	4	0.399992	0.199998	0.999950	0.666644	0.571420	0.307690	0.0	1.0	6.0	...	1	76	

5 rows × 27 columns

In [56]:

```
df = df.merge(data, on='id',how='inner')
print(df.shape)
df.head()
```

```
(404290, 30)
```

Out[56]:

	id	question1	question2	is_duplicate	cwc_min	cwc_max	csc_min	csc_max	ctc_min	ctc_max	...	freq_qid2	q1len	q2len
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	57
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	88
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	59
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	65
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	39

5 rows × 30 columns

In [57]:

```
#Taking a random sample of 100k data points

sample = df.sample(n=100000,random_state = 42)
sample.shape
```

Out[57]:

```
(100000, 30)
```

In [58]:

```
#Taking the class lables from the data fram
y_true = sample['is_duplicate']
y_true.shape[0]
```

```
y_true.shape[0]
```

Out[58]:

```
100000
```

5.2.1 Random train test split(70:30)

In [59]:

```
from sklearn.model_selection import train_test_split
X_train,X_test, y_train, y_test = train_test_split(sample, y_true, stratify=y_true, test_size=0.3)
```

In [60]:

```
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 : (70000, 30)
Number of data points in test data : (30000, 30)
```

In [61]:

```
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:  0.6287857142857143 Class 1:  0.3712142857142857
---------- Distribution of output variable in train data ----------
Class 0:  0.3712 Class 1:  0.3712
```

5.2.2 Featurizing text data with tfidf

In [82]:

```
vect = TfidfVectorizer(lowercase=False)
train_q1 = vect.fit_transform(X_train['question1'])
test_q1  = vect.transform(X_test['question1'])
train_q2 = vect.fit_transform(X_train['question2'])
test_q2  = vect.transform(X_test['question2'])
```

In [83]:

```
print(train_q1.shape)
print(test_q1.shape)
print("*"*15)
print(train_q2.shape)
print(test_q2.shape)
```

```
(70000, 37120)
(30000, 37120)
***************
(70000, 34496)
(30000, 34496)
```

In [84]:

```
from scipy.sparse import hstack
Train_data = hstack((train_q1,train_q2))
Test_data = hstack((test_q1,test_q2))
```

```
print(Train_data.shape)
print(Test_data.shape)
```

```
(70000, 71616)
(30000, 71616)
```

In [87]:

```
#Extraction 26 featurese from train and test data frame
train_df = X_train.drop(['id','question1','question2','is_duplicate'], axis=1, inplace=False)
test_df = X_test.drop(['id','question1','question2','is_duplicate'], axis=1, inplace=False)
print("train Shape:",train_df.shape)
print("test shape:",test_df.shape)
```

```
train Shape: (70000, 26)
test shape: (30000, 26)
```

In [89]:

```
X_train_tfidf = hstack((train_df,Train_data))
X_test_tfidf = hstack((test_df,Test_data))

print(X_train_tfidf.shape)
print(X_test_tfidf.shape)
```

```
(70000, 71642)
(30000, 71642)
```

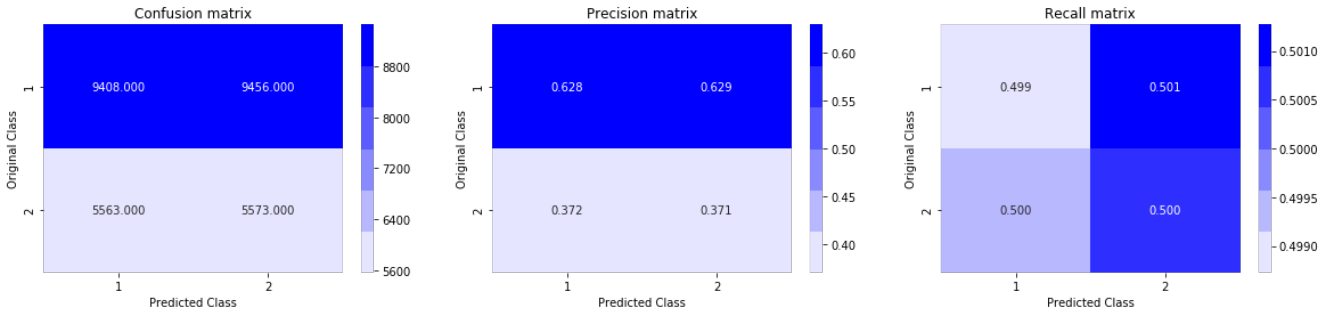
5.3 Building a random model (Finding worst-case log-loss)

In [97]:

```
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 0.8849848790191922
```



5.3.1 Logistic Regression with hyperparameter tuning

In [99]:

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

log_error_array=[]
for i in alpha:
    clf = SGDClassifier(alpha=i, penalty='l2', loss='log', random_state=42)
    clf.fit(X_train_tfidf, y_train)
```

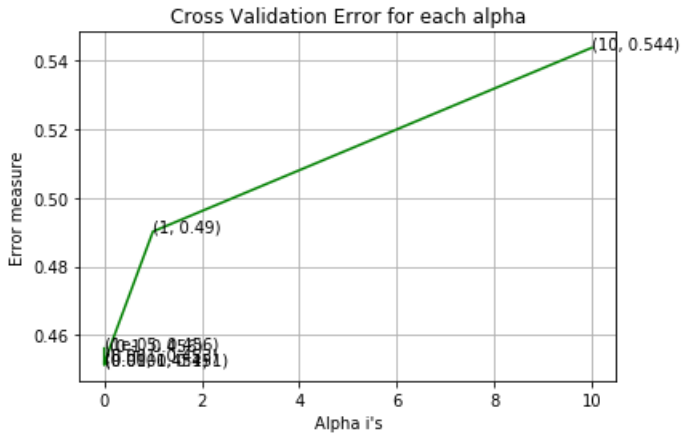
```
    sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
    sig_clf.fit(X_train_tfidf, y_train)
    predict_y = sig_clf.predict_proba(X_test_tfidf)
    log_error_array.append(log_loss(y_test, predict_y, labels=clf.classes_, eps=1e-15))
    print('For values of alpha = ', i, "The log loss is:",log_loss(y_test, 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()

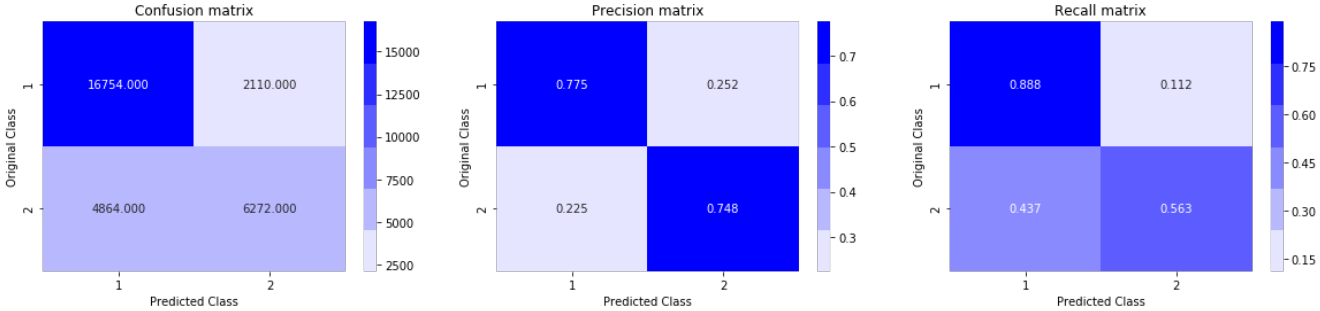

best_alpha = np.argmin(log_error_array)
clf = SGDClassifier(alpha=alpha[best_alpha], penalty='l2', loss='log', random_state=42)
clf.fit(X_train_tfidf, y_train)
sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
sig_clf.fit(X_train_tfidf, y_train)

predict_y = sig_clf.predict_proba(X_train_tfidf)
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_tfidf)
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: 0.4561824066110501
For values of alpha =  0.0001 The log loss is: 0.4513461331823313
For values of alpha =  0.001 The log loss is: 0.45264151688397863
For values of alpha =  0.01 The log loss is: 0.4514760278903491
For values of alpha =  0.1 The log loss is: 0.45577846438226766
For values of alpha =  1 The log loss is: 0.4902087836358565
For values of alpha =  10 The log loss is: 0.5437718913436526
```




```
For values of best alpha =  0.0001 The train log loss is: 0.45488707473791223
For values of best alpha =  0.0001 The test log loss is: 0.4513461331823313
Total number of data points : 30000
```



5.3.2 Linear SVM with hyperparameter tuning

In [101]:

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

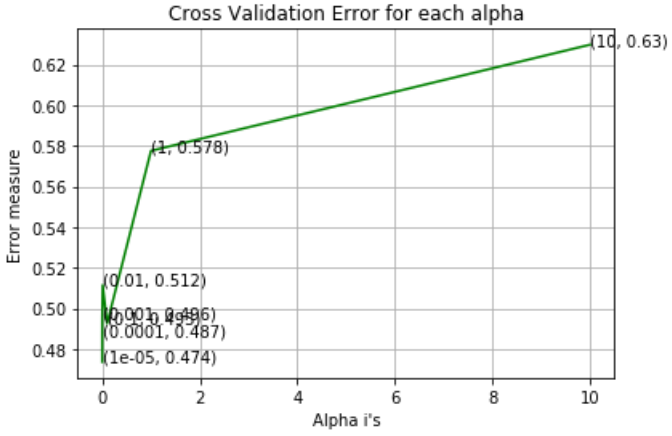
log_error_array=[]
for i in alpha:
    clf = SGDClassifier(alpha=i, penalty='l1', loss='hinge', random_state=42)
    clf.fit(X_train_tfidf, y_train)
    sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
    sig_clf.fit(X_train_tfidf, y_train)
    predict_y = sig_clf.predict_proba(X_test_tfidf)
    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_tfidf, y_train)
sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
sig_clf.fit(X_train_tfidf, y_train)

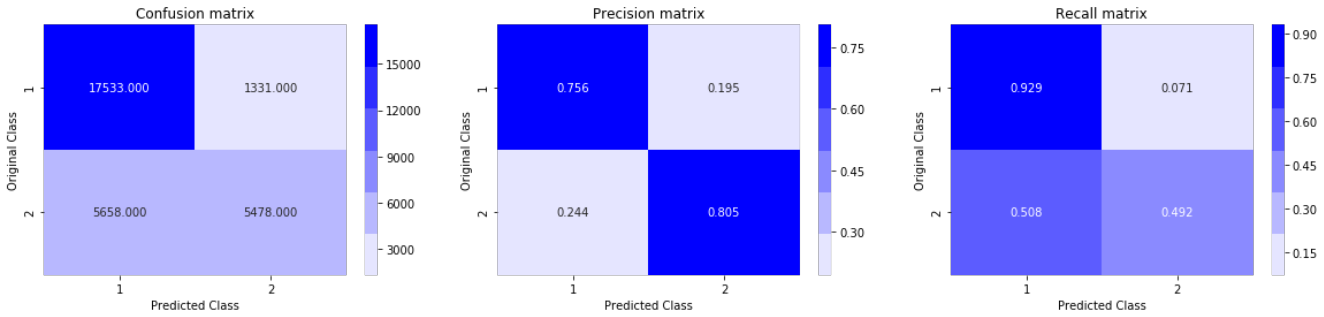
predict_y = sig_clf.predict_proba(X_train_tfidf)
print('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(y_train,
predict_y, labels=clf.classes_, eps=1e-15))
predict_y = sig_clf.predict_proba(X_test_tfidf)
print('For values of best alpha = ', alpha[best_alpha], "The 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: 0.4737451413724052
For values of alpha =  0.0001 The log loss is: 0.4868747392634236
For values of alpha =  0.001 The log loss is: 0.495560071960926
For values of alpha =  0.01 The log loss is: 0.5115242943592478
For values of alpha =  0.1 The log loss is: 0.49258573926068977
For values of alpha =  1 The log loss is: 0.5775389917454128
For values of alpha =  10 The log loss is: 0.6297178940309919
```




```
For values of best alpha =  1e-05 The train log loss is: 0.47827727803155495
For values of best alpha =  1e-05 The test log loss is: 0.4737451413724052
```

```
Total number of data points : 30000
```



6. Conclusion:

1. Initially, after importing the data we've performed the EDA to understand what all the features are important.
2. Before pre-processing the data, we've performed some basic feature engineering and extreacted 11 additional features and analysed the features using violin plots, PDF plots to understand the how the features have impact on data.
3. Now, we've performed the pre-processing steps like Removing html tags, Removing Punctuations, Performing stemming, Removing Stopwords, Expanding contractions etc., on the data.
4. In the next step, we've performed advanced feature engineering using NLP and fuzzy features where we've extracted 15 additional features.
5. We've analysed these features using word clouds, pair plots, violin plots and PDF plots to understand the behaviour of data with specific features.
6. Using all these features, we have visualized the data using T-SNE in both 2-D and 3-D.
7. We now have featurized the data with TF-IDF weighted wors2vec and TF-IDF and trained different machine learning models like Logistic regression, Linear SVM and XG Boost on top of it using log-loss as our metric.

In [104]:

```
from prettytable import PrettyTable
x = PrettyTable()

x.field_names = ["Model", "Vectorizer", "Train Loss", "Test Loss"]

x.add_row(['Logistic Regression', 'TF-IDF weighted W2V', 0.508, 0.517])
x.add_row(['Linear SVM', 'TF-IDF weighted W2V', 0.477, 0.486])
x.add_row(['XGBoost', 'TF-IDF weighted W2V', 0.344, 0.357])
x.add_row(['XGBoost(hyperparameter tuning)', 'TF-IDF weighted W2V', 0.186, 0.343])
x.add_row(['Logistic Regression', 'TF-IDF', 0.454, 0.451])
x.add_row(['Linear SVM', 'TF-IDF', 0.478, 0.473])

print(x)
```

```
+--------------------------------+---------------------+------------+-----------+
|             Model              |      Vectorizer     | Train Loss | Test Loss |
+--------------------------------+---------------------+------------+-----------+
|      Logistic Regression       | TF-IDF weighted W2V |   0.508    |   0.517   |
|           Linear SVM           | TF-IDF weighted W2V |   0.477    |   0.486   |
|            XGBoost             | TF-IDF weighted W2V |   0.344    |   0.357   |
| XGBoost(hyperparameter tuning) | TF-IDF weighted W2V |   0.186    |   0.343   |
|      Logistic Regression       |        TF-IDF       |   0.454    |   0.451   |
|           Linear SVM           |        TF-IDF       |   0.478    |   0.473   |
+--------------------------------+---------------------+------------+-----------+
```

In [ ]:

```
```